Morphological Characterization of Local and Introduced Finger millet (*Elusine coracana* (L.) Gaertn) Germplasm in Sri Lanka

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ABSTRACT: *Finger millet, a self-pollinated cereal crop with high nutritional value, is grown in arid and semi arid tropics. Plant Genetic Resource Center of Sri Lanka conserves 462 local and introduced finger millet (*Elusine coracana* (L.) Gaertn) germplasm accessions. A total of 139 accessions were morphological characterized using 14 quantitative characters during two seasons in late Maha 2016 and Maha 2016/17 at Field Crops Research and Development, Institute, Mahailluppallama. The highest variability was observed in grain yield, panicle exertion, weight of 20 mature ears, number of productive tillers and length of the longest finger. Correlation analysis showed that the grain yield was significantly and positively correlated with the number of productive tillers, weight of 20 mature ears, threshing ratio and panicle exertion. However, the grain yield was significantly and negatively correlated with flag leaf width and 1,000 grain weight. Hence, these traits can be used for selecting germplasm for improvement. The Principal Component Analysis showed that the first six principal components with eigenvalue greater than 0.8 have contributed to 78 % of total variability. Eight different clusters were formed in cluster analysis based on first six principal component scores. Two major clusters (1 and 3) were consisted with 55 % of total accessions. The main traits contributed to separate genotypes into different clusters were grain yield, weight of 20 mature ears, days to 50% flowering and 1000 grain weight. The Sri Lankan finger millet germplasm collection exhibited the similar variability with global finger millet germplasm collections. Hence, the variability shown in characterization can be used effectively for finger millet improvement in Sri Lanka.*

Keywords: Characterization, finger millet, germplasm, morphological traits

INTRODUCTION

Finger millet, *Elusine coracana* (L.) Gaertn is a self-pollinated cereal crop belonging to the family Poaceae and subfamily Cloridoideae. It is an allotetraploid with chromosome number of 2n=4x=36 (Khidir and Wet, 1976). Finger millet was native and first domesticated in Ethiopian highland and Western Uganda at least 5,000 years ago and was introduced to India, Sri Lanka and China approximately 3,000 years ago (Upadhyaya *et al.,* 2006). Finger millet is an important subsistence cereal in semi-arid tropics and subtropics which is

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cultivated in more than 25 countries in Africa and South Asia. Globally finger millet is cultivated on 5 million hectares of land with a total production of 4.5 million tons of grains (FAO, 2011). It is a popular crop due to high nutritional value which is rich in calcium (1.8-4.8 g/kg), iron (21.7-65.23 mg/kg), zinc (16.5-25 mg/kg) and protein (6-11%) (Upadhyaya *et al*., 2011).

Genebank at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) conserves 7,186 germplasm accessions of finger millet originating from 25 countries. To enhance the utilization of finger millet germplasm, a core collection (10% of entire collection) consisting of 622 germplasm accessions and mini core collection (10% of core collection or 1% of entire collection) were developed at ICRISAT, India (Upadhyaya *et al.*, 2006; Upadhyaya *et al*., 2010).

Phenotypic variations in accessions of finger millet germplasm collections have been reported by several authors. Upadhyaya *et al.* (2007) evaluated 909 finger millet germplasm accessions originating from Southern and Eastern Africa, and reported that 65.3% accessions were of green plant type and other accessions were of pigmented type. Other characters such as plant height ranged from 50-180 cm, days to 50% flowering ranged from 62-96 days, inflorescence length ranged from 30-190 mm and panicle exertion ranged from 0- 215 mm. Bharathi *et al*. (2013) have evaluated the global finger millet composite of 1,000 accessions. In Sri Lanka finger millet is the third most important cereal after rice and maize and is cultivated in 6,000 ha with a production and productivity of 6,946 t and 1.2 t/ha (Agstat, 2014). It is mostly cultivated as a mixed crop with legumes such as mungbean, cowpea and black gram in upland in subsistence farming in dry and intermediate zones of Sri Lanka. Finger millets and other minor millets have been neglected in commercialized agriculture due to its lower productivity. However, demand for finger millet is increasing due to its high nutritional value and medicinal properties.

Plant Genetic Resource Center (PGRC) of Department of Agriculture of Sri Lanka has a collection of 462 germplasm accessions of finger millet (21, 17,3 and 30 accessions obtained from India, Zimbabwe, Nepal and unknown exotic origins, respectively and the remaining 393 have been collected from different districts of all over the country (PGRC, 2016). According to gene bank exploration data, these local germplasm accessions were collected since year 1987 from 18 districts. These germplasm accessions were used for breeding and research activities at the Field Crops Research and Development Institute, Mahailluppallama (FCRDI) during the last 30 years (Anonymous, 2011; Dasanayaka, 2016) morphologically characterized 24 finger millet accessions of PGRC as a pot experiment in green house condition. Although a comprehensive morphological characterization of fairly large number of germplasms of finger millet is fundamental for its breeding programs. However, large number of germplasm were not characterized in open field conditions in uplands of dry zone in past. Therefore, the objective of this study was morphological characterization of local and exotic finger millets accessions collected and conserved at the PGRC, Sri Lanka to facilitate the breeding programme of finger millet.

MATERIAL AND METHODS

The morphological characterization study included a total of 139 germplasm accessions which were selected from the passport data base of finger millet germplasm at the PGRC, Sri Lanka. Among them 100 accessions were from local collection from 15 districts and 26 accessions were from exotic collection from India, Nepal, Zimbabwe and unknown exotic

origin, 9 were collected from farmer fields at Mahiyanganaya, and 4 were received from Regional Agriculture Research and Development Center Killinochchiya (Annex 1). The recommended varieties Rawana (exotic accession 10326) and Oshadha (local accession 108) were also included in the assessment as standards.

The evaluation was done in the research fields of FCRDI, Mahailluppallama during the late *Maha* 2015/16 (Season 1, February 2016 to May 2016) and *Maha* 2016/17 (Season 2, November 2016 to March 2017) in Randomized Complete Block Design with 2 replicates. The experiment site is located at an altitude of 117 m, longitude of 80 $^\circ$28" E and latitude of 80 $^\circ$07" N. The transplanting was done with 20 days old seedlings. The plot size was 5 m long and 60 cm width and the spacing between two plants was 10 cm. The final plant density was 50 plants per row. Basal fertilizer of 65 kg of urea, 55 kg of triple super phosphate, 85 kg of murate of potash and top dressing about 150 kg of urea per hectare 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 irrigation was provided whenever needed.

Following IBPGR (1985) as a guide observations were recorded from 5 randomly selected plants from middle of plot for 9 quantitative traits such as plant height (PH), flag leaf blade length (FLL), flag leaf blade width (FLW), peduncle length (PL), panicle exertion (PE), number of finger per panicle (NF), length of longest finger (FL), finger width (FW) and number of productive tillers (NT), days to 50% flowering (DF) was recorded for plot basis whilst the data such as weight of 20 mature ears (20 EW), threshing ratio (TR; 20 ear grain weight divided by 20 ear weight), grain yield (YLD) and 1,000 grain weight (1,000 GW) were recorded after harvesting.

Data analyses

The analysis of variance was done for each season and the genotype into season interaction (G x E) effect was analyzed by using analysis of variance for two seasons data. The major descriptive statistics were calculated. Correlation coefficient among qualitative characters was estimated by the formulae of Snedecor and Cochran (1980). Principal Component Analysis (PCA) was done using standardize quantitative variables using MINITAB 14 software (MINITAB, 2004). The season 2 data were used for correlation analysis and cluster analysis as the experimental error was lower in season 2 compared to season 1.The scores of first six principle components which accounted for more than 75% of the total variability were used for the cluster analysis. The similarity matrix was calculated using Euclidean distance and germplasm accessions were grouped using Wards linkage method (Ward, 1963). Dendrogram was obtained from MINITAB 14 software.

RESULTS AND DISCUSSION

Summary statistics of morphological traits

The analysis of variance performed for two seasons and result is presented in Table 1. The characterized accessions were significantly diverse for most of the traits except for finger within season 2 and finger width, number of tillers and flag leaf length in season 1. Analysis of genotype into season interaction effect was significant for days to 50% flowering, plant height, panicle exertion, weight of 20 mature ears, threshing ratio, grain yield and 1000 grain weight. Hence, other traits which have not shown significant genotype into season interaction

are highly heritable characters with less or no environment effect. The mean, standard deviation. coefficient of variation, minimum and maximum for 14 quantitative traits for two seasons are given in Table 2.The mean values of traits for two seasons were significantly different for many traits except flag leaf width, finger length and number of fingers per ear. Hence some accession had not shown the similar performance in both seasons. Finger millet is a photo and thermo-sensitive crop, and therefore any fluctuation in day length and daily temperature would have direct effect on the growth and development of vegetative growth of the crop (Senthil *et al*., 2005).

The highest coefficient of variation was observed in grain yield (t/ha). Therefore, it provides the opportunity to improve the yield potential by direct selection from the germplasm accessions. Further, panicle exertion, weight of 20 mature ears, number of productive tillers and finger length showed a higher variability (table 2). (Ulaganathan and Nirmala kumara, 2015), reported the highest variability in grain yield per plant, flag leaf blade length and number of productive tillers in 300 finger millet genotypes collected from different geographical regions of India and evaluated in *Kharif,2011* in India.The range for days to 50% flowering for this study was 47 -101 days. Manyasa, (2013)analyzed the diversity of East African finger millet germplasm and found the days to 50% flowering 41 to 114 days and finger mini core collection reported the 59 -109 days in the same study. It revealed that local finger millet germpalsm showed the almost same variability found tin African and Asian finger millet germplasm. Further grain yield of germplasm accessions ranged from 0.6 to 4.1 t/ha in pooled data. The similar yield range also recorded East African germplam by Manyasa (2013). However, Bharathi,(2013) reported the 0.02 – 2.6 t/ha of lower yield in finger millet global composite.

Table 1.   Analysis of Variance (ANOVA) of 14 morphological traits for 139 finger millet germplasm accessions during two seasons

	Season 1				Season 2				G *E Pro.
Trait	MSS	EMS	Pro.	CV%	MSS	EMS	Pro.	CV%	
DF	2506	2959	0.0001	6.7	141	7.27	0.0001	3.4	0.0001
PH	298	161	0.024	17.9	131	31.19	0.0001	7.4	0.0001
FLL	3835	3375	0.769	179	23.34	8.81	0.0001	4.3	0.669
FLW	60.38	10.4	0.0001	22	2.50	3.62	0.0001	7.6	0.128
PL	5896	4668	0.09	36	5.71	2.80	0.0001	7.8	0.0339
PE	11.41	4.22	0.001	34	10.94	4.95	0.0001	25	0.004
FL	3.72	0.59	0.0001	11	5.71	0.98	0.0001	15	0.726
FW	8.73	8.5	0.451	26.1	3.26	2.73	0.149	14	0.691
NF	2.35	0.85	0.0001	11	3.12	0.77	0.0001	10	0.718
NT	5.31	5.27	0.49	49	2.86	1.04	0.0001	28	0.124
20EW	1194	452	0.0001	27	2076	2.42	0.0001	10	0.0001
TR	0.01	0.004	0.0001	8.6	0.01	0.00	0.0001	6.6	0.0001
YLD	1.48	0.35	0.0001	34	1.65	0.20	0.0001	23	0.0001
1000GW	0.123	0.0022	0.0001	2.2	0.11	0.01	0.0001	3.7	0.0001

*MSS – Mean Sum of Square, MSE – Mean Square Error, CV%- Coefficient of variation, Pro. – probability of F test. G*E finger millet genotypes season interaction*
Note: 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 (NT), days to 50% flowering (DF) weight of 20 mature ears g(20EW), threshing ratio (TR) and grain yield per ha t/ha (YLD) and 1000 grain weight g (1000GW)

Table 2. **Summary statistics and significance test of means of 14 Qualitative morphological traits derived from 139 Finger millet accessions evaluated in two seasons**

Trait	late *Maha* 2016 (Season 1)					*Maha* 2016/17 (Season 2)					T-test Probability
	Mean	SD	CV	Min	Max	Mean	SD	CV	Min	Max	
DF	81	11.1	13.8	47	101	78	8.39	10.7	50	94	0.01
PH	70.0	9.57	13.6	37.5	93.5	75.3	8.15	10.8	52	91	0.0001
FLL	30.9	4.90	15.8	18	47.5	40.4	3.44	8.51	34	55	0.0001
FLW	11.0	1.60	14.6	7	17.5	11.1	1.19	10.7	9	16	0.667
PL	17.9	2.14	11.9	8.5	24	21.5	1.75	8.14	18	28	0.001
PE	5.8	2.48	42.4	0	11.5	8.3	2.34	28.2	4	19	0.0001
FL	6.5	1.42	21.7	4	15	6.4	1.68	26.0	4	17	0.536
FW	12.5	2.07	16.5	9	28	11.6	1.30	11.1	8	22	0.0001
NF	8	1.14	14.0	4.5	12	8	1.25	15.2	5	12	0.39
NT	5	1.95	42.3	2	17	4	1.20	33.3	1	7	0.0001
20EW	76	24.4	32.2	18	165.5	143	32.2	22.5	43.5	210	0.0001
TR	0.74	0.07	9.8	0.34	0.88	0.79	0.05	6.68	0.6	0.9	0.0001
YLD	1.73	0.86	49.9	0.14	4.05	1.94	0.72	37.3	0.3	4.61	0.028
1000GW	2.08	0.25	11.9	1.46	3.04	2.31	0.24	10.4	1.7	3.09	0.0001

Note: 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 (NT), days to 50% flowering (DF) weight of 20 mature ears g(20EW), threshing ratio (TR) and grain yield per ha t/ha (YLD) and 1000 grain weight g (1000GW)

Table 3 showed the most diverse accessions for 14 morphological traits. The shorter plant height (52 -55 cm) and early flowering (50 – 60 days after sowing) were observed in Ac2384 (Jaffna) and TVFM013-1 (Killinochchiya). Further Ac955 (Hambantota) showed the shorter plant height and lower length of longest finger (4 - 4.5 cm) too. The Ac2381 (Jaffna) showed the lowest number of fingers (4 fingers) and lower 20 ear weight (45 - 56 g). The Acc. 1331 (Ratnepura) showed the shorter plant height and lower length of longest finger (4 - 4.5 cm). The lower grain yield (>1.0 t/ha) was recorded in Ac2384 (Jaffna) and TVFM013-1 (Killinochchiya), Ac1815 (Kandy), Ac11350 (Kandy), Ac13361 (Matale) and Ac12629 (Polonnaruwa).

Based on data of two seasons, the Ac8613 (Ratnepura), Ac12038 (Anuradhapura) and Ac10098 (Monaragala) were the late flowering germpalsm (90-94 days to flowering). Among the germplasm studied the Ac7110 (Zimbabwe), Ac12269 (Anuradhapura), Ac7823 (Kandy) and Ac9304 (Exotic) recorded the tallest accessions (86 – 90 cm). The longer and wider flag leaf was observed in exotic germplasm. However, wider flag leaf also recorded in few local germpalsm. The length of longest finger (17 cm) was recorded in exotic finger millet accession Ac7110 origin in Zimbabwe. The higher yield (3 - 4 t/ha) were recorded in germpalsm collected from Mahiyangana (M4 and M9), recommended variety Rawana (Ac10326), two accessions from Kurunegala (Ac12449 and Ac11347), Ac12248 from Kandy and Ac12280 from Anuradhapura.

Table 3. The most diverse (higher and lower ranks) finger millet germplasm accessions for 13 morphological traits

Trait	Germplasm accession number and their origin in abbreviation	
	Lower ranks	Higher ranks
DF	EXO-IN_910, JAFF_2384, JAFF_12968, KILLI_TVFM013-1, KILLI_TVFM-02	EXO_11819,MAT_6586,RAT_8613, POL_10453,ANU_12038,EXO_12639,MON_10098
PH	MON_12927,HAM_955,RAT_1331,KILLI_TVFM013-1, JAFF_2384, KILLI_TVFM-04	EXO-ZIM_7110, ANU_12269,KAN_7823,EXO_9304
FLL	RAT_1329,ANU_12269,EXO_12639,JAFF_2384,ANU_12225	EXO-ZIM_7110,EXO-NEP_12494,EXO-ZIM_7112,EXO-ZIM_7107,EXO_9304,EXO-ZIM_7109
FLW	ANU_12201,JAFF_2384,MAHI_M5,RAT_1331,MAHI_M8	EXO_9304,KURU_11352,EXO-ZIM_7107
PL	EXO_9313	EXO-NEP_12494
PE	ANU_5047,RAT_10371	EXO-ZIM_7117,MAT_11818,EXO-NEP_12494
FL	HAM_955,RAT_1331,POL_7769	EXO-ZIM_7110
NF	JAFF_2384,RAT_1331,ANU_12269,EXO-IN_910,EXO-ZIM_7109,ANU_12329	NELYA_1460,KAN_8660,ANU_7770
NT	KILLI_TVFM-02,EXO-ZIM_7107,EXO-ZIM_7112,EXO_9311,EXO-IN_907,EXO_9304	ANU_12401
20EW	JAFF_2384,RAT_1331,KILLI_TVFM013-1,KILLI_TVFM-04,MON_12927	EXO-ZIM_7112,ANU_12276,EXO-ZIM_7107
TR	EXO_9313	EXO-IN_10326,KURU_11347
YLD	KAN_1815,JAFF_2384,KAN_11350, MAT_12261,KILLI_TVFM013-1,POL_12629	MAHI_M4,KAN_12248,KURU_11347,EXO-IN_10326,KURU_12449,ANU_12280,MAHI_M9
1000 GW	MAHI_M8	KURU_11352,EXO-IN_927,KILLI_TVFM -01,EXO-IN_10326

Note: 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 (NT), days to 50% flowering (DF) weight of 20 mature ears g(20EW), threshing ratio (TR) and grain yield per ha t/ha (YLD) and 1000 grain weight g (1000GW)

Correlation coefficients of morphological traits

The correlation coefficient among the traits showed consistence in two seasons for many traits. However, there were non consistence correlations between few traits that were observed in two seasons, such as days to 50% flowering and grain yield. Hence correlation coefficient value of season 2 is presented as season 2 showed lower experimental error

compared to season 1 (Table 4). Correlation analysis shows the association of the all morphological traits. These associations of traits are very useful in crop improvement through selection. The grain yield is the most prioritized trait in finger millet breeding. Therefore, knowledge on associated traits with grain yield would improve the selection efficiency. The grain yield was significantly positively correlated with 50% days to flowering, the number of productive tillers, weight of 20 mature ears and threshing ratio. Early characterization studies reported not only above three traits but also many other traits such as plant height and flag leaf length also positive correlated with grain yield (Barathi, 2011). The grain yield was significantly negative correlated with 1000 grain weight and flag leaf width.

Table 4. Pearson's correlation coefficient among the 14 qualitative traits of 139 finger millet accessions at FCRDI, Sri Lanka, 2016/17

Trait	DF	PH	FLL	FLW	PL	PE	FL	FW	NF	TC	20EW	TR	YLD
PH	-0.03												
FLL	0.08	0.56**											
FLW	-0.16	0.45*	0.59**										
PL	-0.44*	0.38**	0.25*	0.39**									
PE	-0.47**	0.36**	0.25*	0.33**	0.72**								
FL	-0.39*	0.45**	0.33**	0.35**	0.38**	0.39**							
FW	0.186*	0.16	0.129	0.052	-0.06	-0.09	-0.04						
NF	0.55**	0.03	0.04	0.04	-0.34**	-0.37**	0.22*	0.19*					
TC	0.36*	-0.27**	-0.14	-0.28*	-0.12	-0.18*	-0.21*	-0.26	0.05				
20EW	0.58**	0.51**	0.47*	0.34**	-0.07	-0.16	0.129	0.31*	0.53**	-0.1			
TR	0.22*	0.10	0.05	-0.04	0.13	0.11	0.03	0.06	-0.08	0.14	0.15		
YLD	0.40**	0.09	-0.01	0.20*	-0.09	-0.18*	0.005	0.003	0.008	0.39**	-0.27*	0.38*	
1000GW	-0.13	0.23*	0.33*	0.41*	0.23*	0.27*	0.36*	0.15*	0.02*	-0.35*	0.18*	0.14	-0.18*

*Correlation coefficient value significant at P<0.05 and ** Correlation coefficient value significant at P<0.01*

Note: 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 (NT), days to 50% flowering (DF) weight of 20 mature ears g(20EW), threshing ratio (TR) and grain yield per ha t/ha (YLD) and 1000 grain weight g (1000GW)

Principal component analysis (PCA)

Principal component analysis (PCA) consists of finding a new set of uncorrelated variables (principal components) from original correlated variables. Hence, principal components are the linear combinations of the original variables. PCA showed that first six PCs with eigen value greater than 0.8 have contributed the 78% of total variability in 139 genotypes for the 14 traits both in seasons (Table 5). The first PCs separated the accessions based on panicle exertion, threshing ratio and grain yield per hectare in season 1. However, season 2 showed similar traits *viz*plant height, flag leaf length, flag leaf width, peduncle length, panicle exertion and length of longest finger for grouping accessions based on first PC. The flag leaf width and finger length and weight of 20 mature ears and 1000 grain weight negatively

contributed to PC2 in season 1. But in season 2 showed the days to 50% flowering, weight of 20 mature ears and number of fingers negatively contributed to PC2.

Therefore, the contribution of traits to different PCs may vary to different seasons or environment. These differences were observed in characterization studies of finger millet global composite collection by Bharathi (2011) in three different locations. The principal component analysis of this study revealed that days to 50% flowering, Plant height, flag leaf length, flag leaf width, finger length, threshing ratio and grain yield per hectare were contributed to first two PCs collectively in 2 seasons. Hence these traits were contributed to the diversity of finger millet genotypes and these traits can be effectively used in breeding programs to generate the variability.

Table 5. **Principal components coefficients of first six principal components and eigenvalues for 14 traits evaluated in two season and pooled data for 2 seasons**

Trait Season-1 (2016)							Season-2 (2016/17)					
	PC1	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**
DF	**-0.34**	0.18	0.35	-0.19	-0.04	-0.09	-0.26	**-0.44**	-0.10	0.03	-0.15	0.14
PH	-0.16	-0.05	**0.56**	-0.31	-0.25	-0.22	**0.34**	-0.26	-0.10	0.10	0.38	0.03
FLL	0.02	-0.39	-0.22	-0.10	**0.46**	-0.08	**0.31**	-0.29	-0.03	0.26	-0.05	0.01
FLW	-0.20	**-0.52**	-0.05	-0.04	-0.01	-0.05	**0.36**	-0.17	0.12	0.26	-0.25	0.08
PL	0.28	0.03	-0.09	**-0.60**	-0.28	0.03	**0.37**	0.14	-0.24	0.02	0.02	**0.43**
PE	**0.45**	-0.03	-0.03	**-0.33**	-0.10	-0.03	**0.37**	0.18	-0.20	-0.01	-0.05	**0.39**
FL	0.02	**-0.46**	0.13	-0.14	0.02	-0.09	**0.35**	0.01	-0.12	0.05	0.20	**-0.58**
FW	-0.01	0.09	0.29	-0.22	0.36	**0.83**	0.04	-0.25	0.22	**-0.59**	0.35	0.29
NF	**-0.34**	-0.20	0.14	0.07	0.03	0.07	-0.15	**-0.38**	0.27	0.17	-0.17	0.16
NT	-0.09	0.13	-0.10	**-0.46**	**0.56**	-0.34	-0.25	-0.01	**-0.44**	0.35	-0.18	0.12
20EW	0.23	-0.33	**0.47**	0.16	0.04	-0.04	0.08	**-0.54**	0.01	0.07	0.08	-0.02
TP	**0.43**	0.12	0.18	0.20	0.01	-0.11	0.02	-0.14	**-0.48**	**-0.49**	-0.35	0.06
Yld	**0.42**	-0.07	0.26	0.17	0.32	-0.08	-0.13	-0.21	**-0.54**	-0.08	0.27	-0.25
1000GW	0.08	**-0.37**	-0.22	-0.10	-0.31	**0.32**	0.29	-0.10	0.12	-0.31	**-0.58**	-0.33
Eigenvalue	3.12	2.68	1.63	1.35	1.04	0.92	3.78	2.84	1.72	1.08	0.85	0.80
Cumulative	0.22	0.41	0.53	0.63	0.70	0.77	0.27	0.47	0.60	0.67	0.73	0.79

Note: Plant height (PH), Flag leaf blade length (FLL, Flag leaf blade width (FLW), peduncle length (PL), Panicle exertion (PE), number of finger per panicle (NF), length of longest finger (FL), finger width (FW), number of productive tillers (NT), Days to 50% flowering (DF) weight of 20 mature ears (20EW), threshing ratio (TR) and grain yield per ha (YLD) and 1000 grain weight (1000GW)
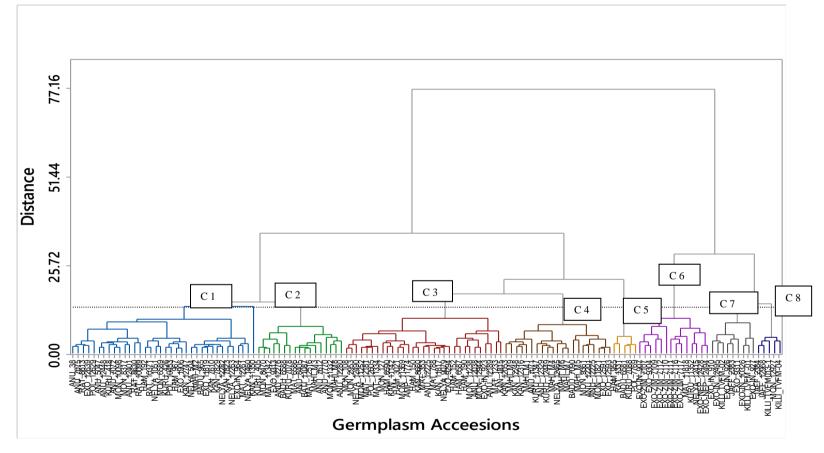
Figure 1. Dendrogram based of six PCs of 14 phenotypic traits of finger millet accessions for pooled data of two seasons using Ward Linkage and Euclidean distance

Cluster analysis

The studied finger millet accessions were grouped in to two main groups based on days to 50% flowering at higher level of distance. Then the main groups were divided in to sub groups based on flag leaf length, panicle exertion, threshing ratio, weight of 20 mature ears and grain yield. Finally, 8 clusters were identified at lower level of Euclidean distance (Figure 1 and Table 7). The 63% of total germplasm were grouped into three clusters, C1 (36 accessions), C3 (31 accessions) and C4 (21 accessions). Cluster C2 with 17 accessions, cluster C6 with 14 accessions and other three clusters (C5, C7 and C8) consisted of less than 10 number of accessions in each. C6, C7 and C8 consisted of shorter and medium days to flowering germplasm and other five clusters were higher days to flowering.

Cluster C8 consisted of early flowering (50-62 days) and lower weight of 20 mature ears (44- 89 g) germplasms. Whereas, germplasm in C7,characterizedby early to medium days to flowering (54 -75 days) and comparatively higher weight of 20 mature ears (75 -161g).The common characters of C6 are early to medium flowering (62 -75 days) and longer finger length (7-17 cm). Cluster C5 included medium days to flower (73- 78 days) and shorter finger length (4-5cm) genotypes which all were from local collection. The some of the high yielding germplasm (1. 98 -4.61 t/ha) grouped in C4. Further, C1, C2 and C3 consisted of higher number of fingers per panicle (8- 12) compared to other clusters. The traits that contributed to group the germplasm were highly varied from clusters to cluster. The clustering information is very vital for selection for germplam in finger millet breeding for different objectives.

Cluster C6 consisted of all exotic germplasm origin in Zimbabwe and local genotypes such as KURU_11352, MAT_11818 and NELYA_12415.These are Asian finger millet germplasm found in Sri Lanka showed the same performance with African finger millet germplasm introduced from Zimbabwe. Hence, the finger millet germplasm accession collected from different districts and introduced germplasm from different countries were grouped together (table 7). Ulaganathan and Nirmalakumari, (2015) also observed similar nature in clustering of finger millet genotypes. Therefore, nature of selection forces operating under one eco-geographical region seemed to be similar to other region, as similar traits have been used to breeding and domestication (Salini *et al.,* 2010).

Table 6. Mean, range and standard deviation (SD) of 14 phenotypic traits of different clusters of finger millet germpalsm accessions for pooled data.

Trait	Cluster	C1	C2	C3	C4	C5	C6	C7	C8
	No. acc.	36	17	31	21	5	14	9	5
DF	Mean	84	82	81	79	75	68	64	55
	Range	76-91	75-90	75-94	75-85	73-78	62-75	54-75	50-62
	SD	3.7	4.2	3.9	2.7	2.1	4.3	7.2	4.4
PH	Mean	75	77	76	72	56	86	79	64
	Range	61-91	66-90	60-89	59-80	52-60	79-91	70-91	55-73
	SD	6.0	5.8	6.1	5.5	3.4	4.0	7.5	7.7
FLL	Mean	41	41	41	38	36	46	38	35
	Range	35-48	37-43	38-46	34-42	35-38	38-55	35-40	34-38
	SD	2.8	1.8	2.2	2.0	1.3	4.2	1.5	1.3
FLW	Mean	11	11	11	10	10	13	11	10
	Range	9-13	10-12	10-13	9-11	9-11	11-16	9-13	10-11
	SD	0.7	0.6	0.7	0.5	0.7	1.6	1.1	0.4
PL	Mean	21	20	22	21	21	24	23	21
	Range	18-23	18-21	20-24	18-24	18-22	22-28	21-25	19-24
	SD	1.1	1.0	1.0	1.2	1.2	1.8	1.1	1.6
PE	Mean	7	6	9	8	8	13	11	8
	Range	5-10	4-8	6-11	6-10	7-9	9-19	9-13	6-11
	SD	1.1	0.9	1.5	1.3	0.9	2.5	1.4	1.9
FL	Mean	6	6	6	7	4	9	8	5
	Range	5-8	5-8	5-7	5-11	4-6	7-17	7-11	5-7
	SD	0.7	0.8	0.7	1.1	0.8	2.6	1.5	0.8
FW	Mean	12	11	12	11	10	11	11	11
	Range	11-22	11-12	10-14	8-12	10-10	10-14	10-13	10-11
	SD	1.8	0.6	0.8	1.0	0.1	1.0	0.8	0.7
NF	Mean	9	9	8	7	7	7	7	7
	Range	8-11	7-12	7-11	6-9	6-8	6-10	6-8	5-8
	SD	0.8	1.1	0.9	0.6	0.7	1.1	0.4	1.1
NT	Mean	3	4	4	4	6	3	2	2
	Range	1-5	3-6	2-6	2-6	6-7	2-4	1-4	1-3
	SD	0.8	0.8	1.0	1.0	0.4	0.6	0.7	0.8
20EW	Mean	167	155	144	132	74	151	110	66
	Range	141-210	98-204	121-172	105-177	50-94	105-200	75-161	44-89
	SD	16.2	25.5	13.9	18.3	18.4	26.2	31.9	17.5
TR	Mean	0.79	0.73	0.80	0.83	0.79	0.81	0.75	0.69
	Range	0.72-0.85	0.61-0.82	0.71-0.84	0.74-0.9	0.71-0.83	0.78-0.84	0.67-0.87	0.63-0.75
	SD	0.03	0.06	0.03	0.05	0.05	0.02	0.07	0.04
Yld	Mean	1.89	2.03	2.01	2.81	1.34	1.56	1.32	0.70
	Range	0.72-3.38	1.31-3.52	1.05-3.24	1.98-4.61	0.32-1.91	0.53-2.69	0.61-2.31	0.32-1.26
	SD	0.6	0.5	0.5	0.6	0.6	0.5	0.5	0.4
1000GW	Mean	2.41	2.07	2.25	2.26	2.09	2.49	2.64	2.13
	Range	2.17-2.74	1.71-2.22	1.95-2.58	1.98-2.62	1.78-2.38	1.85-2.89	2.24-3.09	1.81-2.31
	SD	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.2

Table 7. Cluster membership of 139 germplasm accessions characterized in 2016/17 at Mahailluppallama

Cluster No	No of Genotypes	Germplasm Accessions and their Origin
1	36	ANU_38, HAM_192, KURU_426, NELYA_504, EXO-IN_964, BADU_965, HAM_967, NELYA_1051, NELYA_1460, EXO_1906, ANU_5047, KURU_418, MON_6589, KAN_7610, ANU_7072, ANU_7075, KAN_7823, KAN_7829, MON_8317, RAT_8613, RAT_8630, MON_10098, RAT_10099, AT_10371, POL_10453, KAN_11350, EXO_11819, MAT_12261, ELYA_12263, NELYA_12282, ANU_12401, ANU_12448, POL_12629, EXO_12639, KAN_12747, MAHI_M2
2	17	KURU_405, MAT_6586, BADU_6588, KURU_7078, ANU_7612, ANU_7770, ANU_8405, MON_8470, EXO_9313, BATI_11087, MON_11332, MAT_11342, ANU_12276, ANU_12280, MAT_12516, MAHI_M3, MAHI_M8
3	31	MON_108, MON_127, HAM_150, HAM_152, HAM_190, MAT_353, MAT_788, EXO-IN_923, MAT_1233, KAN_1815, MON_2953, HAM_3021, HAM_6587, HAM_6590,KAN_8660, NELYA_9079, EXO_9294, MON_11369, KAN_11142, MON_11238, MON_11252, MAT_11334, AMP_11774, KAN_11817, ANU_12038, MAT_12181, ANU_12189, ANU_12225, NELYA_12490, POL_12605, MON_12944
4	21	KAN_12053, ANU_7071, BADU_7090, MON_9361, KURU_11347, MON_11821, ANU_12201, ANU_12225, KAN_12248, KAN_12316, ANU_12329, KURU_12449, NELYA_12465, EXO_12591, EXO_12593,MAHI_M1, MAHI_M4, MAHI_M5, MAHI_M6, MAHI_M7, MAHI_M9
5	5	HAM_955, RAT_1331, BADU_6581, KURU_7088, POL_7769
6	14	EXO-IN_907, EXO-ZIM_7107, EXO-ZIM_7109, EXO-ZIM_7110, EXO-ZIM_7111, EXO-ZIM_7112, EXO-ZIM_7116, EXO-ZIM_7117, EXO_9304, KURU_11352, MAT_11818, NELYA_12415, EXO-NEP_12428, EXO-NEP_12494
7	9	EXO-IN_910, EXO-IN_926, JAFF_2383, EXO_9311, EXO-IN_10326, EXO-IN_927, EXO-IN_12495, KILLI_TVFM -01, KILLI_TVFM-02
8	5	JAFF_2384, JAFF_12968, MON_12927, KILLI_TVFM013-1, KILLI_TVFM-04

CONCLUSION

The characterization of finger millet germplasm accessions provides information of variability of germplasm exists in the country. This study revealed that Sri Lankan finger millet germplasm collection showed the similar variability for evaluated qualitative

morphological characters such as days to flowering, grain yield, length of longest finger with finger millet global composite as well as finger millet mini core collection at ICRISAT, India. The traits with higher variability such as grain yield, panicle exertion, weight of 20 mature ears, number of productive tillers and length of the longest finger and traits with significant positive correlation with grain yield can be used to select germplasm accessions for direct introduction to farmers through adaptive research. Moreover, finger millet improvement through hybridization and selection can be done tedious manual crossing by selecting parents from different clusters for different breeding objectives.

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Annex 1:Characterized Finger millet germplasm accession number and their place of collection.

District (Abbreviation)	Total No. of accessions available at PGRC	No. of accessions selected for study	PGRC Accession Number		
Anuradhapura (ANU)	56	18	000038	007770	12225
			005047	008405	12269
			007071	012038	012276
			007072	012189	012280
			007075	012201	012329
			007612	012448	012401
Badulla (BADU)	29	4	000965	006588	
			006581	007090	
Baticoloa (BAT)	2	1	011087		
Hambantota (HAM)	43	8	000152	000955	006587
			000190	000967	006590
			000192	003021	
Jaffna (JAFF)	5	3	002383	002384	012968
Kandy (KAN)	51	12	001815	007829	011817
			012053	008660	012248
			007610	011142	012316
			007823	011350	012747
Kurunegala (KURU)	33	8	000405	007078	011352
			000426	007088	012449
			000418	011347	
Matale (MAT)	39	10		353	
			012516	006586	011818
			000788	011334	012181
			001233	011342	012261
Monaragala (MON)	53	16	108	008443	011238
			000127	008470	011252
			002953	009361	011332
			006589	010098	011821
			008317	011369	012927
			012944		
NuwaraEliya (NELYA)	33	9	000504	009079	012415
			001051	012263	012465

			001460	012282	012490
Polonnaruwa (POL)	15	4	007769 010453	012605	012629
Putlum	4	0			
Ratnepura (RAT)	23	6	001329 001331	008613 008630	010099 010371
India (Exo_IN)	21	7	000907 000910 000923	000926 000964	000927 012495
Nepal (EXO_NEP)	3	2	012428	012494	
Zimbabwe (EXO_ZIM)	17	7	007107 007109 007110	007111 007112	007116 007117
Exotic "Unknown' (EXO)	30	10	001906 009294 009304 012639	009311 009313 010326	011819 012591 012593
Killinochchi (KILLI)		4	TVTM013-1 TVFM-02	TVFM -01 TVFM-04	
Mahiyanganaya (MAHI)	Collection from farmer field	9	M1 M2 M3	M4 M5 M6	M7 M8 M9
Total No. Acc.	462	139			

Source: PGRC, Sri Lanka.