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Diversity of Sorghum (Sorghum bicolor L. Moench) Germplasm from Tanzania

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Abstract
Sorghum (*Sorghum bicolor* L. Moench) is an important cereal crop cultivated in varied agro-ecological zones of Tanzania ranging from the southern highlands to coastal lowlands. Different cultivars and varieties of sorghum are needed for cultivation in such varied zones. Phenotypic properties of Tanzanian sorghums are not well-studied. Objective of this study was to phenotype some sorghum germplasm from Tanzania using morphological markers to establish their diversity for future use in breeding programs. Ninety-eight sorghum genotypes were evaluated at Bumala and Amagoro in Western Kenya during 2009 and 2010 seasons in a randomized complete block design. The International Plant Genetic Resource Centre descriptors of 1993 were used for data collection. Accession MCSR T29 was the earliest which took only 64 days while MCSR T80 was the latest taking 86 days to attain 50% flowering compared to the overall mean of 71 days. The MCSR T71 was the best yielder (114.6 g/ panicle) and MCSR T10 was the lowest (10.3 g/panicle) compared to overall mean of 92.4g/panicle. About 60% of the sorghums had brown and only 2.2% had black grains. MCSR T90 had bold grains with 1000 seed weight of 55.2g. Leaves per plant ranged from 7 in MCSR T69 to 17 in MCSR T25. Plant height ranged from 72.8 cm in MCSR T53 to 434.6 cm in MCSR T80. This study showed that, Tanzanian sorghums are diverse therefore could be used in future breeding programs for developing multipurpose and adapted cultivars.
Keywords: Cultivars, Diversity, Phenotype, Varieties, Sorghum

1. Introduction
Sorghum (*Sorghum bicolor* L. Moench) is one of the most important drought tolerant cereals grown in arid and semi-arid parts of Africa (Abdulai *et al*., 2012). This crop contribute to food security and contain high calorie content, and also provides metallic nutrients, particularly iron and zinc, which also makes it competitive with maize (Koenders, 2010). In spite of its importance, sorghum yield in East Africa is low (<1t ha^{-1}) mainly because of the traditional farming practices characterized by use of low yielding cultivars and landraces that are susceptible to the biotic and abiotic stresses. Climate change models indicate that many parts of Africa shall experience reduced and erratic rainfall as the temperatures increase (Rowhani *et al*., 2011). Therefore, the importance of drought tolerant cereals, especially sorghum is likely to increase in the continent. Furthermore, the emerging market for sorghum in the brewing industry will create high demand especially for the white varieties. Deployment of adapted sorghum cultivars can significantly increase yields in sorghum growing areas (House *et al*., 1997), including the dry and sub-humid agroecologies of East Africa. The disparity of the agroecologies in which sorghum is cultivated in semi arid region indicates that there could be significant genetic differences among the sorghum landraces that can be exploited in sorghum improvement. Phenotyping these differences and use the knowledge in breeding to fill the current yields and stress tolerance gaps. Identification and documentation of agronomic traits in sorghum genotypes is important because such information facilitate conservation process and also use in agriculture. Plant characterization has been done mostly on morphological or agronomic descriptors because they do not depend upon expensive, sophisticated equipment (Mace *et al*., 2005). Morphological traits are reliable and easy to study at relatively low cost and characterization is of great importance to breeders as it provide necessary information for selection and breeding purposes. Rao *et al*. (1998) employed agronomic characters of 152 sorghum genotypes from Rwanda and ICRISAT and showed significant variability in sorghum genotypes. Amsalu and Endashaw (2000) also used morphological characters to determine the genetic variations of 415 sorghum genotypes from Ethiopia and Eritrea. Using similar approach, Sallu (2007) reported wide genetic variations among sorghum collections in Tanzania gene bank. Warkad *et al*. (2008) reported significant variations in sorghum yield and yield components particularly plant height, number of leaves, days to 50% flowering days to maturity, dry fodder weight, panicle length and width, and 1000 seed

weight. Kolberg (1999) reported substantial morphological variations for agronomic traits in 124 sorghum genotypes from Namibia. The aim of this study was to evaluate 98 sorghum genotypes from Tanzania for morphological characteristics hence facilitate selection and breeding for adapted cultivars.

2. Materials and Methods

2.1 Description of Experimental Sites

The experiments were conducted in Bumala (0° 25' N and 33° 54' E) and Amagoro 0°37′30″ N and 34°19′37″ E in Western Kenya. Bumala is found at an altitude altitude 1175m asl whereas Amagoro is at 1208m asl (Jaectzold and Schmidt, 1983). Bumala receives mean annual rainfall of 800-1600 mm and the temperature ranges from 26°C to 30°C while at Amagoro, the annual rainfall is <800mm and mean temperatures varying from 24°C to 29°C. Bumala soils are moderately deep, generally rocky and stony consisting of well drained red clays of low fertility. The Orthic ferralsols is predominant in this area with pH ranging from 4.7 to 5.0 and Al content of of 43.5% (McKnight report, 2004). At Amagoro site, an average pH of 6.5 prevails and the Orthic acrisols and ferralsols soils types dominate (McKnight report, 2004).

2.2 Planting, Data Collection and Analysis

Ninety eight sorghum genotypes collected from various parts of Tanzania by ICRISAT (Appendix 1) were sown out in a randomized block design with three replications in 5 meters row length with inter-row spacing of 60 cm. A basal fertilizer application to supply 20 kg ha-1 (N/ha), and 20 kg ha-1 (P/ha) was given at sowing in all blocks. Thinning was done two weeks after emergence to 2 plants per hole. Three weeks after emergence, an additional 45 kg ha-1 N, in form of urea, was top-dressed and other agronomic practices including weeding and disease control was followed as per requirements. Phenotypic characterization was done using the sorghum descriptors, from International Plant Genetic Resource Institute (IPGRI, 1993). Scoring of phenotypic characters was done on ten plants that were randomly selected and tagged just before flowering. Data were recorded for days to 50% flowering, number of leaves per plant, leaf length, leaf width, number of tillers per plant, plant height, panicle length, panicle width and grain yield per panicle and 1000 seed weight. Statistical analyses were done on the quantitative morphological characters using GenStat 2003 software. Moreover, analysis of frequency was performed for the qualitative traits using the Pivot table Analysis method. Differences were accepted as significant at $p \leq 0.05$. Cluster analysis, based on Euclidean distances as similarity measures and the Unweighted Pair-Group Method with Arithmetic Averages (UPGMA), was used to determine the contribution of the differences to the discrimination of the genotypes. Principal Component Analysis was used to determine the traits that contributed significantly to the discrimination of the genotypes.

3. Results

There was significant ($p \leq 0.05$) phenotypic variations among sorghum genotypes for leaves per plant (LV), Leaf length (LL), Leaf width (LW), number of tillers per plant (TL), plant height (HT), days to 50% flowering (DAF), panicle shape (PS), panicle length (PL), panicle width (PW), grain yield per panicle (YP) and 1000 seed weight (TSW) for the genotypes evaluated (Table 1).

Table 1. *Analysis of Variance for Phenotypic Characters in Sorghum*

Source of variation	DF	Leaves Per plant	Leaf length	Leaf width (cm)	Tillers per plant	Plant height (cm)	Days to 50% flowering
Genotype	97	6.4**	8.8**	131.9*	3.4**	8.8**	8448.6**
Location	1	3.9	0.1*	287.3	0.1	0.1*	4534.6
Error	30	1.6	7.2	82.4	1.1	7.2	1904.4

Table 1. *Continued*

Source of variation	DF	Panicle shape	Panicle length (cm)	Panicle width (cm)	Yield per panicle(g)	1000 seed weight (g)
Genotype	97	0.9**	90.1**	316.7**	2.1**	741.3**
Location	1	0.1	21.9**	254.9	0.4**	64.3**
Error	30	0.1	13.4	48.8	0.5	117.2

Note: **, ** significant at 5% and 1% probability level respectively*

The genotypes showed phenotypic variations across locations in different magnitudes as indicated in Table 2. There was variation although statistically not different in, LV, LW, DAF, TL, PW and TSW between the locations. For instance the number of leaves per plant was 11 across both locations while the leaf width was relatively higher but not significant about 9 cm at Bumala than at Amagoro that was about 8 cm. The average panicle length was 28.7cm at Bumala and 20.3cm at Amagoro. The number of tillers per plant was about 3 in both locations. The sorghum genotypes at Bumala had an average of 72 days while that at Amagoro had 70 days to attain 50% flowering. The average yield per panicle at Bumala was 97.3g while it was 61.3g at Amagoro.

Table 2. Means for agronomic traits of 31 sorghum genotypes from two locations

Agronomic trait	Location		Overall
	Bumala	Amagoro	Mean ± S.E
Days to 50% flowering	72.0a	70.0a	71.0 ± 0.2
Leaves per plant	11.0a	11.3a	12.1 ± 0.6
Leaf lenght (cm)	81.8a	78.3b	80.1 ± 2.5
Leaf width (cm)	8.5a	8.4a	8.4 ± 0.3
Tillers per plant	3.2a	2.8a	3.1 ± 0.5
Panicle lenght (cm)	28.7a	20.3b	24.4 ± 2.6
Panicle width (cm)	4.9a	3.2a	4.1 ± 0.5
Plant height (cm)	213.9a	202.7b	208.3 ± 3.7
Yield per plant (g)	98.6a	86.3b	92.4 ± 0.7
1000 seed weight (g)	26.0a	24.2a	25.1 ± 1.2

Means in a row sharing the same letter are not significantly different at $p < 0.05$

The yield and yield traits performance of some genotypes is presented in Table 3. Plant height recorded significant variations but most genotypes were tall with the shortest being MCSR T53 (81.6 cm) while MCSR T80 was the tallest and attained 434.6 cm. The panicle length varied significantly and the highest value (43.8 cm) was expressed in MCSR T25. Concerning a thousand seed weight, MCSR T90 gave the largest (55.2g). The genotype, MCSR T10 expressed the lowest grain weight per panicle (10.3g) while MCSR T71 had the highest (114.6g).

Table 3. Means for phenotypic characteristics of best 33 sorghum genotypes for yield evaluated at Bumala and Amagoro in 2009/10 Seasons

Genotype	Leaves per plant	Leaf length (cm)	Leaf width (cm)	Tillers per plant	Panicle length (cm)	Panicle width (cm)	Plant Height (cm)	Yield/ panicle (g)	Thousand seed weight (g)	Days to 50% flowering
MCSR T6	12.2 [a]	73.12jkl	10.78	1.8[a-f]	26.06e-k	6.2i-n	290.2wx	10.83a	29.64jk	4b
MCSR T10	11.3 [a]	71.43jkl	11.43	1.7[a-f]	25.57e-k	5.66i-n	288.4wx	10.74a	29.80jk	4b
MCSR T16	12.8[a]	96.86v	9.0s	2a-g	31.38j-l	4.8b-j	301.6x	35.84b-o	38.29lmn	3a
MCSR T25	10.5 [a]	91.41uv	8.33q-u	3.7g-n	43.81	5.6f-m	336.2m	23.27a-h	41.78op	5abc
MCSR T35	10.0 [a]	82.8r-t	6.26g-i	1a	35.92j-l	6.8k-o	238.3np	33.03a-o	25.02c-h	3a
MCSR T28	11.0 [a]	57.88b-e	6.36f-i	1.8a-f	34.62uv	4.8b-j	118.6b-e	28.27a-l	31.31k	3a
MCSR T29	11.0 [a]	86.8r-t	6.3g-i	1a	35.88j-l	6.76k-o	236.5np	32.96a-o	24.90c-h	3a
MCSR T30	12.8 [a]	80.0r-t	8.03m-r	3.8h-o	28.23h-k	4.4a-i	254.54u	18.09a-e	23.06cd	4b
MCSR T34	12.7 [a]	79.14r-t	9.34st	2.1a-h	26.52e-j	5.7g-m	240.0np	44.54g-q	37.96lm	5bc
MCSR T49	12.1 [a]	86 r-t	8.95r	8.1r	27.59g-i	4.8b-j	252.0t	18.96a-f	37.89lm	4ab
MCSR T51	10.0	70.53h-q	8.03m-r	1a	34.83v	5.2c-l	115.6b-e	52.0l-r	37.89lm	3a
MCSR T52	10.0 [a]	73.74 h-q	9.6stu	1a	22.68a-o	5.2c-l	106.8a-e	49.34i-q	65.39v-w	3a
MCSR T53	10.4 [a]	69.16g-o	7.88k-p	1a	30.36i-k	4.6a-j	81.6b	49.38i-q	58.13v	3a
MCSR T54	10.2[a]	70.76h-r	7.32j-o	1a	29.42i-k	5.0c-k	92a-d	50.16j-q	60.53v-w	3a
MCSR T59	11.4 [a]	67.81h-l	8.19o-t	2.1a-h	20.08a-g	3.8a-f	181.2g-j	50.34j-q	53.61v	4ab
MCSR T65	10.7[a]	66.761h-l	8.2o-t	2.2a-h	20.10a-g	3.7a-f	182.0g-j	49.86j-q	49.91v	4ab
MCSR T71	10.0 [a]	74.76l-u	5.3b-e	1.5b-e	17.2abcd	3.5a-d	120.9b-e	114.62t	50.16v	3a
MCSR T72	10.2 [a]	87.84 r-u	9.64stu	5.4op	33.02t	6.8l-q	273w	36.29b-o	58.84vw	4ab
MCSR T74	12.2 [a]	76.58m	9.4st	3.4e-n	33.6t	8.0o	261t	29.53a-n	54.26v	5abc
MCSR T77	12.0 [a]	76.84 n	9.7tu	2.0b-g	36.96tu	4.6a-j	117.2b-e	30.63a-n	47.13st	3a
MCSR T78	10.0 [a]	84.02r-t	5.8def	2.4b-l	34.14v	3.2ab	171.8fgh	21.18a-g	50.21v	5ab
MCSR T80	10.6 [a]	74.91l-u	5.1a-d	1.8b-f	16.9abc	4.0a-g	434.6i-u	27.11a-k	47.53s-v	5abc
MCSR T79	11.4 [a]	85.92r-t	9.38st	3.0c-i	20.72a-i	5.0c-k	262.8w-	32.17a-n	58.47v	4ab
MCSR T82	11.0 [a]	83.5r-t	9.09s	2.9c-i	32.08p-s	4.7a-j	231.4n	35.61a-o	57.61v	4ab
MCSR T60	12.8 [a]	74.49l-s	7.12i-l	2.6b-j	20.82a-i	3.4abc	266.0w	33.82a-o	54.91v	4ab
MCSR T83	11.0[a]	84.76r-t	8.54pq	2.8b-k	29.84k-r	5.8g-n	268.2w	36.55b-o	57.23v	4ab
MCSR T90	10.8 [a]	89.85t	9.61[st]	4.2j-o	34.59v	6.6k-l	218.5i-t	22.11a-h	45.49q-t	3a
MCSR T93	11.3 [a]	86.38t-v	9.03s	2.0a-g	25.83d-t	5.6f-m	227.6k-	43.05d-o	51.83	3a
MCSR T94	10.8 [a]	84.38p-t	9.5st	1.4b-e	26.23d-t	5.1c-l	146.5efg	43.2d-o	46.15r-t	3a
MCSR T96	10.2 [a]	79.64k-l	8.45p-r	2,5b-j	25.14c-s	4.2a-h	200.3h-o	73.58rs	37.71m	3a
MCSR T97	10.7 [a]	80.95k-n	8.54p-s	2.6b-j	25.98e-v	4.8a-j	141.6ef	57.26o-s	48.17s-v	3a
MCSR T106	11.8 [a]	82.1l	8.88r-s	1.8b-f	15.42a	5.2c-l	192.4h-l	25.93a-j	18.25a	4ab
MCSR T107	10.1 [a]	79.43kl	8.33q-u	1.1ab	29.72j-r	5.3d-m	227.1k--	41.56d-o	43.41o-s	3a
Means	**11.2**	**79.2**	**8.4**	**3.1**	**28.8**	**5.0**	**212.9**	**35.9**	**45.2**	
SE	**0.5**	**0.2**	**0.1**	**0.1**	**0.2**	**0.1**	**1.3**	**0.7**	**0.2**	

Means followed by the same letter in a column are not significantly different at 5% level of significant;
Days to 50% flowering: very early (< 56 days) =1, early (56 – 65 days) =2, medium=3 (66 – 75 days), late =4 (75 – 85 days), very late =5 (> 85 days)

The evaluated sorghum genotypes exhibited different panicle shapes as shown in Table 4 and Figure 1. A total of

46 genotypes had loose drooping primary branch panicles; 20 had semi loose primary branches while 12 and 10 genotypes, respectively, had half broomcorn and very lax panicles respectively. Grain characteristics indicated that most genotypes were brown (60.2%), creamy white seeded (34.1%) but a few were red (3.4%) and black (2.2%) seeded. It was interesting to note that all sorghum germplasm evaluated had single grain form (Figure 2).

Table 4. Frequency distribution of qualitative traits in sorghum evaluated at Bumala and Amagoro during 2009 and 2010 seasons

Qualitative trait considered	Genotypes out of 88 genotypes survived	Frequency (%)
Panicle shape		
Half broom corn	12	13.6
Semi loose drooping primary branches	20	22.7
Loose drooping primary branches	46	52.2
Very lax panicle	10	11.4
Grain colour		
Brown	53	60.2
Creamy white	30	34.1
Black	2	2.2
Red	3	3.4
Grain form		
Single	88	100.0
Twin	0	0.0
Grain plumpness		
Plump	83	94.3
Dimple	5	5.7
Awns at maturity		
Present	2	2.3
Absent	86	97.7
Leaf color pigmentation		
Pigmented	3	3.4
Non-pigmented	85	96.6

(i) (ii) (iii) (iv) (v)

Figure 1. *Different panicle characteristics of evaluated sorghum (i) Semi compact elliptic shape (ii) compact elliptic (iii) loose and drooping (iv) Sorghum with awns (v) awnless sorghum*

MCSR T4 *MCSR T72* *MCSR T57*
(Cream) *(Brown)* *(Red)*

Figure 2. *Variation in Seed Color and Shape for Some Tanzanian Sorghum*

Only two genotypes, MCSRT 17 and MCSR T41 had awns at maturity while the remaining 86 genotypes were awnless. There was variation in grain plumpness whereas about 94% of the genotypes had plump grains while only 6% were dimpled. Regarding leaf color pigmentation, only three genotypes *viz* MCSR T34, MCSR T65 and MCSR T77 had purple coloration while the rest were not pigmented (Figure 3).

(a) pigmented (MCSRT57)

(b) non –pigmented(MCSR T4)

Figure 3. *Genetic Variation on Sorghum Leaf Collar*

Some traits showed significant positive correlation with days to maturity that included leaf length (r = 0.5**), plant height (r = 0.3*) and number of leaves per main stem (r = 0.3**) (table 5). Plant height showed moderate positive and significant correlation (r = 0.4*) with number of leaves and very low but significantly correlated with yield (r = 0.1*).

Table 5. Correlations among seven quantitative traits in 98 sorghum genotypes

	Days to 50% flowering	Leaf width (cm)	1000seed weight (g)	Plant height (cm)	Leave/ plant	Yield/ plant
Days to 50% flowering						
Leaf width (cm)	0.39**					
1000seed weight(g)	0.15	0.08				
Plant height (cm)	0.27*	0.22	0.03			
Leaves per stem	0.33**	0.58**	0.3	0.41*		
Yield/plant (g)	0.02	0.06	0.07	0.08*	0.13	
Leaf length (cm)	0.50**	0.19	0.16	0.31	-0.04	-0.1

Note: *, ** *significant at 5% and 1% probability level respectively*

Results from cluster analysis revealed two major distinct groups with five subgroups each (Figure 4). The first cluster (Cluster 1) was the largest and consisted of 37 landraces. This group is dominated by landraces that are very late maturing, taking more than 85 days to 50% flowering. Most of the genotypes in this group produced white grains. The next group (Cluster 2) composed of 33 genotypes characterized by late maturity time taking 76 - 85 days to 50% flowering. The third cluster comprised a total of 16 genotypes. This group of genotypes was similar in plant height, (150 – 220 cm) and high 1000 grain weight (36 - 45g/plant). Cluster 4 comprised of only MCSR T70 and MCSR T84. These two genotypes were white seeded with medium height. They were collected from the same region (Mwanza) so they could be similar in many ways since farmers share seed for planting. The last, cluster 5 had only one genotype, MCSR T71. This accession had the heaviest average yield per plant (114.6 g). Additionally, two genotypes *viz* T59 and T107 shared the same tree on the dendrogram.

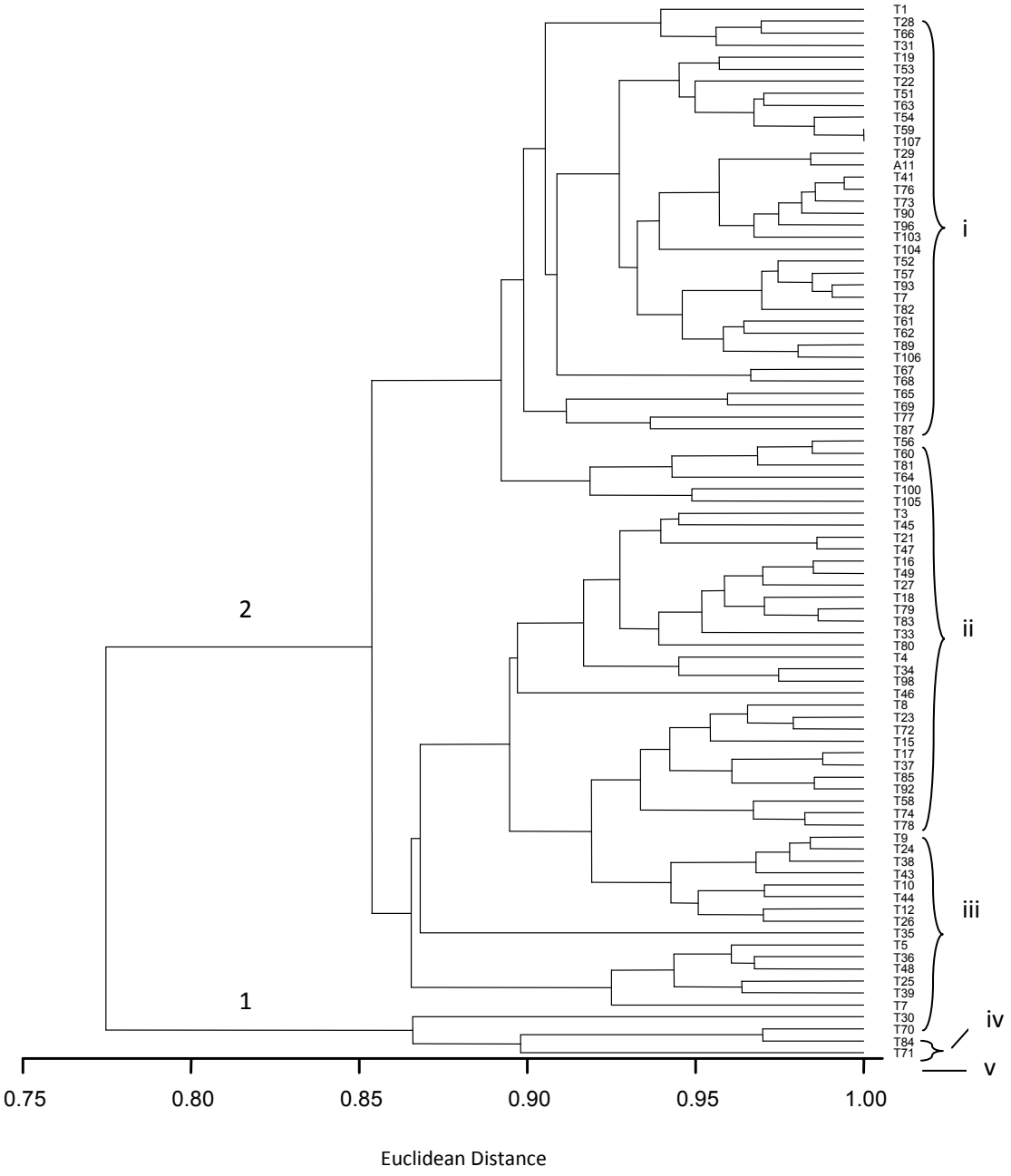

Figure 4. *Dendrogram Based on Average Linkage of Evaluated Sorghum Genotypes*

4. Discussion

Phenotypic differences recorded in sorghum lines for the agronomic traits evaluated could be associated with the varied genetic materials used in this study. Significant variations in sorghum for yield and yield traits across environments have also been reported by Madhusudhara and Patil, 2013; Warkad *et al*. 2008; Bucheyeki, 2008). Moreover, the differences in grain yield and its associated traits between environments could be due to location's differences in rainfall during growing season. Bumala site received higher annual rainfall (835mm) than Amagoro (600mm) resulting to overall high grain yield. Majority of sorghum genotypes used in this study were early to medium maturing as they took 64 to 75 days to attain 50% flowering. However, most sorghum takes about 60 – 70 days to 50% flowering as reported by Doggett, (1988). The reason for the delayed flowering expressed by the genotypes in this study could be due to the fact that these materials were collected from various areas including lowlands and highlands agro-ecologies therefore varying maturity period. For the Bumala site and surrounding areas, late maturing sorghum varieties would be most suitable as they could mature relatively late when the rains have stopped because too much rain favors mold development hence affect seed quality, a major production constraint in areas receiving high rainfall. There was high tendency for tillering among the

evaluated sorghum genotypes with MCST 79 producing an average of 13 tillers per plant across locations. Similar observations have been report by Bucheyeki *et al*. (2008). Variation in tillering affects the dynamics of canopy development hence timing and nature of crop water limitation. Generally tillers may contribute to overall yield of a sorghum crop when water supply is not limiting as for the case of Bumala, but profuse tillering is not desirable for dry or sub-humid agroecologies because many tillers would reduce water use efficiency. Crop maturity, harvesting and grain quality may be adversely affected if the tillers mature at different times. Most of the sorghum lines had semi-loose drooping primary branches and loose-drooping primary branches which give wide scope for selection to meet farmer's preferences especially in the areas characterized with high rainfall. Such variations in panicle shape have being reported by Doggett (1988). Open panicles are preferred in high rainfall and humid areas to avoid mold and ergot diseases (Singh *et al*,. 1997). Leaf collar pigmentation was rare trait as it was only noted in three genotypes and this feature can be a good phenotypic marker for breeders. Purple pigmentation on the leaves is closely associated with the seed colour and tannin content of the grains (Earp *et al*., 2004). In line with this, all pigmented genotypes had red seeded grains implying that pigmentation could be highly associated with grain colour. Accession MCSRT 53 which was dwarf could be used in breeding program for short cultivars. Shorter sorghums are preferred in dry lowlands as they require relatively shorter period to maturity compared to taller ones thus can escape terminal drought (Grenier *et al*., 2001). The shorter plant type also withstands lodging and is easier to harvest (Sing *et al*, (1997). Madhusudhara and Patil, (2013) reported wide variations of plant height in sorghum. Tall plants can easily lodge but they are beneficial in areas where more priority is for fodder, biomass fuel and thatching. The short sorghum varieties are mostly grown in dry areas of Central Tanzania as opposed to Southern and Northern part of the country where tall genotypes are common because these areas experience relatively longer period of rainfall.

Most of the sorghums in this study did not develop awns at maturity possibly because they are less preferred hence rarely grown by farmers in Tanzania. Awnless sorghum genotypes are more preferred because of relatively less effort during cleaning. The genotypes MCSR T17 and MCSR T41 that expressed awns should not be included in breeding program because of difficulties associated with threshing and cleaning the seed. Although, sorghum genotypes with awns are less eaten by birds this study found all awned genotypes to be low grain yielders across locations. The findings from this study indicated that majority of sorghum germplasm evaluated produced brown grains. The brown seeded sorghums are often associated with relatively high tannin content and are less preferred by birds (Doggett, 1988). Preference for brown sorghum may be associated with their localized use for brewing. Most of the brown seeded genotypes were collected from Lake Zone and Western Tanzania. Local brews made from sorghum are common in these areas. This concurs with the findings by (INTSORMIL/USAID, 2006). The variation observed on panicle width, length, yield per panicle, and 1000 seed weight could be explained by the fact that, the germplasm were collected from diverse geographical locations in Tanzania. Moreover, some of the materials might have originated from different neighboring countries in East and Central Africa and therefore distantly related to the native Tanzanian material therefore uncontrolled intercrossing might have occurred. The germplasm evaluated most likely represents the diverse races of *S. bicolor* grown in Tanzania. As such, one would expect a high level of phenotypic variation. Similar variations were reported by Bucheyeki *et al*. (2008). The high yielding MCSRT 71 is a good genetic material that can be exploited in sorghum breeding program in Kenya and Tanzania for yield improvement.

Correlation analysis revealed that the leaf length, height and number of leaves were positive and significantly correlated with days to maturity. A reason for positive correlation relationships is due to the nature of sorghum collections used in this study. Sorghum landraces that are late maturing tend to accumulate more biomass in shoots and leaves, which leads to increased height and leaves. These results are similar with those reported by Empilli *et al*., (2000). Results on correlation of morphological traits with yield showed that, correlation coefficients were low. However, correlations among growth traits themselves were high. The positive correlation between plant height and yield is due to the fact that, the taller the plant grows the higher the yield it produces. However, this is not the case all the time, it can be the vice versa. These findings agree with those reported by Ejeta *et* al., (2000). This study recorded five clusters with one major cluster largely composed of genotypes from the Southern Tanzania and the next one was materials from Lake Zone. The genotypes from other regions such as Kagera, Kigoma and Mara were clustered together. The two genotypes sharing the same tree (MCSR T59 and MCSR T107) are most probably duplicates since they were collected from the same region. There is a high chance that some genotypes used in this study come from different races. For instance, *kafir* one of the five sorghum races is characterized by relatively compact panicles that are often cylindrical in shape, has elliptical sessile spikelets and tightly clasping glumes that are usually much shorter than the grain. This race is common across the eastern and southern Savannah from Tanzania to South Africa (Bucheyeki *et al*. (2008). It is possible that majority of genotypes collected from Southern Tanzania belong to this race due to the fact that they exhibited similar characters to *kafir.* Another race is *bicolor* that is characterized by open inflorescences and long

clasping glumes that enclose the usually small grain at maturity. These cultivars are grown in Africa and Asia (Dogget, 1988) and majority of the genotypes from Lake and central zone had similar characteristics to this race.

Conclusion

Determination of genetic variability in traits of agronomic importance constitutes the foundation for sustainable management of genetic resources particularly sorghum. Such management is of central importance in breeding for improvement and conservation of genetic materials. This study confirmed that sorghum germplasm from Tanzania has a wide genetic variability that could be exploited in breeding programs. The high yielding and early maturing varieties identified in this research are potential resources to improve sorghum in Tanzania and western Kenya.

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Appendix 1. List of sorghum genotypes used in the study with their origin

No.	Accession	Origin	No.	Accession	Origin	No.	Accession	Origin
1	MCSRT1	Mbinga	**34**	MCSRT26	Sumbawanga	**67**	MCSRT52	Ilonga
2	MCSRT2	Mara	**35**	MCSRT27	Sumbawanga	**68**	MCSRT53	Ilonga
3	MCSRT3	Mara	**36**	MCSRT28	Sumbawanga	**69**	MCSRT54	Ilonga
4	MCSRT4	Mbinga	**37**	MCSRT29	Mwanza	**70**	MCSRT55	Ilonga
5	MCSRT5	Serengeti	**38**	MCSRT30	Ilonga	**71**	MCSRT56	Sumbawanga
6	MCSRT6	Ukerewe	**39**	MCSRT31	Nzega	**72**	MCSRT58	Biharamulo
7	MCSRT7	Mtwara	**40**	MCSRT32	Ilonga	**73**	MCSRT63	Tarime
8	MCSRT8	Mtwara	**41**	MCSRT33	Ukerewe	**74**	MCSRT61	Tarime
9	MCSRT9	Serengeti	**42**	MCSRT34	Mwanza	**75**	MCSRT69	Musoma rural
10	MCSRT10	Mtwara	**43**	MCSRT35	Igunga	**76**	MCSRT64	Ukerewe
11	MCSRT11	Igunga	**44**	MCSRT36	Lindi	**77**	MCSRT57	Serengeti
12	MCSRT12	Igunga	**45**	MCSRT37	Lindi	**78**	MCSRT74	Musoma rural
13	MCSRT13	Dodoma	**46**	MCSRT38	Nachingwea	**79**	MCSRT94	Igunga
14	MCSRT14	Dodoma	**47**	MCSRT39	Sumbawanga	**80**	MCSRT91	Igunga
15	MCSRT15	Dodoma	**48**	MCSRT40	Igunga	**81**	MCSRT105	Nzega
16	MCSRT16	S.Tanzania	**49**	MCSRT41	Ilonga	**82**	MCSRT78	Serengeti
17	MCSRT17	Nzega	**50**	MCSRT42	Musoma rural	**83**	MCSRT83	Serengeti
18	MCSRT18	Ilonga	**51**	MCSRT43	Igunga	**84**	MCSRT84	Ukerewe
19	MCSRT19	Kasulu	**52**	MCSRT44	Dodoma	**85**	MCSRT77	Biharamulo
20	MCSRT20	Ilonga	**53**	MCSRT45	Nachingwea	**86**	MCSRT75	Ukerewe
21	MCSRT21	Ukerewe	**54**	MCSRT46	Nzega	**87**	MCSRT81	Ukerewe
22	MCSRT22	S.Tanzania	**55**	MCSRT47	Musoma rural	**88**	MCSRT72	Musoma rural
23	MCSRT23	S.Tanzania	**56**	MCSRT48	Dodoma	**89**	MCSRT88	Ukerewe
24	MCSRT24	Kasulu	**57**	MCSRT49	Musoma rural	**90**	MCSRT68	Serengeti
25	MCSRT25	Kasulu	**58**	MCSRT51	Ilonga	**91**	MCSRT100	Igunga
26	MCSRT82	Tarime	**59**	MCSRT66	Bukoba rural	**92**	MCSRT99	Nachingwea
27	MCSRT80	Ukerewe	**60**	MCSRT65	Ukerewe	**93**	MCSRT101	Igunga
28	MCSRT85	Ukerewe	**61**	MCSRT70	Ukerewe	**94**	MCSRT97	Kasulu
29	MCSRT87	Biharamulo	**62**	MCSRT73	Mwanza	**95**	MCSRT89	S.Tanzania
30	MCSRT102	Igunga	**63**	MCSRT71	Bukoba rural	**96**	MCSRT90	S.Tanzania
31	MCSRT59	Biharamulo	**64**	MCSRT103	Nachingwea	**97**	MCSRT95	S.Tanzania
32	MCSRT67	Biharamulo	**65**	MCSRT60	Musoma rural	**98**	MCSRT98	Kasulu
33	MCSRT76	Ukerewe	**66**	MCSRT79	Sumbawanga			

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