Research Paper

Regional Diversity of Local and Exotic Finger Millet Germplasm Based on Qualitative and Quantitative Traits in Sri Lanka

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Abstract

Finger millet (*Eleusine coracana* (L.) Gaertn) is hardy and one of the cereal most adaptable over a wide range of agro-ecological zones worldwide. Based on five qualitative and fourteen quantitative traits, the regional diversity of finger millet was assessed for 135 finger millet accessions at the Field Crop Research and Development Institute, during 2016 and 2017. These accessions represented the eco-geographical regions of Sri Lanka and geographical locations of exotic germplasm. Incurved panicle shape, decumbent growth habit, non-pigmented plants, light brown grain color and late flowering phenotypes were predominant in the germplasm studied. Shannon-Weaver diversity index value ranged from 0.33-1.07. The highest diversity was observed in growth habit. Almost all phenotypic classes were observed among local and exotic germplasms. Significant quantitative trait variability was observed among regions. Northern region, India and Zimbabwe germplasm were significantly different for days to 50% flowering, plant height, finger length, panicle exertion and peduncle length. Based on both qualitative and quantitative traits, regions were grouped into two main clusters. All the regions of Sri Lanka except the Northern region formed a large cluster. Hence, phenotypic resemblance among local germplasm was evident and this may be due to selection of traits preferred by farmers and exchange of promising cultivars/farmers' varieties among regions.

Keywords: **Cluster analysis, Diversity index, Finger millet, Phenotypic classes, Regional diversity**

Introduction

Finger millet is an enduring cereal for diverse agro-ecosystems and a good candidate cereal for drought prone low input agricultural systems. It plays a vital role in ensuring food and nutritional security in rural farming community in semi-arid tropics. Finger millet was a dominant cereal in the dry zone agriculture in Sri Lanka until 1980s. It is considered as a traditional cereal among rural farming community and cultivating finger millet in their farm lands gave good assurance for food security even with the presence of adverse weather. Presently, finger millet remains as the third important cereal in Sri Lanka and with 6770 ha of cultivation extent in 2018 (Agstat, 2019).

Finger millet originated and first domesticated in Eastern Africa where Western Uganda and the Ethiopian highlands are located. It is an allotetraploid (2n =4x =36, AABB) and evolved from diploid species in which E. *indica* was the "A" genomic donor (Hilu, 1988; Hiremath and Salimath, 1992; Bisht and Mukai, 2001). The "B" genomic donor can be either E. *faccifolia* or an extinct species (Neves *et al*., 2005; Liu *et al*., 2014). Based on inflorescence compactness and shape, finger millet germplasm is classified into races and subraces. *Eleusine coracana* subspecies *coracana* consists of four cultivated races, namely *elongata, plana, compacta* and *vulgaris*. Each of these races is further classified into sub races (Upadhyaya *et al*., 2007). The qualitative trait diversity studies revealed that there is substantial diversity among landraces and farmer cultivars in Africa and India (Bharathi, 2011; Manyasa, 2013).

Plant Genetic Resource Center (PGRC) of the Department of Agriculture of Sri Lanka which was established in 1988 has conserved total of 551 finger millet germplasm accessions. According to gene bank exploration data, 482 have been collected from different districts of all over the country and the rest 69 are introductions from India, Zimbabwe, Nepal and unknown origins. International Crops Research Institute for Semi-Arid Topics (ICRISAT) finger millet core collection consisted of two Sri Lankan finger millet accessions, namely IE2983 and IE2971 (Upadhyaya *et al.*, 2006).

A study of 46 local finger millet accessions in a pot experiment showed only green type plant (Dassanayaka and Kaluthanthri, 2017). Hence, morphological evaluation of fairly large number of germplasm from local collection in large open field plots, in the dry zone environment is important to assess of existing diversity. Thus, the objective of the present study was to assess the regional diversity of finger millet germplasm in Sri Lanka based on qualitative and quantitative traits.

Materials and Methods

A total of 135 germplasm accessions, including recommended varieties Rawana (AC010326 from India) and Oshadha (AC000108 from Monaragala) were evaluated at research fields of the Field Crops Research and Development Institute (FCRDI), Mahailluppallama, Sri Lanka in 2015/16 and 2016/17 *Maha* seasons. The

candidate accessions were collected from PGRC and grouped into eleven geographical regions based on the locations from which they were collected (Table 1). Apart from local accessions, the exotic accessions from Zimbabwe, India and Nepal and unknown origin were included in the study.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with two replications. The coordinates, altitude and Agro-ecological region of the experimental site was 80º28"E, 8º07"N, 117 m, and DL_{2b}, respectively. Twenty day old seedlings were transplanted in a single row plot of 5 m long and 0.6 m width. The spacing between two plants was 0.1 m and plant density was 50 plants per plot. Basal fertilizer of 65, 55 and 85 kg of urea, triple super phosphate and murate of potash, respectively and top dressing of urea 150 kg ha^{-1} was applied 20 days after transplanting. Chemical control of insect pest and diseases was done to keep the field free of pest and diseases and the field was irrigated when required.

Following IBPGR (1985) as a guide, observations were recorded on qualitative and quantitative traits. Records on four qualitative traits namely plant pigmentation (PP), panicle shape (PS), grain color (GC), and growth habit (GH) were taken on plot basis. Flowering groups (FG) were identified based on days to 50% flowering and converted to a qualitative characteristic. Measurements on quantitative traits namely plant height (PH), flag leaf blade length (FLL), flag leaf blade width (FLW), peduncle length (PL), panicle exertion (PE), number of fingers per panicle (NF), length of longest finger (FL), finger width (FW) and number of productive tillers (NT) were taken on 5 randomly selected plants from middle of the plot. Days to 50% flowering (DF) was recorded for plot basis whilst the data such as weight of 20 mature ears (TWEW), threshing ratio (TR; weight of grains 20 ears divided by ear weight of 20 ear), grain yield (GY) and 1,000 grain weight (THGW) were recorded after harvesting.

Data Analysis

Analysis of variance was performed for quantitative traits and regional mean values for each trait were compared based on Duncan Multiple Range Test using SAS software (SAS, 2003). (version 9.1, SAS Institute, USA). The regional genetic diversity of qualitative traits was determined by Shannon-Weaver index (*H*) using following formulae for qualitative traits;

$$H = - \sum_{i=1}^{n} p_i \log_e p_i \quad \text{..... (1)}$$

Where: *H*-Shannon Weaver index, p_i –the proportion of entries in the i^{th} class of *n* class trait.

The percentage frequency distribution of qualitative traits across regions was calculated and regional cluster dendrogram was obtained for standardized percentage frequency distribution based on Ward linkage. Cluster dendrogram based on quantitative traits was obtained using scores of first five principal components that captured 90% variability of 14 traits. The MINITAB statistical software was used for cluster analysis (Minitab 17 Statistical Software 2010) (version, Minitab Inc.).

Table 1. Eco geographical regional information of finger millet germplasm accessions used in the study

Region**	Abbreviation	District	No. of accessions	PGRC Accession Number	Agro ecological Region*
North central	NC	Anuradhapura	18	000038, 007770, 012401, 005047, 008405, 012329, 007075, 012201,012225, 007071, 012038,012225, 012276, 007072, 012189, 012280, 007612, 012448,	DL_{1b}, DL_{2b}
		Polonnaruwa	4	007769, 012605, 012629, 010453	
East	E	Baticoloa	1	011087	DL_{2a}, DL_{2b}
		Ampara	1	011774	
Southeastern	SE	Badulla	4	000965, 006588, 006581, 007090	IL_{2}, IL_{1c},IU_{3c}
		Monaragala	15	000108 (Oshadha), 011238, 000127, 008470, 011252, 002953, 009361, 011332, 006589, 010098, 011821, 008317, 011369, 012927, 012944,	
		Mahiyanganaya	9	Farmer cultivars -M1, M4, M7, M2, M5, M8, M3, M6, M9	
Northwestern	NW	Kurunegala	8	000405, 007078, 011352, 000426, 007088, 012449, 000418, 011347	IL_{1a}, IL_{3},
Central	C	Kandy	12	001815, 007829, 011817, 012053, 008660, 012248, 007610, 011142, 012316, 007823, 011350, 012747	WM_{1a}, WM_{2b}
		Matale	8	012516, 006586, 011818, 000788, 011342, 012181, 001233, 000353	
		Ratnepura	4	008613, 001331, 008630, 010371	
Northern	N	Jaffna	3	002383, 002384, 012968	
		Killinochchi	4	Farmer cultivar; TVTM013-1, TVFM -01, TVFM-02, TVFM-04	DL_{3},DL_{4}
Southern	S	Hambantota	9	000150, 000152, 000955, 006587, 000190, 000967, 006590, 000192, 003021	DL_{1a}, DL_{1b}
Highlands	H	Nuwara Eliya	9	000504, 009079, 012415, 001051, 012263, 012465, 001460, 012282, 012490	WU_{3}
Exotic India and Nepal	EIN	India	8	000907, 000926, 000927, 000910, 000964, 012495, 000923, 010326 (Rawana)	not applicable
		Nepal	2	012428, 012494	
Zimbabwe	EZ		7	007107, 007111, 007116, 007109, 007112, 007117, 007110	
Unknown	U		9	001906, 009311, 011819, 009294, 009313, 012591, 009304, 12593, 012639	
		Total No. Acc.	135		

* Punyawardha *et al*., (2003) ** East region was combined to Southeastern region for qualitative diversity analysis

Results and Discussion

Frequency distribution of phenotypic classes

Different phenotypic classes were observed for finger millet germplasm accessions studied under each of five qualitative traits (Table 2). Five different phenotypic classes were observed in panicle shape. Incurved panicle shape was dominating (61%) and followed by fisty (21%). The droopy panicle shape was observed only in exotic accessions from Zimbabwe. Germplasm collected from most regions in Sri Lanka recorded, either top curved, curved or fisty panicles. The droopy and open panicle shapes were observed in exotic germplasm and germplasm from Northern region of Sri Lanka. Diversity studies of qualitative characteristics of East and South east African and Nepalese finger millet land races showed open panicle shape, which was prominent in population (Lule *et al*., 2012; wachira *et al*., 1995; Bastola *et al*., 2015).

Purple pigmentation in internodes, leaf ligule or flag leaf was observed only in 10% of the germplasm accessions studied and rest were green. Purple pigmentation was observed in some of the germplasm in Southern (AC000192, AC000967), Northern (AC002383 and AC012968) and exotic origins (AC000910, AC012495, AC007107, AC007111, AC007112, AC007116 and AC007117). The diversity study of East African finger millet germplasm showed that the pigmented type was abundant over the green type. Purple pigmentation is predominant in Race *Vulagris* and germpalsm from East African region (Bharathi, 2011).

Only two phenotypic classes, erect and decumbent were found for growth habit in local germplasm collection. However, prostate growth habit has been reported in some of Asian and African origin germplasm (Bharathi, 2011). The decumbent growth habit was prominent in total collection. However, regional distribution of growth habit showed erect type and it was predominant in few regions (Northern. India and Zimbabwe origin). The diversity studies in India and Africa showed that the erect type is dominant (Bharathi, 2011; Manyasa, 2013). In contrast, Bezaweletaw *et al*. (2007) found that decumbent and prostate type were more frequent in landraces due to their ability to compete with weeds at early growth stage. However, harvesting is difficult with prostate type and decumbent type due to their lodging vulnerability.

The 85% of accessions used in the study belonged to late flowering group (>75 days to 50% flowering). However, 57% of accessions collected from Northern region of Sri Lanka were early flowering (<55 days to 50% flowering) and the rest were grouped in medium flowering. Germplasm from India and Nepal showed almost equal proportions of medium and late flowering. Studies on East African germplasm and global composite collection showed a higher proportion of late maturity germplasm in the population (Bharathi, 2011; Manyasa, 2013).

Table 2. Percentage of frequency distribution and Shannon Weaver Index (H) of five qualitative traits of 135 finger millet accessions collected from seven different regions in Sri Lanka and three exotic locations.

Trait**	Phenotypic class	Percentage of frequency distribution***											Diversity index*			
		NC	SE	S	NW	C	H	N	EIN	EZ	U	Total	H_d	H	H_d/ H	H-H_d /H
GH	1. Erect	36	33	33	50	46	68	100	90	86	78	53	0.52	0.69	0.76	0.24
	2. Decumbent	64	68	68	50	54	33	0	10	14	22	47				
PP	1. Green	100	97	78	100	100	100	43	80	29	100	90	0.25	0.33	0.75	0.25
	2. Purple	0	3	22	0	0	0	57	20	71	0	10				
FG	1. Early	0	0	0	0	0	0	57	10	0	0	4	0.35	0.52	0.68	0.32
	2. Medium	0	3	0	13	0	11	43	50	57	11	12				
	3. Late	100	97	100	88	100	89	0	40	43	89	84				
PS	1. Droopy	0	0	0	0	0	0	0	0	14	0	1	0.88	1.07	0.82	0.18
	2. Open	0	0	0	0	0	0	14	30	29	11	5				
	3.Topcurved	9	10	0	13	17	22	14	20	43	0	13				
	4. Incurved	77	73	22	63	63	67	57	30	14	89	61				
	5. Fist like	14	17	78	25	21	11	14	20	0	0	19				
GC	1. Dark brown	0	0	0	0	0	0	0	20	0	0	1	0.46	0.47	0.98	0.02
	2. Copper Brown	0	7	22	25	0	11	43	30	43	22	13				
	3. Light brown	100	93	78	75	100	89	57	50	57	78	85				
Pool diversity index		0.27	0.39	0.45	0.51	0.32	0.44	0.64	0.83	0.73	0.35	0.62	0.49	0.62	0.80	0.20

**Note: =Average diversity index across the regions, =Total diversity index for the collection, =Proportion of diversity within location, =Proportion of diversity between locations in relation to total variation.*

***PS=Panicle shape, PP=Plant Pigmentation, GH=Growth habit, FG=flowering group (early -<55 days to 50% flowering, Medium 55-75 days to flowering, Late ->75 days to flowering) GC=Grain Color.*

****NC-North central, S- Southern, SE-South eastern (2 Accessions from Eastern region included), NW-Northwestern, C-Central, H-highlands, N-Northern, EIN-India and Nepal, EZ- Zimbabwe, U-unknown*

Three types of grain color were observed in the collection. The light brown was most predominant (85%), followed by copper brown (13%) and dark brown grains (3%). However, white color was not found in this collection studied. Bezaweletaw *et al*. (2007) reported that farmers prefer dark seed color as it is associated with high yield and hardness to adverse climatic conditions as drought. However, lighter color grains can get higher market price. The percentage distribution into different phenotypic classes of age and grain colour was more-or-less similar with global composite collection (Bharathi, 2011).

Diversity of qualitative traits

Shannon diversity index estimates the diversity and evenness of distribution of accessions into different phenotypic classes. The diversity index for the average across regions for traits varied from 0.33 to 1.07 (Table 2). The highest total diversity was observed in panicle shape and lowest total diversity was observed in plant pigmentation. However, diversity for other qualitative traits was comparatively low. It was evident that unequal frequency distribution of germplasm was present among different phenotypic classes.

The partitioning of total diversity within and between regions was estimated using proportion of diversity by method proposed by Wachira *et al*. (1995). The diversity within regions (total diversity) was higher than that of between regions (Average *H* across regions) for all the measured traits. Gashaw *et al*. (2016) reported similar results of partitioning diversity within and between regions for sugarcane diversity analysis study. The regional diversity of panicle shape was higher for germplasm from Northern region, India, Nepal and Zimbabwe. Other than that Northern region showed higher diversity for other phenotypic traits except for growth habit. Informal transfer of seeds of millets from India to northern region must have caused an increase in diversity within region compared to other regions of the country.

The regions that showed lower pooled diversity index across traits, were traditional finger millet growing areas in Sri Lanka such as Southeastern region (SE) and North Central (NC) including, Monaragala, Badulla and Anuradhapura districts. Hence, land races and farmers' varieties from these regions were similar in morphological characteristics such as top or incurve panicle shape and medium or late maturity.

Quantitative trait diversity

Regional mean performance of quantitative traits showed significant variability among regions (Table 3). The Northern region showed significantly the lowest mean performance for traits such as days to flowering (56 days), plant height (63 cm), grain weight of twenty ear (57 g) and grain yield (1.17 t ha^{-1}) compared to other regions and exotic locations. The Indian and Nepal germplasm showed second lowest days to flowering (67 days), highest peduncle length (22 cm) and panicle exertion (10 cm) compared to all the other regions.

Table 3. Regional means of 14 quantitative traits of 135 finger millet germplasm accessions collected from eight regions in Sri Lanka and three exotic locations.

Region	Means of quantitative traits*, **													
	DF	PH	FL L	FL W	PL	PE	FL	FW	NF	TC	TW EW	TR	TH GW	GY
NC	84^{a}	72^{bc}	35^{bc}	11^{cd}	19^{b}	6^{bc}	6^{d}	11^{b}	8^{b}	4^{ab}	98^{b}	0.76^{abc}	2.09^{d}	1.9^{bcd}
E	85^{a}	81^{a}	37^{b}	10^{d}	20^{b}	7^{bc}	6^{de}	12^{ab}	8^{bc}	5^{a}	101^{b}	0.76^{abc}	2.09^{d}	2.1^{abc}
SE	82^{ab}	72^{bc}	34^{c}	10^{cd}	20^{b}	7^{bc}	6^{de}	11^{b}	8^{bc}	4^{ab}	91^{b}	0.78^{abc}	2.08^{d}	2.1^{abc}
S	81^{ab}	72^{bc}	36^{bc}	11^{cd}	20^{b}	8^{b}	5^{e}	12^{ab}	8^{ab}	4^{ab}	99^{b}	0.80^{a}	2.14^{cd}	2.3^{ab}
NW	78^{b}	71^{c}	36^{bc}	11^{bc}	20^{b}	7^{bc}	7^{cd}	11^{b}	8^{bc}	4^{ab}	100^{b}	0.79^{ab}	2.17^{cd}	2.5^{a}
C	85^{a}	73^{bc}	36^{bc}	11^{bc}	19^{b}	6^{c}	6^{d}	11^{b}	8^{bc}	4^{bc}	93^{b}	0.76^{abc}	2.17^{cd}	1.5^{de}
H	81^{ab}	75^{bc}	36^{bc}	12^{b}	20^{b}	7^{bc}	7^{c}	12^{a}	9^{a}	4^{bc}	97^{b}	0.76^{cbc}	2.36^{ab}	1.5^{de}
N	56^{d}	63^{d}	34^{c}	10^{cd}	20^{b}	7^{bc}	6^{d}	11^{b}	7^{d}	3^{c}	57^{c}	0.75^{bc}	2.35^{ab}	1.2^{e}
EIN	67^{c}	72^{bc}	37^{b}	12^{b}	22^{a}	10^{a}	8^{b}	11^{b}	8^{bc}	3^{c}	91^{b}	0.76^{abc}	2.43^{a}	1.7^{cd}
EZ	71^{c}	77^{ab}	43^{a}	13^{a}	20^{b}	9^{a}	10^{a}	11^{b}	7^{cd}	3^{c}	125^{a}	0.78^{abc}	2.39^{a}	1.9^{bc}
U	81^{ab}	75^{bc}	37^{b}	12^{b}	19^{b}	7^{bc}	6^{cd}	11^{b}	8^{ab}	4^{ab}	96^{b}	0.74^{c}	2.26^{bc}	1.6^{cd}

**Mean values with the same letter within a column are not statistically different at P<0.05. **NC-North central, E-Eastern, SE-South eastern S-Southern, NW-Northwestern, C-Central, H-highlands, N-Northern, EIN- India and Nepal, EZ- Zimbabwe, U-unknown.*

Days to 50% flowering (DF), Plant height-cm (PH), Flag leaf blade length-cm (FLL, Flag leaf blade width-mm (FLW), peduncle length-cm (PL), Panicle exertion-cm (PE), number of finger per panicle (NF), length of longest finger-cm (FL), finger width-mm (FW), number of productive tillers (TC), weight of 20 mature ears-g (TWEW), threshing ratio (TR), 1000 grain weight –g (THGW) and grain yield t ha^{-1} (GY)

The germplasm from Zimbabwe also showed second lowest days to flowering (71 days), highest flag leaf length (43 cm), flag leaf width (13 mm), longest finger length (10 cm) and highest grain weight of twenty ears (125 g) compared to those of other regions. The germplasm of the Eastern region recorded the highest plant height (81 cm). The germplasm of the Southeastern region showed significantly lower flag leaf length (34 cm). The germplasm of the Southern region showed the lowest finger length (5 cm). However, the germplasm of different regions of Sri Lanka except Northern region showed less variability for many traits. Germplasm of the regions such as Southeastern, Northwest, Eastern and Central part of Sri Lanka showed the higher grain yield compared to that of other regions (2-2.5 t ha^{-1}). Therefore, the diversity among major finger millet growing regions such as North Central, Southeastern and Southern was less compared to that of India, Nepal, Zimbabawe and Northern regions of Sri Lanka. Hence exchange of farmer selected varieties with preferable traits such as medium days to flowering, higher yield, medium plant height which resist lodging and incurved panicle shape with medium or lower finger length which reflects ear size, is evident.

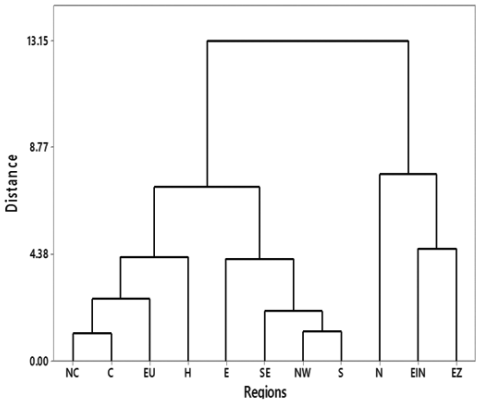

Figure 1. Cluster dendrogram of 135 finger millet accessions among regions in Sri Lanka and exotic origin based on principal scores of 14 quantitative traits using Ward linkage and Euclidean distance

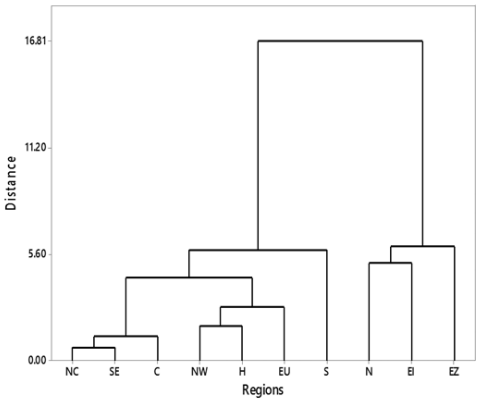

Figure 2. Cluster dendrogram of 135 finger millet accessions among regions in Sri Lanka and exotic origin based on frequencies five qualitative traits using Ward linkage and Euclidean distance.

Note: NC-North central, E-Eastern, SE-South eastern S-Southern, NW-Northwestern, C-Central, H-highlands, N-Northern, EIN or EI- India and Nepal, EZ- Zimbabwe, EU-unknown

Cluster analysis

The regions were clustered into two main clusters in both dendrograms based on quantitative and qualitative traits. The Northern region, exotic India and Nepal and Zimbabwe germplasm grouped together in both dendrograms. Hence, both qualitative and quantitative traits demonstrated almost similar pattern of clustering the germplasm based on geographical regions (Figure 1, 2). The Northern region showed higher within region diversity due to informal germplasm transfer from India. Further, 13% of exotic germplasm from total collection contributed to the highest diversity of finger millet conserved in gene bank of Sri Lanka.

Conclusions

Notably, almost all phenotypic classes were observed among local and exotic finger millet germplasm in Sri Lanka and contributed higher total diversity than the average diversity across regions. Hence, local finger millet gene pool showed substantial diversity which can be immensely utilized for varietal development including direct selection. However, uneven distribution of germplasm among phenotypic classes was evident by lower diversity index of many traits. Grouping of main finger millet growing regions into one main cluster indicated that the high yielding varieties/ cultivars were preferred by farmer with similar morphological traits have been exchanged among regions. Local germplasm from Northern region and exotic germplasm in the gene bank contributed to the highest qualitative and quantitative diversity to finger millet germplasm collection of PGRC, Sri Lanka.

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