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Genetic diversity of maize landraces from Tanzania as compared with commercial improved varieties and elite lines through morphological characterization

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Abstract

Maize production challenges require well-known genetic diversity to ensure effective improvement. The study aimed at conducting morphological evaluation on 50 maize landraces from Tanzania compared with 7 commercial varieties and 11 elite lines from CIMMYT, Kenya. The experiments were conducted in randomized complete block design at three locations in Arusha region, Tanzania. Data were collected on 19 quantitative and 12 qualitative traits that were subjected to analysis of variance, descriptive and multivariate statistics. Significant variations ($p<0.05$) were observed for all traits while higher contribution for accessions variability were found with yield, a thousand kernel weight, flowering traits, kernel, ear and vegetative plant characteristics. Commercial varieties were characterized by significant yield (107.4g per plant) and yield related parameters of (a thousand seed weight, number of rows per ear, ear diameter, ear length) also early days to tasseling and silking of 67.7 and 73 respectively. CIMMYT elite lines were characterized by significant low plant and ear height of 138.9cm and 50.6cm respectively as well as flint kernel type. Landraces were more diverse in every trait evaluated with significant long anthesis-silking interval of 7.5 days and large ear height of 95.9cm. Some landraces (eg TZA 2793 and TZA 5170) expressed significant traits that would be tapped for further crop improvement. Other landraces clustered themselves irregularly in terms of their collection sites within their major group due to selection and exchange of seeds. Thus, farmers as custodians of landraces are supposed to be involved in a systematic selection and breeding.

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Introduction

Maize (*Zea mays* L.) sustains a huge population in the world (Romay *et al.*, 2013) and even equated to the national food security in Tanzania (Katinila *et al.*, 1998). However, its average yield is still very low with 1.2 metric tonnes per hectare in Tanzania as compared with the estimated potential yields of 4 to 5 metric tonnes per hectare (Moshi *et al.*, 1990; Otunge *et al.*, 2010). Low yield has been connected to factors such as lack of quality inputs (eg seeds, fertilizer), drought, pests and diseases. Nevertheless, maize is a crop which is potentially diverse in terms of phenotypic and genetic characters (Whitt *et al.*, 2002). The genetic variation of maize constitute a very important package for breeding (Prasanna, 2010; Yao *et al.*, 2007) which requires the availability of desirable characters for maize crop improvements (Ristic *et al.*, 2013). However, for the past decades, breeding in maize have been concentrated in short breeding programs that uses inbred lines, elite lines and breeder materials (Cömertpay, 2012; Yao *et al.*, 2007). These materials are in most cases uniform that for a long time have caused the existence of narrow based genetic background (Shiri *et al.*, 2014; Yao *et al.*, 2007). The narrow based genetic background has always been coupled with genetic erosion and habitat alteration that resulted in an increased sensitivity to new pathogenic races as well as decreased resistance and tolerance to environmental extremes (Prasanna, 2010). Germplasm that is heterogeneous in nature and which are open pollinated have a wide range of adaptability to an extensive range of environmental variability (Rahman *et al.*, 2008). Maize landraces are reported to be genetically heterogeneous populations which have been selected by farmers for environmental adaptability (Aci *et al.*, 2013; Ignjatovic *et al.*, 2013).

They can also be used to explore for resistance and tolerance against biotic and abiotic environmental stress factors (Molin *et al.*, 2013). Salami *et al.* (2015) found significant morphological variation with Benin local and improved maize varieties on all traits with distinctive potential highlight on early maturity and sensitivity to maize streak virus. Traits such as plant growth, tassel characteristics and yield had a significant contribution to phenotypic variation between maize landraces that were assessed by Ristic *et al.* (2014). Significant amount of variability was observed by Rahman *et al.* (2008) from the morphological traits evaluated in maize population from Pakistan. Italian maize landraces has shown significant morphological variation on earliness, plant architecture traits, tassel, ear and kernel characteristics (Hartings *et al.*, 2008). Asare *et al.* (2016) concluded by suggesting that maize landraces presents a significant genetic diversity reserve of important morphological characteristics on phenology, plant growth, grain yield, and leaf photosynthesis that reflects farmer preferences and worth for maize crop improvement.

In Tanzania, Nestory and Reuben (2016) evaluated maize landraces from northern part of the country and obtained high traits variability that serve as an opportunity for enhancing genetic improvement to maize germplasm required by the community. On the other hand, Bucheyeki (2012) evaluated maize landraces from Tanzania and identified potential sources of northern leaf blight disease resistance. However, Tanzania still holds a vast majority of germplasm that remain marginally exploited and are of great importance for food, adaptability, resistance to pests and diseases as well as for quality attributes (Ngwediagi *et al.*, 2009).

The general decreasing trend in maize production and yield in Tanzania is caused by recurrent abiotic and biotic stresses (Bucheyeki, 2012) and recently Tanzania and east Africa in general has been hit by another new deadly disease called Maize Lethal Necrosis disease (Kabululu *et al.*, 2017., Kiruwa *et al.*, 2016., Wangai *et al.*, 2012). Thus detailed characterization of landraces and other germplasm is required to establish a gene pool for crop improvement (Drinic *et al.*, 2012; Obeng-Antwi, 2012; Saad and Rao, 2001). The objective of this study was therefore to evaluate the genetic diversity of maize accessions from Tanzania through morphological characterization in order to establish the existing genetic diversity worth for maize crop improvement.

Materials and methods

Seed materials

The 68 accessions used in this study included 50 landraces collected in Tanzania, seven improved commercial varieties in Tanzania and eleven elite lines from CIMMYT, Nairobi, Kenya (Table 1). Seeds of the 50 landraces of maize were obtained from the National Plant Genetic Resources Centre (NPGRC) in Arusha, Tanzania and had been collected from different parts of the country (Fig. 1). The sampling of the collected maize accessions was done considering a wide distribution over the country. Also seven improved commercial maize varieties were obtained from the agro-input shops in Arusha and CIMMYT inbred lines were sourced from CIMMYT, Nairobi, Kenya.

Both improved commercial maize varieties and CIMMYT inbred lines were used in this study as checks.

Table 1. List of maize accessions and their source as used in the genetic diversity evaluation study in Tanzania.

SNo.	Accession	Source	SNo.	Accession	Source
1	CKDHL0500	CIMMYT	35	TZA3171	Kigoma
2	CKDHL120552	CIMMYT	36	TZA3181	Kigoma
3	CKSBL10205	CIMMYT	37	TZA3206	Tabora
4	CLRCY034-B	CIMMYT	38	TZA3310	Tabora
5	CLRCY039	CIMMYT	39	TZA3536	Morogoro
6	CLYN261	CIMMYT	40	TZA3544	Morogoro
7	CML440	CIMMYT	41	TZA3585	Mtwara
8	CML442	CIMMYT	42	TZA3614	Mtwara
9	CML443	CIMMYT	43	TZA3837	Mtwara
10	CML544	CIMMYT	44	TZA3914	Mara
11	DEKALB (DK8031)	Commercial Variety	45	TZA3926	Mara
12	DH04	Commercial Variety	46	TZA3958	Mara
13	PIONEER (Phb 3253)	Commercial Variety	47	TZA3971	Mara
14	SC403	Commercial Variety	48	TZA4020	Mwanza
15	SITUKA1	Commercial Variety	49	TZA4164	Kagera
16	SITUKAM1	Commercial Variety	50	TZA4203	Mwanza
17	TMV-1	Commercial Variety	51	TZA4320	Kagera
18	TZA163	Mtwara	52	TZA4351	Kagera
19	TZA1723	Njombe	53	TZA4574	Mwanza
20	TZA1724	Njombe	54	TZA4667	Mwanza
21	TZA1745	Njombe	55	TZA5102	Tanga
22	TZA1753	Mbeya	56	TZA5129	Tanga
23	TZA1757	Mbeya	57	TZA5138	Tanga
24	TZA212	Mbeya	58	TZA5162	Tanga
25	TZA2263	Lindi	59	TZA5169	Tanga
26	TZA2264	Lindi	60	TZA5170	Tanga
27	TZA2330	Lindi	61	TZA5200	Tanga
28	TZA2338	Mtwara	62	TZA5205	Tanga
29	TZA2731	Morogoro	63	TZA5618	Manyara
30	TZA2793	Morogoro	64	TZA5619	Manyara
31	TZA2813	Tanga	65	TZA599	Singida
32	TZA2843	Tanga	66	TZA608	Singida
33	TZA2904	Ruvuma	67	TZA93	Rukwa
34	TZA3167	Kigoma	68	TZMI730	CIMMYT

Field location and experimental design

Morphological characterization experiment was laid out in a randomized complete block design with three replications. The experiment was conducted in three locations in Arusha region as follows; Mlangarini at S 03°26' 12", E 036°47' 13.4" with elevation of 1128 meters above sea level; Tengeru at S 03°22' 30.2", E 036°48' 30.2" with elevation of 1237 meters above sea level;, and Selian at S 03°21' 31.4", E 036°37' 51.9" with elevation of 1415 meters above sea level. Maize accessions were planted in rows per each plot at spacing of 75 cm between rows and 30 cm within rows. Each row had 4 meters length and with an approximation of 44, 444 plants population per hectare. The seeds were planted during rainy season in 2015 where irrigation was applied whenever necessary to provide as optimum growing condition as possible. Two seeds were planted per hill followed by thinning to one plant per hill in two weeks after sowing. At planting.

NPK (40:20:20) was applied at a rate of 100kg N per hectare and top dressing with Urea (46%) were applied later at a rate of 100kg N per hectare. Data collection generally included: vegetative, ear and kernel characteristics (Table 2). The data were collected according to the descriptor list by IBPGR (1991).

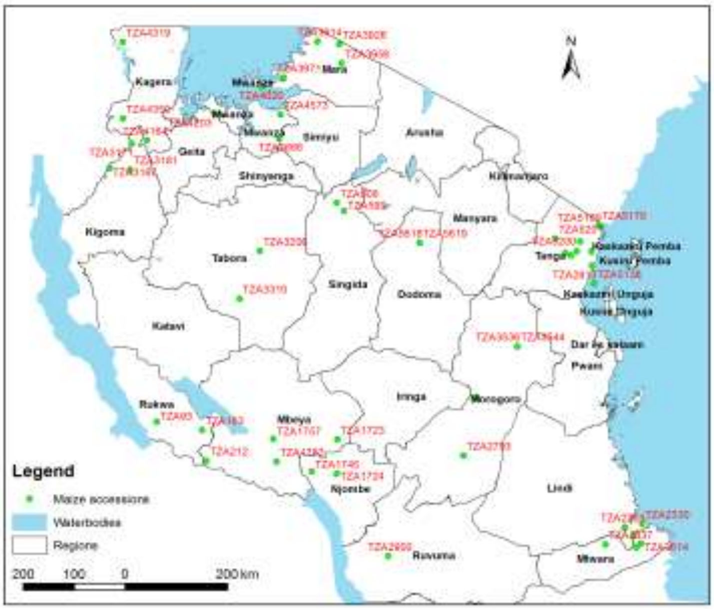

Fig. 1. Map of Tanzania showing the collection sites of the 50 maize landraces

Table 2. Some of the descriptors that were used to evaluate genetic diversity through morphological characterization (IBPGR, 1991).

ITEM		DATA COLLECTION PROCEDURE
Vegetative	Abbreviation	
Days to tasseling	D50T	Number of days from sowing to when 50% plants shed pollen
Days to silking	D50S	Number of days from sowing to 50% plants with silks
Anthesis-Silking Interval	ASI	Difference between days to silking and anthesis stages
Plant height (cm)	PH	Ground level to the base of the tassel. After milk stage
Ear height (cm)	EH	Ground to the node at the uppermost ear. After milk stage
Foliage	FG	Rating of total leaf surface. After milk stage, on 20 plants
Number of leaves above the uppermost ear	NLAUME	Counted on at least 20 plants. After milk stage
Stem colour	SC	Observed between the two topmost ears. At flowering
Sheath pubescence	SP	The hairy condition of leaf base encasing the stem of a plant
Leaf length	LL	From ligule to apex of the uppermost ear leaf. After flowering
Leaf width (cm)	LW	Mid-way along its length. Measured on the same leaf
Ear data Ear length (cm)	EL	Measured from the base to the tip of the uppermost ear
Ear diameter (cm)	ED	Measured at the central part of the uppermost ear
Kernel row arrangement	KRA	Pattern and arrangement of rows of the uppermost ear
Number of kernel rows	NKR	Counting kernel rows in the central part of the uppermost ear
Cob diameter (cm)	CD	Mid-way of cob length
Rachis diameter (cm)	RD	Diameter of the inner part of the cob
Number of kernels per row	NK_R	Count number of kernel in a single row of the uppermost ear
Cob colour	CC	Rating colours of the cobs
Shape of uppermost ear	SOUME	Determining the shape through observation
Kernel data		
Kernel type	KT	Indicate up to three kernel types in the order of frequency
Kernel colour	KC	Indicate up to three kernel colours in the order of frequency
1000 kernel weight (g)	1000KW	Adjusted to 10% moisture content
Kernel length (mm)	KL	Average of 10 kernels from the row in the middle
Kernel width (mm)	KW	Measured on the same 10 kernels
Kernel thickness (mm)	KTH	Measured on the same 10 kernels
Shape of upper surface of kernel	SOUSOK	Determining the shape through observation
Endosperm colour	EC	Colour of the tissue inside the seeds
Yield per plant (g)	Y_P	Grain yield per plant in grams

Data analysis

Descriptive statistics on means, minimum, maximum, standard errors and coefficient of variation using STATISTICA 8.0 were obtained for quantitative traits while one-way analysis of variance (ANOVA) was applied for significance test on morphological differences among maize accessions. Box and whisker plot was also used to show variability within quantitative characters. Cluster analysis was performed based on average linkage method through Genstat discovery edition 4 to generate similarity and dissimilarity accessions and eventually comparing between groups of accessions clustered together. Principle component analysis was done to identify traits with significant contribution to the overall variation within each principle component.

Results

Variability in quantitative characters

The descriptive statistics and analysis of variance of the 19 quantitative traits revealed a significant ($p<0.05$) variation of all the traits among landraces (Table 3). Significant variations were observed in commercial varieties as well except for leaf width, cob diameter, rachis diameter, kernel width, kernel thickness and yield per plant. The CIMMYT elite lines had also the significant traits variability except for only ear diameter and cob diameter. Significant coefficient of variation was observed with anthesis-silking interval as well as with yield per plant.

The box and Whisker plot farther displayed the performance and variability among the groups of maize accessions, where the overall grain yield per plant was higher with commercial varieties, but high variability is seen with landraces portrayed by the range of non-outliers values (Fig. 2A). This was also observed with the weight of a thousand seed weight (Fig. 2B) where commercial varieties generated heavier seeds than other groups, but also the variability of this trait in landraces is more than other groups. Landraces showed high variation in number of kernel rows per ear while commercial varieties exhibited higher variability for number of kernels per row than other groups (Fig. 2D and E). For flowering behaviour, commercial varieties flowered earlier as compared with other groups which had almost the same median value. Landraces showed high variation in flowering as well as for plant height when compared with other groups (Fig. 2C and F).

Table 3. Mean with standard errors, minimum and maximum (range), and coefficient of variation of the 19 quantitative morphological descriptors generated from the performance of the three groups of accessions.

	Landraces			Commercial varieties			CIMMYT lines		
[a]Descriptor	Mean ± SE	Range	CV	Mean ± SE	Range	CV	Mean ± SE	Range	CV
D50T	80.2±0.4***	61.0-94.7	6.6	67.7±0.9***	62.3-75.0	6.0	80.6±0.9***	70.0-91.7	6.5
D50S	87.7±0.5***	74.0-108.3	7.4	73±0.7***	69.0-79.7	4.5	84.6±0.9***	73.7-94.3	6.2
ASI	7.5±0.2***	2.0-15.7	32.7	5.3±0.4***	2.0-7.7	32.5	4.0±0.4***	0.3-8	52.7
NLAUME	6.5±0.0***	5.6-7.7	5.4	6.7±0.1***	6.1-7.1	4.5	6.6±0.1***	5.2-7.6	10.3
PH (cm)	205.4±1.8***	162.1-275.0	11.0	211.8±3.4***	187.3-239.1	7.3	138.9±3.6***	96.6-172.9	15.0
EH (cm)	95.9±1.4***	59.6-156.8	18.1	78.7±2.4***	61.9-100.2	14.1	50.6±1.6***	29.8-65.6	18.7
LL (cm)	80.1±0.4***	69.2-95.7	6.2	83.2±0.8***	74.2-90.2	4.7	70.7±1.3***	59.1-85.5	10.8
LW (cm)	9.1±0.1***	7.5-12.0	7.5	9.7±0.1^{ns}	9.1-11.1	5.3	8.7±0.2***	7.0-11	12.4
EL (cm)	14.6±0.1***	10.9-18.4	8.8	16.4±0.2***	15.1-18.2	4.5	12.7±0.3***	9.4-20	15.4
ED (cm)	4.8±0.0***	3.6-6.2	9.1	5.2±0.1***	4.3-6.1	7.4	4.4±0.1^{ns}	3.3-5.4	12.9
CD (cm)	3.0±0.0***	2.3-4.0	10.6	3.1±0.1^{ns}	2.8-3.8	8.1	2.8±0.1^{ns}	2.3-3.6	10.6
RD (cm)	1.6±0.0***	1.2-3.6	14.5	1.6±0.0^{ns}	1.5-1.8	4.4	1.4±0.0***	1.1-1.7	11.8
NK_R	24.7±0.3***	12.6-33.3	15.1	32.6±0.4***	29.6-37	6.3	19.1±0.5***	14.2-26.5	14.6
NKR	12.0±0.1***	9.1-14.7	9.0	13.1±0.1***	12.3-14.8	5.2	12.6±0.2***	9.0-14.8	9.0
KL (cm)	1.0±0.0***	0.8-1.2	6.7	1.1±0.0***	1.0-1.3	6.3	0.9±0.0***	0.7-1.1	11.3
KW (cm)	1.0±0.0***	0.8-1.4	7.4	1±0.0^{ns}	0.9-1.2	6.6	0.8±0.0***	0.7-0.9	5.5
KTH (cm)	0.5±0.0***	0.4-0.9	12.8	0.5±0.0^{ns}	0.4-0.5	4.8	0.6±0.0***	0.5-0.8	11.1
1000KW (g)	256.2±2.7***	160.0-340.0	12.9	281.8±6.5***	237-334.4	10.5	199.1±4.4***	148.2-257.3	12.6
Y/_P (g)	60.6±1.7***	9.8-133.7	34.3	107.4±4.8^{ns}	50.1-136.6	20.4	45.2±3.0***	11.5-85.9	38.4

[a] abbreviation of the descriptors are defined and explained in Table 2

***stands for significant difference at $P<0.05$

^{ns} not significant different

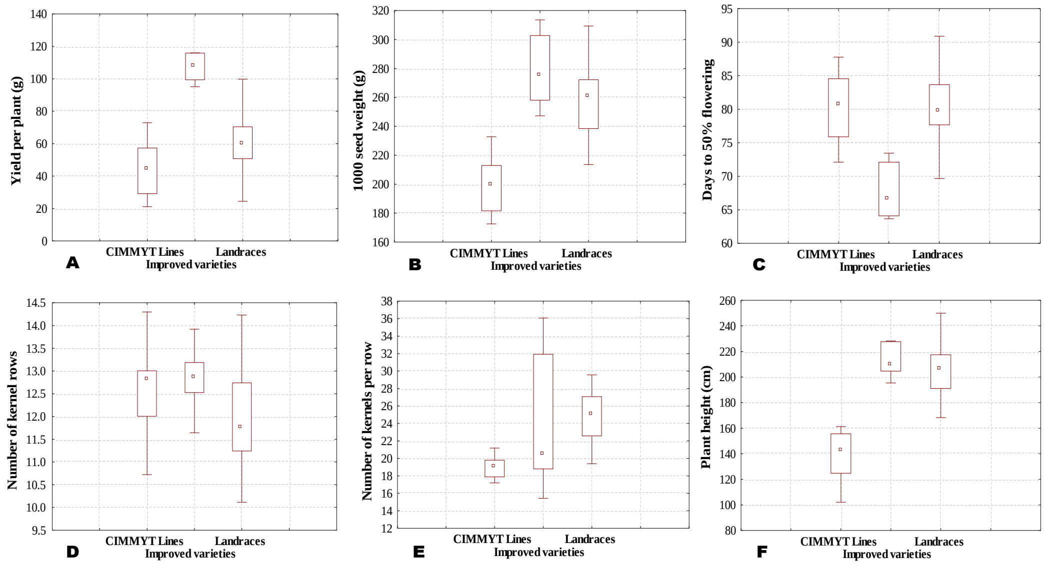

Fig. 2. Box plots displaying variability in morphological descriptors given by the three different groups of CIMMYT inbred lines, commercial/Improved varieties and landraces from Tanzania. Small empty boxes inside big boxes represent median, big vertical boxes show a range of values falling between 25% and 75% and the vertical lines cover the range of non-outliers.

Qualitative characters

The qualitative data of the 68 accessions observed into three groups showed landraces to be more diverse as compared with the commercial varieties and CIMMYT lines (Table 4). That means landraces had the accessions distributed in classes of all the 12 qualitative traits while for the other groups the accessions distribution was not in all classes of each trait. The percentage distribution of accessions at each trait differentiated the three groups of accessions in terms of foliage (rating of total leaf surface), where landraces were mostly characterized as intermediate (44.9%), commercial varieties were large (63.5%) while CIMMYT lines were small (70.7%). With regard to tassel size, landraces and commercial varieties were medium with 48.4% and 49.2% respectively, while CIMMYT lines were small with 70.7%. On shape of upper surface of kernel, landraces and CIMMYT lines were characterized as rounded with 71.8% and 49.5% respectively while commercial varieties were mostly shrunken with 41.3%. The kernel type characterized landraces and commercial varieties to be dent with 55.8% and 54.0% respectively while CIMMYT lines were mostly semi-flint with 41.4%.

The rest of traits characterized the groups similar though with different percent accessions distribution, that is stem colour as all green, sheath pubescence as intermediate, tassel type as primary-secondary, cob colour as white, upper most ear shape as conical, kernel row arrangement as regular, kernel and endosperm colour as white.

Table 4. The 12 qualitative morphological descriptors with their percentage (%) frequency accessions distribution as generated from the performance of three different groups within 68 maize accessions used in this study.

Morphological descriptor	Class	Landraces	Commercial Varieties	CIMMYT Lines
1. Stem colour	Green	95.1	100.0	100.0
	Purple	4.9	0.0	0.0
2. Sheath pubescence	Sparse	1.1	4.8	3.0
	Intermediate	94.2	85.7	82.8
	Dense	4.7	9.5	14.1
3. Foliage	Small	18.7	12.7	70.7
	Intermediate	44.9	23.8	26.3
	Large	36.4	63.5	3.0
4. Tassel type	Primary	3.6	0.0	23.2
	Primary-secondary	96.4	100.0	76.8
5. Tassel size	Small	4.4	6.3	70.7
	Medium	48.4	49.2	25.3
	Large	47.1	44.4	4.0

Morphological descriptor	Class	Landraces	Commercial Varieties	CIMMYT Lines
6. Cob colour	White	96.0	100.0	100.0
	Red	3.3	0.0	0.0
	Purple	0.7	0.0	0.0
7. Uppermost ear shape	Cylindrical	0.7	0.0	3.0
	Cylindrical-conical	6.2	0.0	17.2
	Conical	93.1	100.0	79.8
8. Kernel upper surface shape	Shrunken	3.3	41.3	9.1
	Indented	23.1	33.3	12.1
	Level	1.3	0.0	26.3
	Rounded	71.8	25.4	49.5
	Pointed	0.4	0.0	3.0
9. Kernel row arrangement	Regular	94.7	71.4	89.9
	Irregular	4.0	0.0	10.1
	Straight	1.3	28.6	0.0
10. Kernel type	Semi-floury	5.8	20.6	7.1
	Dent	55.8	54.0	28.3
	Semi-dent	32.9	14.3	19.2
	Semi-flint	5.5	11.1	41.4
	Flint	0.0	0.0	4.0
11. Kernel colour	White	84.4	100.0	67.7
	Yellow	9.3	0.0	28.3
	Purple	0.4	0.0	0.0
	Variegated	2.7	0.0	2.0
	White cap	1.3	0.0	2.0
	Red	1.8	0.0	0.0
12. Endosperm colour	White	94.4	100.0	78.8
	Pale yellow	0.4	0.0	0.0
	Yellow	4.7	0.0	21.2
	White cap	0.4	0.0	0.0

Principal components analysis (PCA)

The analysis of principal components for the 25 morphological traits are shown in Table 5. The first six components expressed 78.36% of the total variation and each had an eigenvalue of more than one. The first principal component (PC1) in particular accounted for 33.36% of the total morphological variation given by the studied traits. Morphological traits that highly contributed to the PC1 include leaf length, ear length, ear diameter, number of kernels per row, kernel length, 1000 kernel weight, and yield per plant. Principal component two (PC2) accounted for 17.91% of the total variation and was highly influenced by days to 50% tasseling and silking, anthesis silking interval, plant height, ear height, kernel width and thickness. Morphological traits that had high contributions to Principal component three (PC3), which accounted for 8.51% variations, were number of leaves above uppermost ear, cob diameter, rachis diameter and number of kernel rows. The fourth component (PC4) was influenced by shape of uppermost ear, kernel colour, leaf width and had 7.94% of the total variation. The fifth component had variability contribution of 5.76% as caused by kernel row arrangement and endosperm colour. The sixth component contributed 4.89% variation given by shape of upper surface of kernel and kernel type. The PCA further characterized the three groups of accessions differently with specific traits discriminating them on a plotted plane (Fig. 3). The commercial varieties were grouped on the upper left hand side quadrant, CIMMYT lines grouped themselves on the upper right hand side quadrant. Landraces were mostly scattered along the origin of the plane and to all the quadrants.

Table 5. Proportions of variability contributions given by the 25 morphological traits in different principle components.

Trait	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6
Days to 50% tasseling	0.177	-0.299	0.282	0.020	0.159	-0.162
Days to 50% silking	0.149	-0.369	0.220	-0.007	0.113	-0.161
Anthesis Silking Interval	-0.003	-0.374	-0.059	-0.079	-0.072	-0.079
Shape of uppermost ear	-0.042	-0.092	-0.107	0.478	-0.421	-0.040
Shape of upper surface of kernel	0.180	-0.169	-0.057	-0.124	-0.166	0.325
Kernel row arrangement	-0.068	0.116	-0.071	-0.287	0.478	-0.202
Kernel type	0.177	0.054	0.201	0.091	-0.067	0.508

Kernel colour	0.029	0.067	-0.212	0.278	0.220	0.172
Endosperm colour	0.088	0.062	0.064	0.359	0.407	0.378
Number of leaves above uppermost ear	-0.003	0.062	0.401	0.309	-0.315	-0.194
Plant height (cm)	-0.247	-0.286	0.033	0.110	0.045	-0.027
Ear height (cm)	-0.156	-0.378	0.059	0.020	0.074	-0.092
Leaf length (cm)	-0.231	-0.177	0.173	0.193	0.215	-0.076
Leaf width (cm)	-0.184	0.003	0.117	0.393	0.259	-0.047
Ear length (cm)	-0.270	-0.095	-0.185	0.033	0.113	0.189
Ear diameter (cm)	-0.324	-0.006	0.149	-0.094	-0.049	0.050
Cob diameter (cm)	-0.258	-0.027	0.312	-0.186	-0.077	0.184
Rachis diameter (cm)	-0.179	-0.028	0.370	-0.247	-0.082	0.324
Number of kernels per row	-0.307	0.104	-0.100	0.057	-0.037	0.007
Number of kernel rows	-0.099	0.281	0.416	-0.070	0.093	0.000
Kernel length (cm)	-0.320	0.026	-0.100	-0.043	-0.064	-0.117
Kernel width (cm)	-0.198	-0.277	-0.183	-0.033	-0.094	0.193
Kernel thickness (cm)	0.164	-0.313	-0.001	0.009	0.171	0.197
1000 Kernel weight (g)	-0.262	-0.100	-0.180	-0.115	-0.054	0.201
Yield per plant (g)	-0.279	0.166	-0.014	0.152	0.055	0.005
Eigenvalues	8.34	4.48	2.13	1.99	1.44	1.22
Total variance (%)	33.36	17.91	8.51	7.94	5.76	4.89
Cumulative total variance (%)	33.36	51.27	59.77	67.71	73.47	78.36

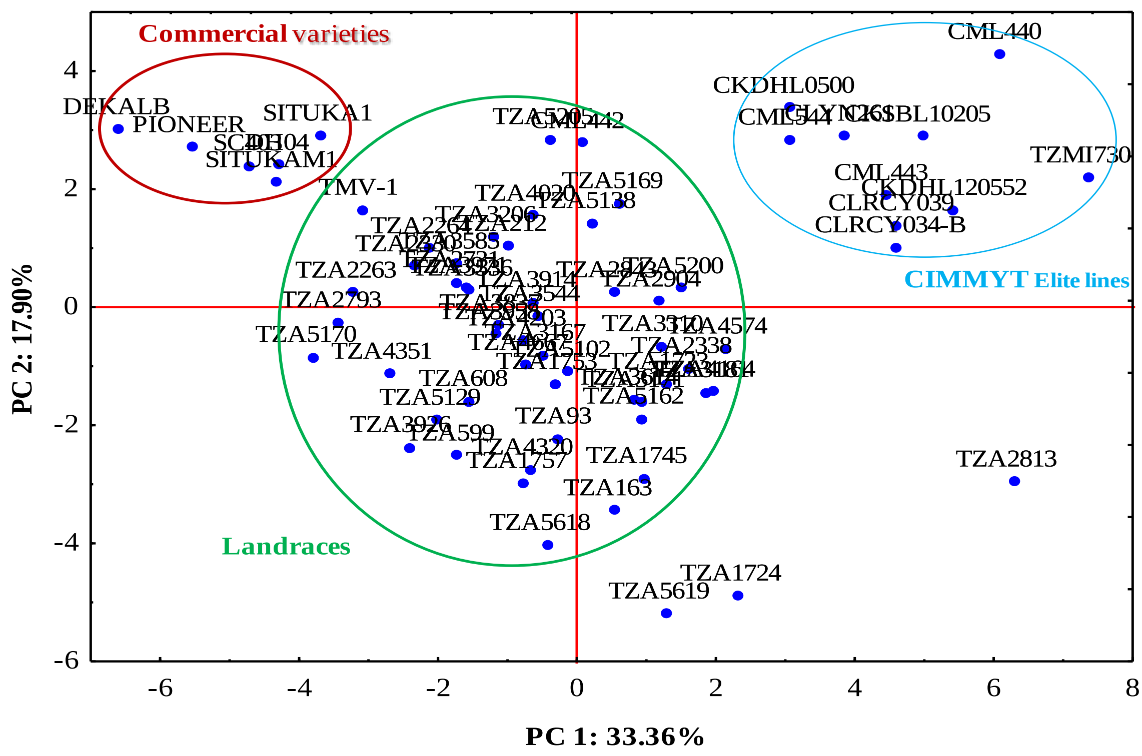

Fig. 3. Principle component analysis distributing the 68 accessions into the first two components as performed through 25 morphological traits.

Cluster analysis

The dendogram of the 68 maize accessions evaluated based on average linkage analysis is presented in Fig. 4. The combined analysis was generated from the 19 quantitative and 12 qualitative traits. The dendogram clustered the accessions into four different groups following their similarity and dissimilarity distances.

Cluster I was comprised of all the seven commercial varieties and two landraces (TZA 2793 and TZA 5170), cluster II had one CIMMYT line (CML 442) and two landraces (TZA 3206 and TZA 5169), cluster.

III grouped the rest of 46 landraces while 10 CIMMYT lines were grouped into cluster IV.

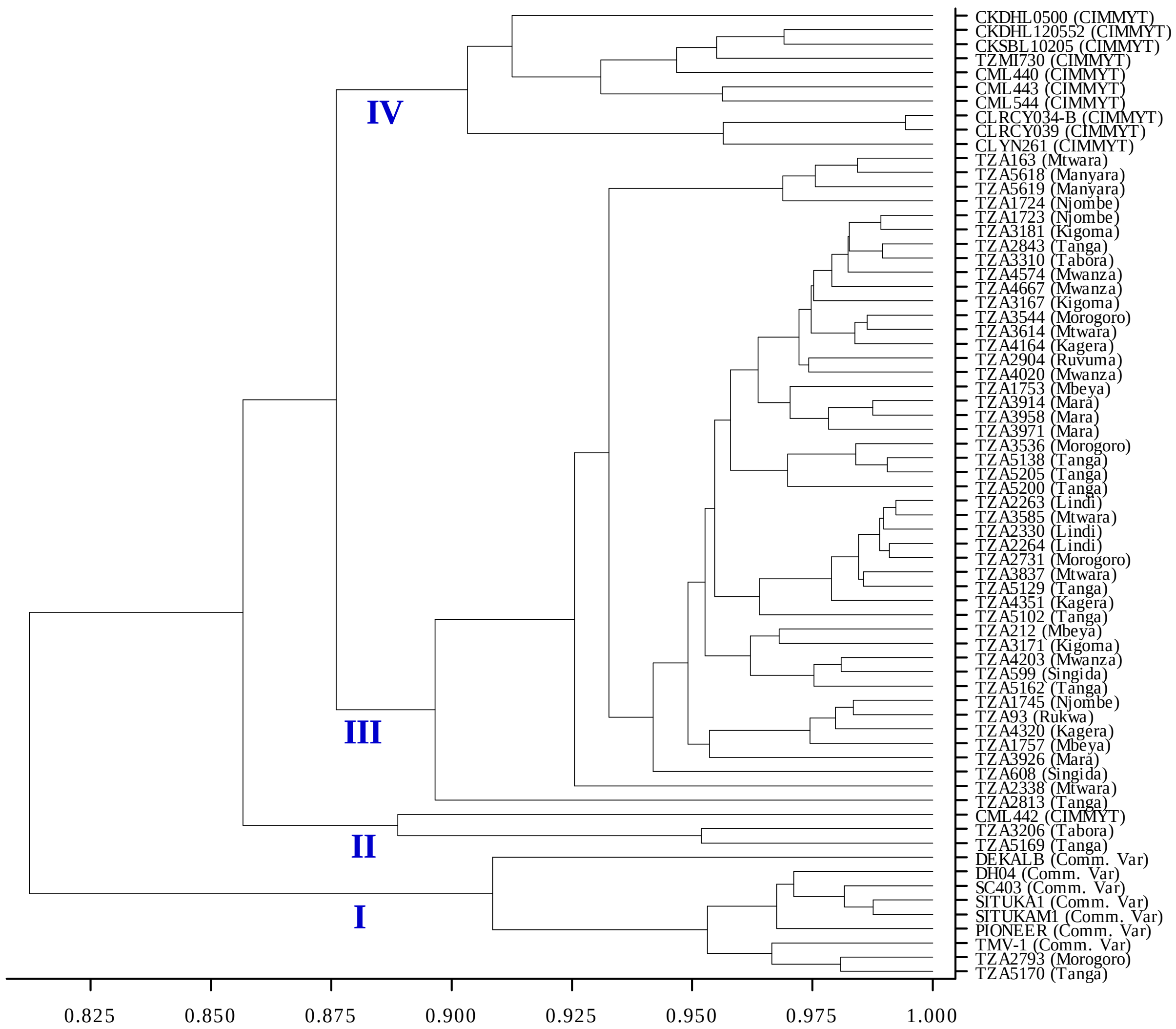

Fig. 4. Dendrogram for cluster analyses based on Euclidean genetic distance with average linkage of the 25 morphological characters generated from the performance of 68 maize accessions. Words in brackets show the source of seeds/collection site.

Discussion

Quantitative morphological traits

Maize is reported to be among the crops with high genetic diversity in terms of morphological as well as genetic variability (Hartings *et al.,* 2008). The maize accessions involved in this study had as well expressed a huge amount of variability in terms of quantitative characteristics. In this study, landraces were found to be more variable than commercial varieties and the CIMMYT lines. Significant coefficient of variation among all evaluated traits in this study includes anthesis-silking interval and yield per plant. This was also observed by Sharma *et al.* (2010) that significant genetic variation among maize landrace populations were found through yield related traits and flowering characteristics.

The flowering behaviour might define the maturity differences among accessions (Olaoye, 2009) and they can also be connected to the yielding ability that early maturing accessions could generate high grain yield while those which are late maturing produce low yield (Lafitte *et al.,* 1997). A wide range of variation in flowering behaviours could signify the potential variability within accessions that would help on developing genotypes adaptable to different areas with different characteristics (Cömertpay, 2012). The existence of wide variability among the 68 accessions evaluated were further strengthened by box plot and Whisker, where landraces had more variability as compared with other groups despite its general low yield and other related parameters.

Moreover, the principal component analysis identified quantitative morphological traits in different components that highly contributed to the total variation expressed by the accessions under study. The traits include 1000 kernel weight, plant height, ear height, yield per plant and days to 50% silking. That means, traits with high values in principle components present the potential characteristics for discriminating and identifying important accessions. The traits could also be used to characterize several maize landrace populations and discover potential candidates as parents for generating elite materials. Moreover, the principal component analysis expressed the distinction of the three groups of accessions used in this study with the traits contributing to their discriminating behaviours. Commercial varieties were discriminately identified by high yield, a thousand seed weight, number of rows per ear, ear diameter, ear length and early days to tasseling and silking. CIMMYT elite lines were characterized by significant low plant and ear height. Landraces were scattered along all quadrants in a PCA plane, which signify them to be more diverse than the rest of the accessions involved in this study.

Qualitative morphological traits

The qualitative traits observed in this study explained distribution of accessions within each trait which differ among landraces, commercial varieties and CIMMYT lines. Only landraces had accessions distributed in each trait and not for commercial varieties and CIMMYT lines. The frequency distribution in percentage of accessions within traits differentiated the three groups in terms of foliage, tassel size, shape of upper surface of kernel and kernel type. Other traits of stem colour, sheath pubescence, tassel type, cob colour, shape of upper most ear, kernel row arrangement, kernel colour and endosperm colour characterized the three groups similar though with different percent distribution. The former traits were able to discriminate between and within the three groups while the later identified differences just within each group. Traits that had higher percentage distribution of accessions towards one class within a trait include stem colour (green), sheath pubescence (intermediate), tassel type (primary-secondary), cob colour (white), shape of uppermost ear (conical), shape of kernel upper surface (rounded), kernel row arrangement (regular), kernel colour (white) and endosperm colour (white). The defined trait classes with high percentage accessions distribution might reflect farmers' preferences through successive selection (Ntundu *et al.,* 2006; Louette and Smale, 2000). In addition to the influence of farmers in shaping the structure of maize population, other factors such as species biology, geographical positioning, climatic settings, agricultural systems biodiversity and local traditions also have impact on population structuring. (Prasanna, 2010; Pressoir and Berthaud, 2004).

Cluster analysis

The clustering indicated that the groups of accessions (landraces, commercial varieties and CIMMYT lines) were quite different from each other, though admixtures were observed. The grouping of the accessions mostly reflected individual performance and type of accessions. The commercial varieties and the two landraces in Cluster I were characteristically isolated due to distinct performance in high yield per plant, 1000 seed weight, number of kernels per row, leaf length, plant height and low number of days to 50% tasseling and silking (Table 3). On the other hand, landraces were more diverse in performance especially those that were grouped in cluster III. They had no specific unique behaviour except for ear height and the lengthy anthesis-silking interval which explain how variable they are in terms of flowering time. CIMMYT elite lines in cluster IV had unique characteristics of low yield per plant, small plant sizes, mostly semi flint kernel type and long days to tasseling (Table 3). The mixed cluster II with one CIMMYT line and two landraces occurred due to the very unique characteristics that isolated them from the specific groups they were supposed to be. For example, CML 442 had a very high grain yield per plant as compared with the rest of CIMMYT lines. It also had intermediate sheath pubescence as compared with sparse pubescence that the rest of CIMMYT lines had (data not shown).

On the other hand, TZA 5169 had the red kernel and cob colour, while TZA 3206 had yellow kernel colour and purplish cob colour different from the rest of the landraces (data not shown). The big cluster III of 46 landraces lack consistent originality grouping in terms of collection sites (Fig. 4). This was related to the finding by Sun *et al.* (2016) who observed geographically close populations of Chinese sweetgum in different clusters. The implication obtained in the current study is that the landraces involved are comprised of a heterogeneous group that would have occurred through repeated exchange and selection of germplasm executed by farmers.

The results of exchange and selection create the occurrence of irregular pattern of clustering (Ntundu *et al.,* 2006). Other reports also relate heterogeneity groupings with socio-economic factors, cultural, biological (open pollination) and migration of maize germplasm from one region to another (Hartings *et al.,* 2008; N'Da *et al.,* 2015; Cömertpay *et al.,* 2012).

The findings by Ashimogo and Rukulantile (2000) explain that 35.4% of farmers in three regions they studied in Tanzania use maize seeds they acquired from their neighbours and 60.1% grow their own saved seeds. Furthermore, the clustering displayed some unique placement of accessions collected from Tanga to different clusters. Accession TZA 5170 from Tanga together with accession TZA 2793 from Morogoro were found in cluster I along with commercial varieties, also accession TZA 5169 from Tanga was grouped with other unique accession of TZA 3206 from Tabora region and CIMMYT line CML 442 in cluster II. In a mixed cluster III accessions TZA 2813, TZA 5162, TZA 5102 and TZA 5200 from Tanga isolated themselves and exerts higher distances (dissimilarities) with other accessions. This suggest the source of high variation from Tanga region.

Conclusion

The results in this study have revealed a significant range of genetic diversity in the 68 maize accessions evaluated. This might provide a source of variation required for breeding programs to hold back the genetic vulnerability raised through the recurrent outbreak of new strains of pest and diseases. It also offers an opportunity to widen the genetic background of the available maize germplasm because the materials that are currently at disposal for several breeding programs are composed of narrow genetic base. The traits that expressed high contribution towards total variability across the three groups of maize accessions used in this study include quantitative characteristics such as a thousand kernel weight, plant height, ear height and yield per plant.

The qualitative traits that had a significant contribution include foliage, tassel size, shape of upper surface of kernel and kernel type. All these traits might serve the purposes of generally discriminating among several populations through morphological characterization. However, each group was characterized specifically from other groups with specific traits and might as well signify the potentials expressed by each group. Cluster analysis identified the potential of landraces towards contributing a wealth of genetic resource for future breeding. Two landraces, TZA 2793 and TZA 5170, were grouped together with commercial varieties. The rest of the landraces possessed a wide range of variability in different traits that form a significant gene pool. That means the accessions might have strong contributions for producing superior varieties when used for introgression of promising traits. The cluster analysis also disclosed the expression of landraces lacking regular pattern in clustering within their major group.

This elucidate the fact that farmers select cultivars based on their preferences and also exchange seed crop materials with fellow farmers even from very distant regions. Farmers play a significant role in shaping the structure of landrace population existing in a certain area. This calls for systematic involvement of farmers in breeding and selection process through participatory breeding in order to have an organized process of population structuring.

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