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Phenotypic Diversity of Ethiopian Finger Millet [*Eleusine coracana* (L.) Gaertn] in Relation to Geographical Regions as an Aid to Germplasm Collection and Conservation Strategy

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ABSTRACT

Sixty-four accessions (960 individuals) of landraces collected from five former regions of Ethiopia and Eritrea covering different agro-ecologies were characterized for growth habit, ear shape, grain shape, grain surface, grain color and pericarp persistence. The objective was to study the pattern and phenotypic diversity of some characters in finger millet. The experiment was laid down in a randomized complete block design (RCBD) with three replications. The percentage frequencies of the phenotypic classes of each character were calculated. The Shanon-Weaver diversity index (H') was used to estimate the magnitude of diversity. One way analysis of variance of the non-normalized H using regions was under taken for individual characters.

All the character considered showed marked differences in their distribution and variation. In no cases monomorphic classes were observed. Regional wise, Gojam and Welega revealed the highest diversity (H'=0.84) while Eritrea showed the lowest (H'=0.67). There was an increasing trend of diversity from north to south. Overall characters revealed intermediate to high diversity ranging from 0.60 for pericarp persistence to 0.99 for grain surface. Ear shape ($P \leq 0.01$), grain shape ($Pd \leq 0.05$) and grain surface ($Pd \leq 0.01$) showed different levels of diversity among regions as opposed to growth habit, grain color and pericarp persistence whose variations were attributed to among accessions. The overall mean diversity estimate was high (H'=0.82). Generally, the result revealed the existence of a vast range of diversity in the indigenous finger millet germplasm.

Key words: finger millet, *Eleusine coracana*, Ethiopia, phenotypic diversity, germplasm

INTRODUCTION

Ethiopia is a diverse country in terms of altitude, temperature, rainfall and soils types. Such diversity of environmental elements have been the cause for the existence of diverse vegetation, crop species and native varieties of crops that are observed in farmers' fields in most part of the country (Vavilov, 1951).

According to N.I. Vavilov and other scientists, Ethiopia represents one of the major center of genetic diversity. Vavilov (1951)

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indicated that some thirty species are connected with Ethiopia as a primary or secondary gene center. Eleven crops including finger millet (*Eleusine coracana*) were indicated as having their center of diversity in Ethiopia (Zonary, 1970) and local domesticates are known to have a wide genetic diversity.

The long history of cultivation and the large agro-ecological and cultural diversity in the country has resulted in large number of landraces of finger millet. The grain is used in different forms for food and the straw for feed, fuel and thatching. However, the national average grain yield of finger millet is low, 1.0 ton/ha, although it has a potential to yield up to 3 ton/ha (Mulatu *et al*., 1995).

More genes for desirable characters and higher biological yield are necessary for further progress in finger millet improvement. The availability of such genes depends on the identification of areas of concentration for various characters of agronomic value. The identification of these sites is a paramount importance for collection and for appropriate *in situ* site selection. And hence, there have been increasing interests in recent years in *in situ* conservation with a view to complement *ex situ* conservation effort. Choices of sites for *in situ* conservation may depend on high diversity estimates based on markers or knowledge of adaptive traits linked to certain ecological conditions (Negessa, 1986; Demisse and Bjornstad, 1996; Workeye, 2002), e.g., co-evolving host-pathogen systems and adaptation to other stress conditions. *In situ* population of the crop species may not only maintain a large level of variation but also a high frequency of desirable genes (Van Leur *et al*., 1989)

About 2,051 accessions have been collected and held by Ethiopian Institute of Biodiversity Conservation (EIBC) from different parts of the country and Eritrea. However, the pattern of gene or character distribution within the country is hardly known. Apparently germplasm collection lacks precisely defined target areas, and this limits the efficiency of its service to crops' genetics and breeding.

A considerable number of diversity studies have been done in Ethiopia on different crops such as tef (Bekele, 1996; Kefyalew *et al*. 2000), barley (Zemede, 1988, 1989; Demissie, 1996), wheat (Bekele, 1984; Negassa, 1986; Belay *et al*., 1997; Kebebew *et al*., 2001) sorghum (Ayana and Bekele, 1998) and chickpea (Workeye, 2002). However, a comprehensive study on finger millet is limited. Hence, this experiment was conducted to study the patterns and phenotypic diversity of some characters in finger millet using frequency distribution and the Shannon-Weaver diversity index.

MATERIALS AND METHODS

The experiment was conducted at Aresi-Negele Research Sub-Center in Ethiopia during 2004 main cropping season. The altitude of the site is 1,960 m asl and located at $7^0 20'$N latitude and 38^0 $09'$E longitude. The soils are dark brown clay loam with pH of 6.3. The annual rainfall during the experimental season was about 980 mm.

Sixty-four finger millet [*Eleusine coracana* (L.) Gaertn] accessions (960 individuals) collected from five former regions of Ethiopia (Tigray, Gonder, Gojam, Welega, Gamo Gofa) and Eritrea covering different agro-ecologies were used for the study (Table 1). The materials along with their passport data were obtained from the Ethiopian Institute of Biodiversity Conservation (EIBC).

The experiment was laid down in a randomized complete block design (RCBD) with three replications. The seeds of each accession were drilled in a 4 m long single row with spacing of 75 cm between rows and 15 cm between plants within a row, which was maintained by thinning. All agronomic managements were undertaken following the location practices. Data on six morphological characters (Table 2) were scored from five plants randomly sampled from each accession and replication using International

Board for Plant Genetic Resources Descriptors for finger millet (IBPGR, 1985).

The percentage frequencies of the phenotypic classes of each character and region were calculated. The Shannon-Weaver diversity index (H') was computed using the phenotypic

Table 1 List of finger millet accessions with their respective region, district (woreda) and altitude.

Region	Accession no.	Woreda	Altitude (m asl)	Region	Accession no.	Woreda	Altitude (m asl)
				Gojam	215841	Bure and Shikudad	2050
Eritrea	230101	Adikuala	1740		215850	Bahir Dar	1800
	230117	Adikuala	1650		215867	Bahir Dar	1990
	230130	Adikuala	1800		215874	Yilma and Densa	2350
	230136	Adikuala	1900		215877	Yilma and Densa	2230
	230714	Dekemehari	1950		215879	-	2400
	230722	Dekemehari	2000		215883	Yilma and Densa	2400
	230724	Dekemehari	2040		215889	Bure and Shikudad	2100
	204747	Debubawi Hamasen	2250		215896	Gwagusa and Wenber	2160
Tigray	234178	-	1840		225895	Mecha	1845
	234205	-	2100		229723	Mandura	1300
	237447	Werr	1570		229726	Dibate	1600
	237449	Adi arbate	1470		229728	-	1440
	237451	Adi arbate	1450	Welega	100094	-	1290
	237452	Adi arbate	1430		100095	-	1480
	237459	Adwa	1940		208730	Seyo	1900
	237462	Tach maychew	2100		216024	Gudru	2330
	237477	Tsimbla	1710		216025	Gudru	2330
	238319	Wemberta	2130		216028	Diga	2150
	238331	Adi hageray	1300		216041	Nejo	1960
	238336	Sheraro	1020		216043	Nejo	1980
Gonder	208444	Dera	2500		216045	Nejo	1880
	215973	Gonder Zuriya	2090		216051	Lalo Asabi	1910
	215977	Dembiya	1940		216052	Lalo Asabi	1660
	235138	-	2200		236447	Sasiga	1630
	235141	Wereta	1870		236450	Sasiga	2230
	235830	Dib Bahir	1640	Gamo Gofa	100055	Jinka	1450
	235838	Lay Armacheho	1290		100084	-	1820
	235842	Lay Armacheho	940		211474	Konso	1560
	242123	Lay Armacho	1720		213035	Gardula	1380
	242125	Lay Armacho	2015		235700	Bako Gazer	1530
	242131	Dembia	2350		241769	Konso	1500
Gojam	208448	Guangua	1250				

- Information not available.

frequencies to assess the overall phenotypic diversity for each character and region. This parameter has been used extensively in evaluating genetic resources to measure phenotypic diversity for discrete characters both among (Jain *et al.*, 1975) and within country gene pools (Negassa, 1986; Bekele, 1996; Demissie and Bjornstad, 1996; Belay *et al.*, 1997; Ayana and Bekele; 1998; Kefyalew *et al.*, 2000; Tsehaye and Kebebew, 2002, Workeye, 2002).The Shannon-Weaver diversity index, H described by Hutchenson (1970) is given as follows:

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

Where *Pi* is the proportion of individuals in the ith class of an n–class character and n is the number of phenotypic classes for a given character. Each value of H was divided by its maximum value, $\log_e n$, and normalized in order to keep the values between zero and one (designated as H’). The non-normalized values H using regions were used for one-way analysis of variance of diversity for individual characters. The computations were conducted using SAS for Windows release 8.2 computer program (SAS, 1999) and Microsoft Excel computer software.

RESULTS AND DISCUSSION

Character distribution

Frequency in phenotypic classes expressed in percentage for characters, region and countrywide are shown in Table 3. The regions in this table were arranged in north-south sequence to follow the pattern of variation. All the traits considered showed marked differences in their distribution and amount of variation. In no cases monomorphic phenotypic classes were observed.

Three phenotypic classes were

Table 2 Characters used for the study and their codes and description.

Character	Code	Description
Growth habit	3	Decumbent
	5	Erect
	7	Prostrate
Ear shape	1	Droopy (fingers lax and drooping)
	2	Open (fingers straight)
	3	Semi-compact (tops of fingers curved)
	4	Compact (fingers incurved)
	5	Fist-like (fingers very incurved)
Grain shape	1	Round
	2	Reniform
	3	Ovoid
	4	Irregular
Grain surface	1	Smooth
	2	Wrinkled
Grain color	1	White
	2	Orange-red
	3	Dark brown
Pericarp persistence	0	Non-persistent
	3	Partially persistence
	7	Persistence

recognized for growth habit. The variation in growth habit showed that the decumbent type was more predominant in all regions followed by prostrate type with overall frequency of 25% whereas erect type was found to concentrate in Eritrea with a frequency of 34%. This implied the former two types might be highly preferred by most farmers in different regions which could be due to their capacity to suppress weeds at early growth stage so that farmers would save their time and could spend it for activities on other crops. The other reason could be that finger millet with these two types of growth habit could relatively stand moisture stress. Such growth habit may cover the soil at early stage and thereby reduce the evapo-transpiration and could enable the plant to perform better. In the areas of low rainfall, spreading types are also preferred in other crops such as chickpea (Singh and Saxena, 1999).

Variable ear shapes were observed in all regions. The droopy finger type was concentrated in Tigray, Gonder and Eritrea, indicating the predominance occurrence of race coracana in the northern part because droopy finger is a characteristic of race coracana (De Wet, 1989). Regions in the northern part, Tigray, Gonder, and Eritrea are known to be relatively hot and dry and race coracana is drought tolerant and competes with weeds (De Wet, 1989). Whereas, the open (straight) one was found at the higher frequency in all regions except Gamo Gofa. The semi-compact, compact and fist like were concentrated mainly in Gamo Gofa. This result is generally in agreement with the findings of Tsehaye and Kebebew (2002) who reported high frequency for droopy finger types in Gojam, Gonder and Tigray and for semi-compact types in Gamo Gofa and Illubabur.

The wide range of agro-climatic condition of the country could lead to the development of different races of finger millet. De Wet *et al*. (1984) indicated that inflorescence morphology was associated with grain yield and is used by the farmers to distinguish complexes of cultivars.

Round type of grain shape was predominant (≥50%) in all regions except in Eritrea (32%) where irregular grain shape was most frequent (46%). The reniform type was found at intermediate frequency (24%) in Gamo Gofa while ovoid type was observed mainly (22%) in Eritrea.

The two classes of grain surface (smooth and wrinkled) were more or less distributed uniformly among all regions and did not show apparent trend relative to particular region showing there was no conscious human selection for these characters in subsistence agriculture. Though their adaptive significance is not known, grains with round shape and smooth surface are preferred by consumers.

The three classes of grain color (white,

Table 3 Percentage frequencies of each character of the 64 finger millet accessions in various regions and the overall collection.

Region	Growth habit			Ear shape					Grain shape				Grain surface		Grain color			Pericarp persistence		
	3[+]	5	7	1	2	3	4	5	1	2	3	4	1	2	1	2	3	0	3	7
Eritrea	54	34	12	37	60	0	0	3	32	0	22	46	38	62	0	38	62	0	14	86
Tigray	55	18	27	32	64	2	0	2	50	4	10	36	32	68	12	38	50	0	9	91
Gonder	42	32	26	30	62	8	0	0	50	10	13	27	40	60	0	27	73	0	20	80
Gojam	53	22	25	25	54	10	6	5	64	11	5	20	46	54	14	26	60	8	31	61
Welega	49	15	36	13	63	15	7	2	61	10	10	19	57	43	22	34	44	7	21	72
Gamo Gofa	62	23	15	7	20	23	20	30	57	24	10	19	51	49	0	26	74	2	46	52
Overall	52	23	25	24	57	9	5	5	54	9	10	27	44	56	10	32	58	3	22	75

[+] For phenotypic classes description codes see Table 2.

orange-red and dark brown) were found in all regions except the white, which was absent in Gonder, Gamo Gofa and Eritrea. The white grain color was rare with a maximum frequency of only 22% in Welega. The orange-red grain color showed intermediate frequency. The dark brown grain color was dominant in all regions reaching 73 and 74% in Gonder and Gamo Gofa, respectively. Similarly, Tsehaye and Kebebew (2002) in finger millet and Workeye (2002) in chick pea observed all classes of grain color in all regions from where the accessions were sampled.

Seed color is one of the most important characters which determine the quality and acceptance of cultivars. It has an economic value because it constitutes the basis for farmers' variety identification and commercial classification of different varieties of crops **(**Tsehaye and Kebebw, 2002**)**. Farmers associated dark-colored with high-yield and hardiness with respect to climatic hazards such as poor soil fertility and they prefer to grow it even though it fitches less money as compared with white and red seed colored (Kefyalew and Ensermu, 1989). This could be the main reason for the preponderance of dark brown colored seed in all regions. Red colored varieties are good for making the local flat bread (injera). However, they require fertile soil that is free of water logging. In Ethiopia there exists an apparent association between phenotype and utility of, especially grain color and human consumption (Zemede, 1988).

The persistence pericarp type was predominant and concentrated in all regions reaching 91% in Tigray. The partially persistence was also distributed moderately almost in all regions, whereas the non-persistence type was absent in some regions but in Gojam, Welega and Gamo Gofa found at lower frequencies of 8, 7 and 2%, respectively. Overall, it comprised only 3%.

Finger millet seed is a challenge to threshing and milling because of its small size and its seed coat is bound tightly to the edible part (endosperm) inside (Tsehay and Kebebew, 2002). Therefore, the entries having low pericarp-persistence (non-persistence type) could be a good source of genes to improve the threshability and milling quality of this crop. Regions such as Gojam, Welega and Gamo Gofa could be considered as center of concentration for this character.

Morphological traits studied except open (straight), compact and fist like ear shapes and white grain color were not conspicuously unique to any single region (Table 3). This could be attributed to germplasm exchange (gene flow) which renders regional boundaries irrelevant. Another human factor that might have played a role as, for example, the various seed colors are traditionally preferred to specialized consumption purposes (Belay *et al*., 1997). Nevertheless, the predominance of some phenotypic classes might indicate the adaptive role as mentioned above for finger ear shape and growth habit which have a role in stress tolerance and weed suppression.

Estimates of diversity

Table 4 shows the estimates of the Shannon- Weaver diversity index for each of the character by region. Overall, all characters revealed intermediate to high diversity ranging from 0.60 for pericarp persistence to 0.99 for grain surface.

Individual characters showed different levels of diversity index in different regions. Grain surface with two phenotypic classes exhibited higher diversity index in most regions than other characters with more than two phenotypic classes. Higher diversity index for characters with less number of phenotypic classes was also reported by Ayana and Bekele (1998) in sorghum. The lower diversity index of characters having greater than two phenotypic classes could be attributed to unequal distribution of the accessions of every region over all the phenotypic classes of the character rather than lack of variation for the character. Hence, it might be misleading to compare the value of diversity index (H') from characters having different classes of phenotypes (Ayana and Bekele, 1998). As reminded by Negassa (1985) caution should be made while interpreting the estimates of diversity of different characters with different phenotypic classes as measured by Shannon –Weaver diversity index.

The highest mean diversity indices pooled over characters within region were recorded for accessions sampled from Gojam (H'=0.84±0.04) and Welega (H'=0.84±0.06) followed by Gamo Gofa (H'=0.79±0.07) whereas accessions from Eritrea and Tigray region showed relatively lower diversity estimates of 0.67±0.09 and 0.71±0.11, respectively. There was an increasing trend from north to south (Table 4 and Fig. 1). Bekele (1996) in tef and Tsehaye and Kebebew (2002) in finger millet also observed similar trend of diversity indices. The former author indicated that migration effect of the Ethiopian people from the diverse central and northern part of the country into the south and southwest carrying their seed stocks with themselves might have partly resulted in increasing diversity in south. He further elaborated that the

Table 4 Estimate of the Shannon-Weaver diversity index, mean diversity and standard error in finger millet by region.

Region	Growth habit	Ear shape	Grain shape	Grain surface	Grain color	Pericarp persistence	H'±Mean
Eritrea	0.86	0.49	0.76	0.95	0.61	0.37	0.67±0.09
Tigray	0.90	0.50	0.77	0.90	0.88	0.28	0.71±0.11
Gonder	0.98	0.53	0.86	0.97	0.53	0.46	0.72±0.10
Gojam	0.92	0.76	0.72	1.00	0.85	0.78	0.84±0.04
Welega	0.91	0.69	0.78	0.98	0.97	0.68	0.84±0.06
Gamo Gofa	0.83	0.95	0.71	1.00	0.52	0.71	0.79±0.07
Overall	0.93	0.73	0.82	0.99	0.83	0.60	0.82±0.06

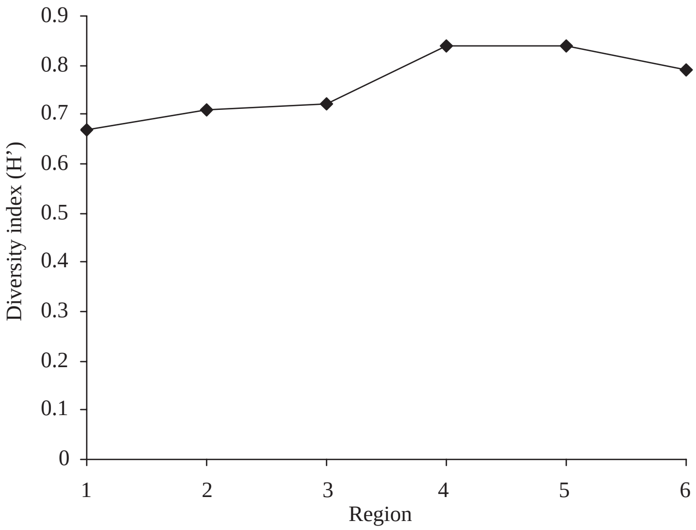

Figure 1 Overall mean diversity index (H') of 64 finger millet accessions across characters in five former regions of Ethiopia and Eritrea: 1=Eritrea, 2=Tigray, 3=Gonder, 4= Gojam, 5=Welega, 6=Gamo Gofa.

diversity of habitats in addition to being wetter could result in accommodating many genotypes.

The overall mean diversity estimate in this study (0.82±0.06) was high and almost similar to estimate (0.73±0.07) of Tsehaye and Kebebew (2002) for Ethiopian finger millet in another set of germplasm. The high level of diversity in finger millet heralds the presence of many important genes for breeding.

Analyses of diversity

The analysis of variance (ANOVA) of the non-normalized diversity index (H) for individual characters is presented in Table 5. The analysis revealed similar levels of diversity among regions for three of the characters (growth habit, grain color and pericarp persistence). Similar results were observed in sorghum (Ayana and Bekele, 1998), chickpea (Workeye, 2002) and finger millet (Tsehaye and Kebebew, 2002). The variances were attributed to among populations rather than between regions. This cautions that future germplasm sampling for these characters (or other characters linked to them) should not make discrimination among regions. Kefyalew *et al*. (2000) in tef observed variation among the regions for some characters as found in this study for ear shape ($P \leq 0.01$), grain shape ($P \leq 0.05$) and grain surface ($P \leq 0.01$) among regions. Accordingly, Gamo Gofa for ear shape (H'=0.95), Gojam and Gamo Gofa for grain surface (H'=1.0) and Gonder for grain shape provided the highest diversity (Table 4).

CONCLUSION

The overall diversity index (0.82±0.06) of finger millet observed in this study is in agreement with the findings of Hussaini *et al*. (1977) and Tsehaye and Kebebew (2002) that indicated the existence of a vast range of genetic variability in the indigenous Ethiopian germplasm. Generally, there was high morphological diversity, implying that *in situ* conservation have been in placed and genetic erosion has not been wide spread. Moreover, the result of this study supports the hypothesis that eastern Africa is a center of domestication for finger millet.

The result could also help in planning future germplasm collection in many geographical areas instead of collecting extensively within individual region. However, future collection operation of finger millet germplasm as source of diversity should also account distribution of polymorphism. Priorities of germplasm collection should focus on areas with relatively large variation.

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Table 5 Mean squares for variations between regions from the one-way analysis of variance of diversity index (H) for individual characters.

Characters	Between region(DF=5)	Between population within regions(DF=58)
Growth habit	0.06	0.08
Ear shape	0.30**	0.07
Grain shape	0.29*	0.10
Grain surface	0.20**	0.04
Grain color	0.09	0.07
Pericarp persistence	0.08	0.06

*,** Significant at 5% and 1% level, respectively; DF= Degree of freedom

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