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Morphological variability for qualitative and quantitative traits in finger millet (Eleusine coracana L. Gaertn)

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ABSTRACT

Information on genetic variation is very important for finger millet breeding program. The objective of this study was to evaluate the extent of genetic variation in finger millet accessions. Eighty two accessions were evaluated in the dry season 2010/11 and the rainy season 2011 at Khon Kaen University, Thailand, and also evaluated in Botswana College of Agriculture in Botswana in rainy season in 2013. The results of combined analysis of variance for mean data of traits studied revealed highly significant variation for most of the traits studied. High variations were observed for yield per plant with a range of 15 g-144 g per plant while low variations were observed for fingers per panicle with a range of 5-11 fingers per panicle. Qualitative traits like seed colors showed high variation with six different colors observed during the study 2,2,4, 49, 8 and 17 accessions had white, light brown, brown, ragi brown, red and purple seed colors, respectively. A dendrogram constructed using the qualitative traits revealed high variation, separated the wild accessions (IE 4709) from the cultivated accessions, then grouped the cultivated accessions into 5 main groups at 86% similarity level. Genetic variation evaluation based on morphological characters has proved to be very informative and can also be manipulated into selecting superior accessions to be utilized as parents for a breeding program.

Indexing terms/Keywords

Genetic diversity; *Eleusine coracana*; cluster analysis; morphological variability.

Academic Discipline And Sub-Disciplines

Agriculture

SUBJECT CLASSIFICATION

Plant breeding and agronomy

TYPE (METHOD/APPROACH)

Field experiment

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INTRODUCTION

The easiest way to do this is simply to download the template, and replace the content with your own material. Finger millet (*Eleusine coracana* L. Gaertn) (2n=4x=36) is one of the most important small grain cereals grown in eastern and southern Africa for food security and subsistent economy itshigh nutritive and cultural value (Dida et al., 2008). Finger millet is an important food in traditional low input cereal-based farming system (Wolie and Dessalegn, 2011), and the crop is also highly cultivated in Southern Asia in India, Myanmar, Sri Lanka, Bhutan and China (Upadhyaya et al., 2004). The nutritional quality of finger millet is highly superior to that of most cultivated cereals in the world, being rich in proteins, fiber and minerals; most importantly calcium and iron, which greatly help in alleviating the problems associated with malnutrition and anemia in countries where it is widely consumed as a staple food (Babu et al., 2006). This crop is also widely used as herbal medicine in many rural areas,and this makes it the most important staple food for the rural populations in developing arid and semi-arid countries. Finger millet is a hardy crop that can withstand harsh environments, making it ideal for the areas that have unsuitable environment for production of other cereal crops (Upadhyaya et al., 2007). The crop can withstand longer periods with minimum rainfall.

The modern varieties of high yielding cereals such as maize and wheat replacedfinger millet in production areas. Finger millet is then cultivated in more marginal soils and growing conditions. Moreover, the continuous breeding program of finger millet is lacking (Dida et al., 2008). The yield and production of finger millet therefore has declined sharply leading to the negligence of the crop.Because of its health benefits, the crop is now receiving more attention from agronomists and plant breeders. The status of finger millet is now changing from neglected and underutilized crop to an emerging high potential crop for health food and functional food product with high value.The finger millet germplasm collected from many origins has been maintained in the International Crops Research Institute for the Semi Arid Tropics (ICRISAT) genebank. Unfortunately, the germplasm has not been adequately evaluated and characterized for further utilization. The information on genetic variation in the landraces, accession and genotypes is a must for breeding programs for crop improvement (Adeniji et al., 2008; Basafa and Taherian, 2009; Mahmood et al., 2003).

Knowledge on genetic variability of germplasm is vitally important for improvement of finger millet. Although novel methods such as molecular techniques are available for correct and more reliable assessment of the germplasm, conventional evaluation of morphological and quantitative traits is still very important. Yield is known to be highly variable and selection for traits associated with yield should indirectly improve yield (Akinyele and Osekita, 2006; Nkongolo et al., 2008; Wilson et al., 2008). Because finger millet has long been neglected by plant breeders, the information on genetic variability and correlations among traits is still lacking, so an extensive study on variation of these traits that are associated with yield will help in identifying and selecting genotypes with superior yield related traits. Genetic evaluation can also be manipulated either for selecting superior genotypes or to be utilized as parents for the development of future cultivars through hybridization (Khan et al., 2011).

To fully exploit genetic potential of finger millet, it is important to know the availability of genetic diversity in the available accessions or landraces. The objective of this study was to determine genetic variations among finger millet accessions for qualitative and quantitative traits. The results will be useful for genetic improvement of finger millet.

Material and methods

Plant materials and weather conditions

Eighty-two accessions of finger millet obtained from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) were evaluated in the dry season (Nov- March 2010/11) and the rainy season (June- Oct 2010) in Khon Kaen University (Thailand) and was also evaluated in the rainy season (Nov-march 2013/2014) in Botswana college of Agriculture (Botswana). The accessions represent the germplasm collected from a wide range of geographic and climatic regions in Africa and Asia (Table 1). The soil of the experimental site in Thailand was sandy loam and the climate of the locality was tropical with annual rainfall of 1200mm, maximum temperature of 40°C in summer and 26°C in dry season, the average annual rainfall in Botswana was 700mm with maximum and minimum temperature range of 20°C at night and 38°C during the day, the soil was loamy soil.

Table 1. The source or origin of Finger millet accessions (continent, countries and number of accession)

Continent	Country	No. of accessions
Africa	Burundi (Bu)	1
	Kenya (Ke)	8
	Malawi (Ma)	4
	Nigeria (Ni)	1
	Senegal (Se)	1
	Uganda (Ug)	10
	Zimbabwe (Zi)	21
	Zambia (Za)	3
America	USA (US)	1
Asia	India (In)	19
	Nepal (Ne)	9
	Maldives (Md)	1
Europe	Germany (Ge)	1
Unknown	Unknown (Uk)	2
	Total	82

Experimental design and crop management

A field experiment was conducted for two consecutive seasons during November 2010 to May 2011 and June 2011 to October 2011 at the Field Crops Experiment Station, Faculty of Agriculture, Khon Kaen University , Khon Kaen, Thailand (16° 30' N, 102° 47' E, 204 m asl), the same experimental design was conducted in Botswana under the Botswana College of Agriculture (N -24° 35' E 25° 56' 1,014 m asl) **.** Eighty two accessions of finger millet were arranged in a randomized complete block design (RCBD) with three replications.

The land was prepared by double plowing and leveling with a tractor, and flat plots of 1 x 5 m were made. Two splits of 15-15-15 fertilizer at the rate of 70 kg ha^{-1} for each split were applied as basal dressing at sowing and top dressing at 40 days after emergence. Supplemental irrigation was supplied to the crop grown in the dry season from planting to soft dough seed stage.

Weed management was done twice at 40 days after emergence just before split fertilizer application and the second weeding was done at flowering. Wild pigeon is the most critical animal pest in the experimenttherefore, nylon net was constructed to cover all plots in the experiment. Neither disease nor insect problem was observed during both planting seasons.

Planting was done manually in the two-row plots with 5 m in length and spacing of 50 cm between rows and 20 cm between plants within rows, giving at total plant stand of 50 plants per plot. Two weeks after emergence, seedlings were thinned down to one seedling per hill.

Data collection

Data were recorded for quantitative and qualitative agronomic traits at different growth stages of the crop from five competitive plants in the middle of every plot. Plant descriptors for finger millet were followed when the data were collected (IBPGR, 1985).Plant pigmentation and growth habit were thequalitative traits recorded at flowering, while days to flowering, numbers of tillers, number of leaves on the main tiller, flag leaf length and width and blade leaf (4th leaf from flag leaf) length and width were the quantitative traits recorded at the same time.

At harvest, panicle shape and lodging were recorded for quantitative traits, whereas days to maturity, number of mature fingers, height of the longest finger, width of the main/tallest finger, plant height, stem diameter recorded from the forth node from the ground and peduncle length were measured for the qualitative traits. Seed color, yield per plot and 1000-seed weight were recorded after threshing and winnowing.

Data analysis

Combined analysis of variance was performed for two seasons for yields, yield components and agronomic traits using MSTAT-C software. Means were compared by the least significant difference test (LSD) at 0.05 probability level. Agronomic data collected from the three replications were averaged and each trait divided into 10 levels based on its mean value and standard deviation. Then the continuous agronomic data were scored 0 and 1 based on the 10 levels, the data was score as 1 where the agronomic trait value was at that level and score 0 where the agronomic trait value was not at that level. The genetic variations among accessions were evaluated by calculating the Jaccard's similarity coefficients for pairwise comparisons based on the presence and absence of morphological data scoring. Numerical Taxonomy System, Version 2.11 (NTSYS-Pc 2.11) was then used to construct a dendrogram based on unweighted pair group method for arithmetic (UPGMA) mean method.

Results and discussion

Qualitative Traits

The pigmentations observed in this study were green (63.4%) and purple (36.6%) (Table2). Green pigmentation was found on leaves and stems, whereas purple pigmentation was found on the stems only. In an earlier study, Upadhyaya et al. (2007) found that 65.3% was green type and 34.7% was pigmented (purple) type in 909 accessions collected in Africa. The variation in pigmentation in the two studies was comparable although number of accessions in this study was much smaller (82 accessions). The results indicated that, if the accessions are deliberately chosen for evaluation, the variations in small number of accessions are similar to those in larger accessions. Low number of accessions is also more manageable size for practical breeding programs.

Finger millet is usually classified into three types of growth habit; decumbent, erect and prostate, in this research most accessions had erect growth habit (98.8%) except for one accession with decumbent growth habit. All the *coracana* species (81 accessions) had an erect growth pattern that is their stems stood up straight vertical to the ground. The only wild species or *africana* spices (1 accession) had decumbent growth habit that is the stems grew parallel to the stem but not lying on the ground. Prostate growth type was not observed in the evaluated accessions. Upadhyaya et al.(2007) also observed only two growth habits, while the prostate growth habit was completely absent. The difference in the results would be due to the inclusion of more accessions in Asia in this study especially those from India.

Table 2. Number and percentage of accession under qualitative traits

Trait	Number of accessions	Percentage
Plant pigmentation	**82**	
Green	52	63.4
Purple	30	36.6
Growth habit	**82**	
Decumbent	1	1.2
Erect	81	98.8
Prostate	0	0
Inflorescence compactness	**82**	
Compact	6	7.3
Fisty	29	35.4
Long open	45	54.9
Pendulous	2	2.4
Grain color	**82**	
White	2	2.4
Light brown	2	2.4
Brown	4	4.9
Ragi brown	49	59.8
Red/dark brown	8	9.8
Purple brown	17	20.7
Lodging susceptibility	**82**	
Susceptible	29	35.4
Resistant	53	64.6

According to de Wet (2006), finger millet accessions could mainly be characterized by the spreading the inflorescence, advanced cultivars have highly proliferated inflorescence branches that are clumped together to form fist-like structure and the most commonly grown cultivars have much smaller inflorescences with more or less spreading branches that may become somewhat incurved or reflexed at maturity.

Inflorescence compactness (panicle shape) could classify the millet accessions into 4 groups. The largest group has long-open (*vulgaris*) inflorescences (54.9%) (figure 1)followed by the smaller group with fisty (*plana*) inflorescences (35.4%), and the last two groups have compact (*compacta*) inflorescence (7.3%) and pendulous (*elongeta*) inflorescences2.4%). According to de Wet (2006),finger millet accessions could be characterized by spreading inflorescence, advanced cultivars have highly proliferated inflorescence branches that are clumped together to form fist-like structure and the most commonly grown cultivars have much smaller inflorescences with more or less spreading branches that may become somewhat incurved or reflexed at maturity. The species *E. coracana* consists of two subspecies, *africana* and *coracana*. The subspecies *africana* consists of two wild species *africana* and *spontanea*, while the cultivated subspecies *coracana* consists of four species namely *elongeta*, *plana*, *compacta* and *vulgaris* (Rao and de wet,1997; Upadhyaya et.al., 2007).

Traditionally, finger millet farmers usually or most of the time use seed color to classify millet and other crops, they even associate color with palatability, whereby light or white color is thought to be more palatable than the darker or red/purple brown colors. Based on seed color, finger millet was classified into 6 different colors (from white to purple brown), with the majority of the accessions being brown and therefore the brown was further classified into light brown (2.4%), brown (4.9%), ragi brown (59.8%), other seed colors observed werewhite (2.4%),red (9.8%) andpurple brown(20.7%), respectively (Table 2).

Figure 1. The four main panicle classifiers of finger millet race, A- compact (*compacta*), B-fisty (*plana*), C- long-open (*vulgaris*) and D- pendulous (*elongeta*)

Plants that could not withstand the heavy rains or heavy winds when theyhad mature panicles were recorded as susceptible to lodging.Using this criterion, 29accessions were susceptible to lodging, whereas 53 accessions showed resistance to lodging.

Continuous evaluation of phenotypic traits is very critical for any breeding program because they are greatly associated with traditional farmers' adoption of new varieties. Traditional farmers adoption is mainly based on yield but other phenotypic characteristics of plants like seed color, pigmentation and lodging susceptibility contributes to the decision by farmers to adopt or not. Available evidence indicates that farmers use certain phenotypic features of plants for selection

and identification (Jarvis et al., 2000) and on farm evaluation is important also to select genotypes that farmer prefer the most and that will help in increasing production.

Quantitative Traits

Sixteen quantitative traits including growth, maturity, yield and yield component traits are presented in Table 3. Significant differences among finger millet accessions were observed for all characters under investigation. Variation in grain yield was high, ranging from 15-144.4 g plant^{-1}, and variation in grain size was also high, ranging from 0.5-5.4 g/1000 grains. There were also high variations for yield component traits such as basal tillers (5-16), finger number (5-11), finger length (4.15-16.18 cm), finger width (1.35-13.40 mm) and peduncle length (4.35-13.4 cm).

Days to flowering and days to maturity were in the ranges of 45-92 days and 65-139 days, respectively. These traits showed high variations and selection for maturity classes that are suitable for cropping systems is possible.

Growth characters showed high variations, ranging from 6-19 leaves for leaf number, 15.95-47.78 cm for flag leaf length, 0.42-1.48 mm for flag leaf width, 19.08-59.47 cm for blade leaf length, 0.56-1.8 mm for blade leaf width and 25.3-128.01 cm for plant height.

Studying the variations among agronomic traits is very important for every breeding program as most of them are highly correlated and have a direct effect on yield, they can either affect yield positively or negative depending on their variations. Ahmad et al. (2011) observed that plant height, days to silking and days to maturity are more related to yield outcome of maize. Among the sixteen plant traits Galarreta and Alvarez (2001) studied, they found out that plant height was the most important for discriminant analysis.

High Yield plant^{-1} variation in this study could be attributed to high variation in genetic make-up of the accession studied thus proving that finger millet has high genetic diversity among its accessions. Grain yield being a complex trait is highly influenced by various environmental factors including biotic and abiotic factors that means the high variations in yield could also be attributed to environmental changes, therefore further evaluation on different environment has to be done to substantiate the variations. It is also interplay of various morphological characters which either favors of worsen final yield (Khan et al., 2011;Ahmad et al., 2011; Lang et al., 2009). Lang et al.(2009) also observed high variability on most of the quantitative traits under the study. High variability existing in these accessions brings forward the much needed information for the genetic improvement program of finger millet.

Grouping the accessions

The dendrogram successfully managed to separate the wild species (*Eleusine coracana* subps*africana)* form the cultivated finger millet at 0.84 similarity level (Figure 2). IE 501 was closely related to IE 4709 (wild species) and also separated from other cultivated finger millet accessions. The remaining 81 cultivated finger millet accessions were grouped into 5 main groups at 0.86 similarity level.

Table 3. Analysis of variance (ANOVA) for quantitative traits

Traits	Range	Prob.	Mean	F-test	C.V. (%)
Flowering (days)	45-92	0.00	76.00	**	2.17
Maturity (days)	65-139	0.00	125.00	**	2.78
Leaf number	6-19	0.00	14.00	**	7.21
Flag leaf length (cm)	15.9-47.8	0.00	36.64	**	3.92
Flag leaf width (cm)	0.42-1.48	0.00	1.17	**	4.01
Blade leaf length (cm)	19.08-59.47	0.00	44.75	**	3.33
Blade leaf width (cm)	0.56-1.80	0.00	1.43	**	1.62
Stem diameter (mm)	1.6-10.4	0.00	10.27	**	4.24
Peduncle length (cm)	14.4-13.4	0.00	23.41	**	4.35
Plant height (cm)	25.3-128.0	0.00	91.10	**	4.18
Finger number	5-11	0.00	18.00	**	10.72
Finger length (cm)	4.15-16.18	0.00	6.71	**	5.82
Basal tillers	5-16	0.00	9.00	**	11.21
Finger width (mm)	1.35-13.40	0.00	10.52	**	4.27
Yield/plant (g)	15-144	0.00	74.16	**	7.18
1000 mass (g)	0.5-5.4	0.00	3.17	**	4.86

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Group 1 includedeight accessions from various countries. Five accessions were from India and three accessions were from other countries. The accessions in this group were describes as late flowering (84 days), high tillering (12 tillers plant^{-1}) and leastnumber of fingers with 7 fingers panicle^{-1} (Table 5).

Group 2 was the largest group consisting of 28 accessions from 10 countries.The group could be further dissembled to form two minor groups whereby the accession were grouped according to continental origin with Asia (Nepal and India) group in the first group and the second group was made up of accessions from Africa (Zimbabwe, Kenyaand Uganda). One accession from USA (IE 2589) was grouped with accession from Africa. The plants in this group were tall (98.19cm), had long flag leaf (45.51cm), long leaf blades(50.16cm)and the largest leaf blades(1.53cm).

Group 3 includessixteen accessions from different countries, but, when the main group was dissembled down to two minor groups, the accessions were clustered according to continental boundaries. The first group was made up with accessions from Asia mainly from India while the second minor group was made up of accessions from Africa with Zimbabwe having majority of accessions in this group. The plants were late maturing (129 days), had small blades(1.33cm), shorter fingers (5.72cm) and shorter peduncles(21.81 cm).

Group 4 was the second largest group with 23 accessions. Nineteen accessionswere from African countriesand 4 accessions (IE 2217, IE 3470, IE 4673 and IE 5201) werefrom India.The plants had higher number of leaves (16 leaves plant^{-1}), big flag leaf (1.51cm), longer fingers (7.55cm) and big stems (10.75mm).

Table 4. Group means, standard deviation and range of quantitative plants traits

Traits	Group 1			Group 2			Group 3			Group 4			Group 5		
	mean	min	max	mean	min	max	mean	min	max	mean	min	max	mean	min	max
Flowering (days)	84.0±0.5	72.0	92.0	76.0±0.3	65.0	88.0	76.0±0.4	63.0	88.0	78.0±0.4	72.0	87.0	73.0±0.5	62.0	82.0
Number of tillers	12.0±0.3	7.0	12.0	9.0±0.2	6.0	13.0	9.0±0.2	6.0	11.0	8.0±0.3	6.0	9.0	7.0±0.7	5.0	8.0
leaf numbers	14.0±0.3	11.0	16.0	14.0±0.2	11.0	19.0	14.0±0.3	11.0	19.0	16.0±0.3	13.0	19.0	14.0±0.7	13.0	17.0
Flag length (cm)	34.1±0.5	27.3	47.8	45.5±0.2	28.6	47.1	32.6±0.4	30.5	38.1	35.9±0.4	29.6	39.2	33.9±0..1	31.4	36.8
Flag width (cm)	1.08±0.02	0.98	1.28	1.3±0.01	1.00	1.46	1.06±0.01	0.81	1.43	1.51±0.01	1.05	1.36	1.2±0.03	1.15	1.33
Blade length (cm)	42.4±0.6	36.8	51.8	50.2±0.3	40.1	59.5	40.2±0.4	33.6	45.3	42.9±0.4	38.8	49.3	40.4±0.8	36.3	44.6
Blade width (cm)	1.34±0.01	1.21	1.61	1.53±0.01	1.17	1.66	1.33±0.01	1.15	1.76	1.46±0.01	1.37	1.61	1.5±0.10	1.41	1.60
finger numbers	7.0±0.3	6.0	8.0	8.0±0.2	6.0	10.0	8.0±0.2	5.0	10.0	8.0±0.3	7.0	10.0	10.0±0.3	9.0	11.0
Finger length (cm)	6.7±0.1	3.5	5.3	7.3±0.1	4.0	16.3	5.7±0.1	4.2	8.6	7.6±0.1	5.6	10.7	5.8±0.2	4.6	7.8
Plant height (cm)	86.1±1.5	73.7	103.5	98.2±0.7	61.5	128.0	79.4±0.9	56.2	115.8	92.7±0.8	72.6	119.9	88.9±0.4	83.9	101.5
Peduncle (cm)	22.7±0.3	19.9	28.6	24.2±0.2	20.5	28.9	21.8±0.2	16.6	30.2	23.9±0.4	19.7	29.9	24.9±0.3	21.6	27.5
Finger width (mm)	10.1±0.2	7.9	11.6	10.9±0.1	7.3	13.3	10.4±0.1	8.8	13.2	10.9±0.1	9.8	12.7	10.1±0.2	9.4	10.5
Stem diameter (mm)	9.9±0.2	8.5	11.9	10.5±0.1	7.9	14.1	10.1±0.1	8.2	11.7	10.8±0.2	7.9	12.8	10.3±0.1	8.2	11.2
Days to maturity	125.0±1.6	92.0	138.0	127.0±0.7	98.0	139.0	129.0±0.9	124.0	133.0	128.0±1.2	112.0	138.0	106.0±1.4	76.0	125.0
Yield/plant (g)	79.5±1.6	53.0	144.4	75.8±0.1	44.4	112.4	74.6±1.4	50.9	108.9	76.2±1.6	39.9	97.8	76.7±3.1	45.5	112.1
1000 seed weight (g)	3.01±0.00	2.53	4.13	3.20±0.00	2.60	4.00	3.11±0.00	2.77	3.73	3.29±0.0.0	2.53	5.00	3.23±0.01	2.60	4.23

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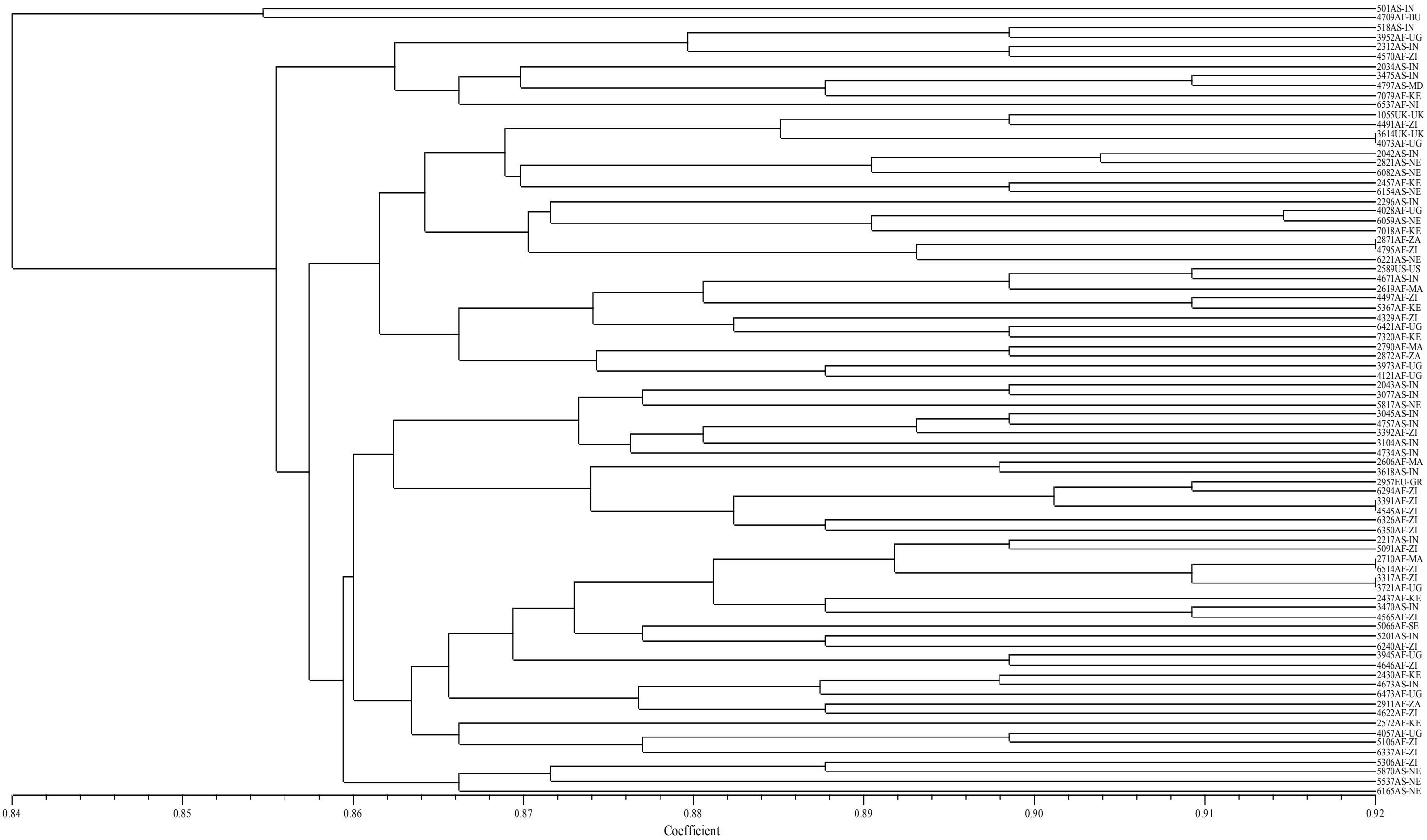

Figure 2. Dendrogram showing genetic similarity of 82 finger millet accessions by UPGMA cluster analysis based on morphological traits (AF-Africa, AS-Asia), (1-5 represent main clusters while a and b represents sub-clusters). Abbreviations for country names is expressed in table 1

Group 5 was the smallest group with four accessions.Three accessions were from Nepal. The plants flowered early with mean of 73 days, mature at 106 days,had the highest number of fingers per panicle (10 fingers panicle^{-1}).

Group 1 and group 5are small groups consisting of accessions mostly in Asia. The other groups were made up of accessions from varying locations both in Asia and Africa. The accessions in large groups (2 and 3) were then divided into sub-clusters (a and b). The sub-clusters showed that the accessions were clustered in relation to their origins mainly from Asia and Africa.

Relationship between genetic diversity and geographical diversity has been a point of debate in the past, and classification of accessions does not necessarily cluster in relation to geographical diversity because genetic drift and selection in different environments could cause higher variation that geographical distance (Murthy and Arunanchalam, 1996). Lang et al.(2009) reported that although the rice landraces came from different places, they can be grouped together because of close similarities in terms of qualitative traits. In contrast, Rohman et al.(2004) reported that genetic diversity in sorghum is generally associated with geographical diversity.

Grouping accessions with related morphological traits is very critical in every breeding program so as to understand and to have basic information on which and how many accessions possess traits of importance. Group information on which a superior accession with economic traits belong will in future help to check more accessions from the same group with similar or closely related economic traits and further be used in finger millet breeding program (Upadhyaya et al., 2004).

Evaluation of genetic variation based on morphological characters has proved to be very informative enough and can also be manipulated into either selecting superior accessions or to be utilized to select parents for a breeding program (Khan et al., 2011; Lang et al., 2009).Mannetji, (1984) argued that genetic diversity based on standard morphological markers has proved to be inadequate because of wide spectrum of phenotype and other interaction with the environment.

Conclusion

The results of the present study highlight the level of variability in the finger millet accessions.The grouping in this study can further be used for selection of parental stocks based on economic traits like yield, days to flowering and maturity which are the most important taxonomic features in breeding. The large variation indicates that a good progress could be obtained through intra-population selection progress. These suggested that adequate scope is available for selection of superior and diverse genotypes for use in a program aimed at enhancing potential production of finger millet. These populations could enhance the genetic base of breeding program in other countries and produce hybrids adapted to many other areas. The research has shown that grouping can be done for each morphological trait either qualitatively or quantitatively.

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