Morphological Characterization of Tanzanian Sorghum [*Sorghum bicolor* (L) Moench] Landraces

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ABSTRACT

Eleven qualitative and 26 quantitative morphological traits were used to determine the genetic relationships in 37 sorghum landraces from Tanzania and two from Zambia. The objectives of this study were to: determine the genetic relationships and thus establish the potential of the landraces as sources of breeding material for future sorghum improvement; and assess important agronomic traits for sorghum classification. Quantitative traits analysis revealed the potential of these landraces as a source of breeding material. Five principal components accounted for 53.64% of the total variability. Cluster analysis revealed two major distinct groups each with two subgroups. There were positive and significant correlations between days to maturity and leaf width (r = 0.477**), plant height (r = 0.353*), main stem diameter (r = 0.399*) and leaves per main stem (r = 0.456**). There was a high positive correlation for leaves per main stem with stem diameter (r = 0.621**) and with leaf width (0.426**). Based on the correlation analysis, it was concluded that there was a possibility of breeding for positively-correlated traits in sorghum. Information collected by this study could be utilized by sorghum breeders for sorghum improvement and classification.

Key words: landraces, morphological characterization, *Sorghum bicolor*, Tanzania, Zambia

INTRODUCTION

Sorghum is one of the five most important cereal crops in the world (Doggett, 1988). It can be utilized in a number of ways ranging from traditional food preparation to as an ingredient of beer. In America, Japan and Europe, sorghum is one of the most important ingredients for animal feed formulation. In Tanzania, sorghum is one of the staple foods benefiting about 80% of smallholder farmers in the marginal areas (Rohrbach *et al*., 2002).

In Tanzania, yields from sorghum have been deteriorating year after year (Rohrbach *et al*., 2002). This has been attributed to various factors affecting the production and utilization of sorghum. The major factors contributing to low yields include: weeds, pests (birds and shoot fly), diseases (such as grain moulds), chemicals (high level of tannin and cyanide content), as well as

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social and economic factors (Kenga *et al*., 2004). An effort to combat these problems has been made by the Tanzanian breeding program through the introduction of improved varieties. However, these varieties were susceptible to both biotic and abiotic stresses as they had not adapted to the local conditions (Medraoui *et al*., 2007). Additionally, improved varieties in general had poor storage, grain quality, processing and nutrition qualities (Beta and Corke, 2001). To date the rate of adoption of new varieties has been very low and frequently coupled with the high rate of abandonment (McGuire, 2008). In contrast, landraces are well adapted to local stresses and have preferred farmers traits (Setimela *et al*., 2007), despite being late maturing and photoperiod-sensitive. It was therefore imperative to study the genetic relationships of landraces and identify the qualitative and quantitative traits that can be incorporated into the sorghum breeding program. Genetic studies that aimed at utilizing locally available materials have been used by several researchers. Ogunbayo *et al*. (2005) used morphological characteristics to study 40 rice accessions by employing 14 agro-botanical traits in Nigeria. Zimeri and Kokini (2003) employed morphological traits to investigate the properties of waxy maize starch. Morphological studies have been widely used in sorghum to study their genetic relationships and have produced useful information for breeders (Barnaud *et al*., 2007). However, there is no genetic information on the landraces in central and southern Tanzania. Therefore, this study was conducted on landrace characterisation using morphological traits, with its objectives to: determine the genetic relationships; establish the potential of the landraces as sources of breeding material for future sorghum improvement; and assess important agronomic traits for sorghum classification.

MATERIALS AND METHODS

Field characterization of the sorghum landraces (Table 1) was carried out at the Mansa Technology Assessment Site (TAS) during the 2004/2005 growing season. The station is 1241.45 m asl and lies at a latitude of 11°14.384 S and a longitude of 28° 57.267 E. Landraces were planted in a randomized complete block design (RCBD) with three replications. Plots were defined by a length of 5 m along two rows, with an inter row spacing of 75 cm and 50 cm between planting hills in a row. Eight to ten seeds per hill were planted. This spacing was selected to eliminate any interplant competition and thereby allow plant traits to be clearly expressed (Lafarge and Hammer, 2002). After thinning, one plant was left per hill. ‘D’ Compound fertilizer (N: P_2O_5: K_2O: S = 10: 20: 10: 5) (basal) was applied at the rate of 200kg/ha. Urea fertilizer (46% N) was applied as a top dressing at the rate of 100kg N/ha four weeks after planting. Stalk borers were controlled by spraying with Phoskill (Monocrotophos 36 SL) using 560 ml in 250 litres of water per hectare.

Measurements and observations were recorded following the International Board for Plant Genetic Resources (IBPGR) and ICRISAT (1993) descriptor list. Qualitative traits were scored as one-or-zero (present/absent) binary data. Traits with more than one state, such as colour, were subjected to a decomposition into binary data by considering one state at a time. Genstat statistical software was used for cluster and principal component analysis. Cluster analysis, based on euclidean distances as similarity measures and the unweighted pair-group method with arithmetic averages (UPGMA) was used to determine the genetic relationships among genotypes. Principal component analysis (eigen values and percentage variations) was used to determine the plant traits that contributed significantly to the discrimination of the landraces. Mpunga -5-38-1 was dropped from the analysis because its germination was below 70%.

Table 1 Sorghum landraces collected from Tanzania and Zambia.

Access-ion no	Name	Meaning	Area	Country
1	Chijenja-3	-	South	Tanzania
2	Chijenja-4	-	South	Tanzania
3	Lionja- B-10	Village name	South	Tanzania
4	Lionja- B-5	Village name	South	Tanzania
5	Chijenja-3-19-1	-	South	Tanzania
6	Chijenja-3-25-7	-	South	Tanzania
7	Chijenja-4-31-1	-	South	Tanzania
8	Chijenja-4-33-3	-	South	Tanzania
9	Mpunga -5-38-1	Rice	South	Tanzania
10	Mpunga -5-40-3	Rice	South	Tanzania
11	Mkia wa kondoo 6-43-1	Sheep tail	South	Tanzania
12	Mwanza 6-44-2	Mwanza town	Central	Tanzania
13	Mkimakuwa 8-51-4	-	South	Tanzania
14	Mkimakuwa 8-53-6	-	South	Tanzania
15	Linjana 9-57-4	-	South	Tanzania
16	Linjana 9-61-8	-	South	Tanzania
17	Mkia wa kondoo 10-64-1	Sheep tail	South	Tanzania
18	Mkia wa kondoo 10-67-7	Sheep tail	South	Tanzania
19	Msumbiji 11-72-1	Mozambique	South	Tanzania
20	Msumbiji 11-74-3	Mozambique	South	Tanzania
21	Nachihaku 12-79-1	A girl	South	Tanzania
22	Nachihaku 12-81-3	A girl	South	Tanzania
23	Saisi 13-86-1	-	South	Tanzania
24	Saisi 13-87-2	-	South	Tanzania
25	Msumbiji 14-91-1	Mozambique	South	Tanzania
26	Msumbiji 14-97-7	Mozambique	South	Tanzania
27	Mkia wa Mwavuli15-100-1	An umbrella	South	Tanzania
28	Mkia wa Mwavuli15-104-5	An umbrella	South	Tanzania
29	Kimakonde 16-108-2	Makonde tribe	South	Tanzania
30	Kimakonde 16-110-4	Makonde tribe	South	Tanzania
31	Nkota B-17-118-2	Sweet sorghum	South	Tanzania
32	Nkota 17-124-2	Sweet sorghum	South	Tanzania
33	Mbagala 19-129-2	-	Central	Tanzania
34	Mbagala 19-133-6	-	Central	Tanzania
35	Mbagala 20-144-2	-	Central	Tanzania
36	Mbagala 20-145-3	-	Central	Tanzania
37	Mbagala 21-149-2	-	Central	Tanzania
38	Mbagala 21-166-22	-	Central	Tanzania
39	Local Nshima	Stiff porridge	Luapula	Zambia
40	Local white	White grained	Luapula	Zambia

RESULTS AND DISCUSSIONS

Qualitative traits analysis

The majority of landraces were not juicy (82.5%), had insipid juice flavour (85.0%), creamy white grain colour (90.0%), corneous endosperm texture (97.5%), intermediate threshability (85.0%), plump grains (87.5%), good stem-tillers flowering synchronization (97.5%) and loose drooping primary branches inflorescence shape (67.5%) (Table 2). This could be attributed to the farmers' preferences to plant sorghum with similar characteristics to meet multiple social and economic demands (Mekbib, 2006). Seed exchange among farmers could also be a contributing factor to little evident variation. Nathaniels and Mwijage (2000) reported that sorghum seed exchange among farmers in the Nachingwea district (Southern Tanzania) was one of the sources of seed for planting. Similar findings have been found in Zambia, where 40% seed exchange among farmers was recorded (Gwanama and Nichterlein, 1995).

Quantitative traits analysis

Table 3 summarizes the 26 studied quantitative characteristics of the 39 sorghum landraces. The mean germination percentage was 87%. Landraces took an average of 4.7 days to emerge while the seedling vigour ranged from 3-7. Landraces had a range of 94-140 days to reach 50% flowering, with an average of 176 days to mature. All landraces were classified as late maturing, since they took more than 91 days to flower (SADC, 1998). Late flowering was considered to be due to the day length variation, which was an indication of photoperiod sensitivity (Grenier *et al*., 2001). The sorghums in this study could only flower if the day length were shorter than the night length. This adaptation mechanism helped them to escape fungal diseases and bird attacks, because they matured during dry periods when birds have alternative food sources. Farmers also selected this type of landrace, because it required less labor and so during peak labor demand, farmers could concentrate on other crops and tend their sorghum later.

There was considerable variation in the stem and leaf characteristics among landraces. Leaf length and leaf width varied from 92-105 and 6.5-10 cm, respectively. The number of leaf tillers per hill varied from 3-89 while the tiller leaf width varied between 1.7-7.7 cm. Sorghum showed good leaf senescence with an average score of 6.1. On average, the landraces had 15.2 leaves per main stem and 3.9 tillers per main stem. Tiller leaf length and diameter varied from 54-102 and 1.02-1.73 cm, respectively, while the main stem basal diameter varied from 1.59-2.69 cm. Landraces recorded an average height of 387.7 cm. The high variations exhibited in leaf length, tiller leaf length, tiller leaf width, plant height and the number of flowering stems indicated the potential of the landraces as a source of breeding material for an end use as animal feed.

There were also differences among the sorghum landraces in: inflorescence, panicle yield, grain characteristics and yield. The mean number of flowering stems varied from 1.2-5.5. Inflorescence length and width varied from 20.2-40.8 and 7.0-30.3 cm, respectively. The mean yield per landrace was 1.6 t ha^{-1} . There was a high variation in grain cover which ranged from 1-5. Landraces showed variations in grain weight per panicle and 100-grain weight from 114-348 and 1.1-4.7 g, respectively. Data on inflorescence, panicle, grain characteristics and yield showed the potential of Tanzanian sorghum landraces for grain production. For example, landraces showed a range in the number of grains per panicle of 971-3980, compared with 6700 for improved sorghum cultivars (Doggett, 1988).

Sorghum landraces showed a high variation in stalk borer infestation and lodging susceptibility which ranged from 1-7. The stalk borer was identified as *Busseola fusca*. Field

Table 2 Frequency distribution of 11 qualitative traits in sorghum landraces.

Descriptor	No. of accessions	Frequency %
Stalk juiciness		
Not juicy	33	82.5
Juicy	7	17.5
Inflorescence compactness and shape		
Very lax panicle	1	2.5
Loose drooping primary branches	27	67.5
Semi-loose drooping primary branches	10	25.0
Half broom corn	2	5.0
Grain colour		
Creamy white	36	90.0
Brown	3	7.5
Black	1	2.5
Grain lustre		
Absent	2	5.0
Present	38	95.0
Grain plumpness		
Dimple	5	12.5
Plump	35	87.5
Endosperm texture		
Mostly corneous	39	97.5
Mostly starchy	1	2.5
Threshability		
Intermediate	4	10.0
Good	34	85.0
Excellent	2	5.0
Stem colour at harvest		
Brown	17	42.5
Purple	13	32.5
Tan	10	25.0
Leaf midrib colour		
White	13	32.5
Sienna	15	37.5
Mahogany	8	20.0
Red	4	10.0
Juice flavour		
Sweet	6	15.0
Insipid	34	85.0
Stem-tiller flower synchronization		
Not synchronous	1	2.5
Synchronous	39	97.5

inspection revealed that sweet stem sorghums were more commonly infected than inspid types. This could be attributed to insect preferences for sweet sorghum. However, further investigation would be needed in this area to provide a conclusive result. Landrace assessment on lodging susceptibility revealed a high variation among genotypes with the range from 1- 9. Various causes of plant lodging could be suggested, ranging from wind to genotype composition to diseases and insect pests. The actual causes of lodging in this study were not established.

Principal component analysis

Table 4 shows the principal components and their contribution to variability. Five principal components accounted for 53.64% of the total variability. The low contribution of the five

Table 3 Quantitative characteristics of sorghum landraces from Tanzania and Zambia.

☐	Minimum	Maximum	Range	Mean	S.D	S.E	C.V
Descriptor							
Germination %	79	97	18	87	4.4	0.7	8.6
Days to emergency	4	7	3	5.3	1.1	0.2	32.8
Seedling vigour (score)	3	7	4	4.7	0.9	0.1	40.0
Days to flowering	94	140	46	119	11.8	1.9	4.7
Days to maturity	161	186	25	176	4.5	0.8	3.7
Stem and leaf characteristics							
Leaf length (cm)	92	105	13	97.5	3.5	0.6	3.5
Leaf width (cm)	6.5	10.0	3.5	8.7	0.7	0.1	12.1
Senescence (score)	5	9	4	6.1	0.8	0.1	19.0
Leaf number per main stem	12.9	18.7	5.8	15.2	1.3	0.2	9.6
Number of tillers/stem	3.0	5.8	2.8	3.9	0.7	0.1	3.5
Number of leaf tillers/station	3.0	89	86	33.7	15.4	1.7	43.7
Tiller leaf width (cm)	1.7	7.7	6	5.2	1.1	0.1	24.2
Tiller leaf length (cm)	54	102	48	83	8.9	1.0	11.7
Tiller diameter (cm)	1.02	1.73	0.71	1.39	0.17	0.03	22.0
Plant height (cm)	290	456	166	387. 7	40.0	6.4	10.8
Main stem basal diameter (cm)	1.59	2.69	1.10	2.11	0.19	0.03	14.8
Inflorescence, panicle and grain characteristics and yield							
Number of flowering stems	1.2	5.5	4.3	3.1	1.1	0.2	9.1
Inflorescence length (cm)	20.2	40.8	20.6	31.3	4.7	0.8	41.7
Inflorescence width (cm)	7.0	30.3	23.3	16.6	4.7	0.758	22.1
Yield (tons/ha)	0.52	3.74	3.22	1.60	0.59	0.09	34.9
Grain covering	1.0	5.0	4.0	2.9	0.9	0.1	25.0
Number of grains per panicle	971	3980	3009	2241.1	758.9	121.5	28.3
Average grain weight (five panicles) (g)	114	348	235	240.5	57.1	9	17.7
Hundred grain weight (g)	1.1	4.7	3.6	2.3	0.7	0.1	20.3
Lodging and tunnelling							
Stalk borer tunnel at harvest	1	7	6	1.8	1.5	0.2	74.4
Lodging susceptibility (score)	1	9	8	3.5	2.3	0.3	63.7

principal components revealed by this study could be due to the uniformity in some traits, especially the qualitative traits (Table 2). Farmers normally prefer certain characteristics such as white grain and thus make their selection based on their preferred traits. Other researchers recorded more than 70% contribution to variability by the first two-to-six principal components (Haussmann *et al.*, 2000; Noffsinger *et al.*, 2000). However, Grenier *et al.* (2001) observed 48.8% of the variance with the two axes of the principal components.

The first and second principal component scores (Figure 1) revealed most of sorghum landraces were clustered in the area between -2 and +2 on principal component one. Msumbiji 14-91-1, Kimakonde 16-110-4 and Nkota B-17-118-2 were recorded as outliers. The presence of outliers revealed by this study indicated that those landraces are likely to have had unique traits compared to the others. These could be a source of breeding material.

Table 4 Principal components and their variability.

Principal component	Eigen value	Percentage variation	Accumulated variability
1	6.54	17.22	17.22
2	4.53	11.92	29.14
3	3.66	9.64	38.78
4	3.13	8.24	47.02
5	2.52	6.62	53.64

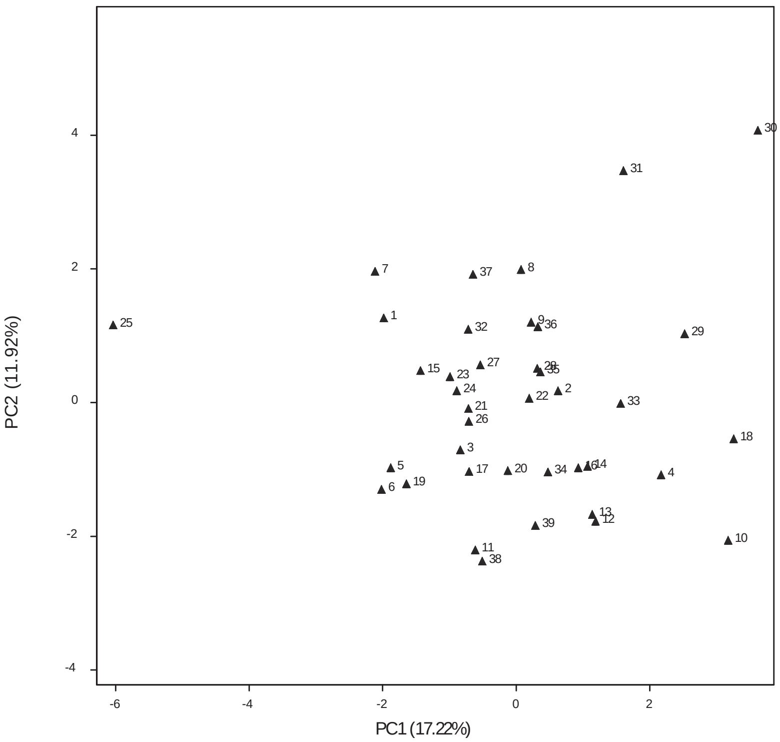

Figure 1 The positions of the sorghum landraces on the first and second principal components based on morphological characters.

Cluster analysis

Cluster analysis based on the morphological characteristics at cluster distance 15 revealed two major distinct groups each with two subgroups (Figure 2). The first group (Cluster I) was the largest and consisted of 25 landraces. Low grain number per panicle dominated this group. Sub-cluster Ia had 20 landraces. These landraces also had low to average grain number per panicle (1624-2265) when compared to the observed mean (2241.1). Sub -cluster Ib of group I had five landraces. Landraces of this subgroup were characterized by purple stem colour and had smaller tiller diameter (1.33-1.37 cm) than the average (1.39 cm). The second cluster (Cluster II) had 14 landraces. Small sized grain seeds dominated this group. Sub-cluster IIa of cluster II had eight landraces. All members in the subgroup had inspid flavour and low to average (1.50-2.70 g) hundred-grain weight as compared to the mean (2.3 g). This subgroup had similar days to maturity (174-184) compared to the mean (176). The subgroup also had similar basal stem diameter (1.92-2.23 cm) compared to the mean (2.11cm).

Sub-cluster IIb of cluster II had six landraces. All members of the subgroup had low (1.10-1.80 g) hundred-grain weight compared to the mean (2.3 g) and had below average to average (1.59-2.12 cm) basal stem diameter compared to the mean (2.11 cm). This group comprised landraces with the highest (3227-3980) grain number per panicle compared to the mean (2241.1).

Correlation analysis

Table 5 shows the simple correlation among some sorghum landraces characters.

Traits that showed a positive and significant correlation with the days to maturity were leaf width (r = 0.477**), plant height (r = 0.353*), main stem diameter (r = 0.399*) and leaves per main stem (r = 0.456**). There was a

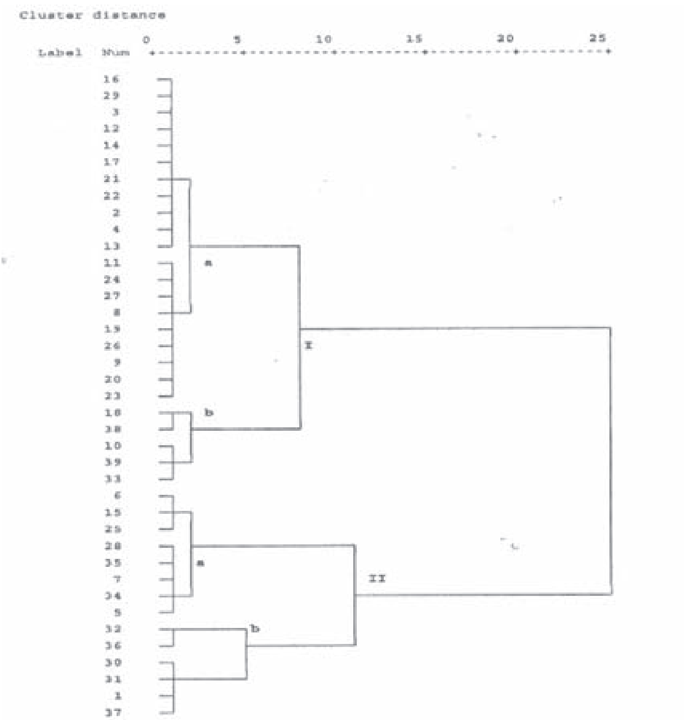

Figure 2 Dendrogram based on the average linkage of 39 sorghum landraces.

Table 5 Correlations among traits of 39 sorghum landraces from Tanzania and Zambia.

	Days to mature	Leaf width (cm)	100 grain weight (g)	Plant height (cm)	Stem diameter stem	Leaves per main (cm)	Yield	Leaf length (cm)
Days to maturity	1.000							
Leaf width (cm)	0.477**	1.000						
100 grain weight (g)	0.184	0.102	1.000					
Plant height (cm)	0.353*	0.310	-0.049	1.000				
Stem diameter (cm)	0.399*	0.410*	0.649**	0.307	1.000			
Leaves per main stem	0.456**	0.426**	0.272	0.327*	0.621**	1.000		
Yield (tons/ha)	0.033	0.061	0.087	0.090	0.135	0.171	1.000	
Leaf length (cm)	0.071	0.259	0.175	0.296	0.046	-0.050	-0.101	1.000

* = Significant at $p \leq 0.05$;
** = Significant at $p \leq 0.01$

positive and highly significant correlation (r = 0.649**) between hundred-grain weight and main stem diameter. Plant height showed a positive and significant correlation (r = 0.327*) with leaves per main stem. There was a high positive correlation for leaves per main stem with stem diameter (r = 0.621**), with leaf width (0.426**) and also with stem plant height (r = 0.327*). The positive correlation relationships shown in this study could be attributed to the natural characteristics of sorghum landraces. Sorghum landraces are a late maturing genotype; so they accumulate more biomass, which leads to an increase in height, stem diameter and the number of leaves. The correlation analysis suggested the possibility of breeding for positively-associated traits in sorghum. These findings are in accordance with those reported by (Empilli *et al*., 2000).

CONCLUSIONS

This study has shown that there are variations in the quantitative morphological traits among sorghum landraces found in Tanzania. Morphological characterization can still be a useful tool in breeding programmes. The study method produced two main clusters of sorghum landraces with each having two sub-clusters. Information gathered by this study could be a vital tool for breeders to avoid duplication of research work. The variation shown by the landraces suggest it could be potentially useful in the selection of breeding material, with information collected by this study utilized by sorghum breeders to improve performance and for the classification of sorghum.

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