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Full Length Research Paper

Diversity of maize landraces collected at farm level in Northern Tanzania

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Crop genetic diversity is the basic key for combating agricultural production challenges resources found in farming communities for genetic improvement and productivity. In this research, 15 maize landraces were evaluated based on morphological traits in a Randomized Complete Block Design with three replications at Selian Agricultural Research Institute during the growing season of 2014/2015. Quantification of variability was done using Shannon-Weaver Diversity Index further subjected to Principle Component Analysis and Cluster Analysis. The results on quantitative and qualitative data indicated high variability of traits with diversity value of 0.99 by Shannon Weaver Diversity Index. Results of Principle Components Analysis showed that 19 variables were reduced and grouped into six principle components of fourteen with eigen values greater than 1. Six principle components were produced and these principle components had cumulative explained variances of 84.23%. The first principle component accounted for 29.40% of the total variation, while principle components two and three accounted for 44.20% and 57.20% respectively. Three clusters were observed with seven maize landraces on the first cluster, five maize landraces were displayed on the second cluster and three maize landraces were displayed on the last cluster. The diversity evident from the quantitative and qualitative traits suggests that there is opportunity for genetic improvement in breeding programs for hybrid development through selection.

Key words: Crop, clusters, genetic, diversity, landraces, component.

INTRODUCTION

Maize (*Zea mays* L.) is a member of the family Graminae (Poaceae) considered as the grass family. Its key importance is based on uses as human food, animal feed and a raw material for various agro-based industries throughout the world (Kapoor and Chinka, 2015). Maize landraces are considered to be a valuable resource and because of their high genetic diversity, they are most connected to the traditional agricultural practices. Preservation of the landraces and traditional agricultural practices is interconnected (Jelena, 2009).

Maize is a staple food in the Eastern African region and in most developing countries especially in tropical and sub tropical regions as reported by Siopongco et al. (1999). It is the major and most preferred staple food and cash crop in Tanzania and popularity of maize is evidenced by the fact that it is grown in all the agro-ecological zones in the country (Rates, 2003). Variation in soils, rainfall, temperature, crop diversity and other factors has made agriculture to be complex in most small scale farmers in the region and the whole world (Kirkby, 1973; Brush, 1980 as cited by Ndiso et al., 2013). However, crop diversity has assisted farmers to combat the challenges in absence of pesticides, though plant breeders develop inbred lines and identify parental combinations for superior hybrids (Semagn et al., 2012). It has been reported that the nature and extent of genetic diversity can be estimated with various techniques based on agronomical, morphological and physiological traits (Mustafa et al., 2015). Assessment of genetic diversity is important to maximize the uses of the collections. This study was done to analyze the diversity maize landraces at farm level, especially to determine the genetic variation with the hope that the information will be used for breeding programs.

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MATERIALS AND METHODS

The experiment was conducted during the 2014/2015 cropping season at Selian Agricultural Research Institute in the Northern zone of Tanzania in Arusha, located at 10° 22'S and 40° 10'E and 1378 m above sea level.

Soil characteristic is silt loamy soil type, with declined soil fertility predominant across the sites.

Experimental design

Randomized Complete Block Design (RCBD) was used to carry out the study and treatments were arranged in three replications. Plots were of size 3 m × 3 m and each plot had 4 rows with 10 plants per row. Two seeds were sown in a hill and later thinned to one plant per hill. Rows were spaced 0.75 m apart and hills spaced at 0.3 m within a row. Fertilizer DAP (Diammonium Phosphate) were applied during planting at the rate of 30 kg P/ha. 60 kg N/ha (urea) was top dressed later at vegetative stage. Other management practices were done as recommended.

Materials

Fifteen maize landraces were used in this study. Landraces were collected from Arusha and Manyara regions from farmers' fields (Table 1).

Data collection

Data on variables were collected according to the protocol developed by IBPGRI (1991).

Days to 50% tasseling

Number of days was recorded by counting the duration from when seeds were planted to when half of the plants in each plot had tasseled.

Days to 50% silking

Number of days was recorded by counting the duration from when seeds were planted to when half of the plants in each plot had silked.

Plant height (cm)

Plant height was measured using 10 plants in a plot, from ground level to the point where the tassel of the plant started branching using a tape measure. The average measurement of 10 plants was recorded as plant height for the plot.

Ear height (cm)

Ear height was measured using 10 plants in a plot, from the ground level to the uppermost bearing ear. The average measurement of 10 plants was recorded as ear height for the plot.

Leaf length (cm)

Leaf length was assessed by measuring the length of a leaf, using a modified metric ruler from the ligule to apex of the leaf which subtends the uppermost ear, using 10 plants in a plot. The average measurement of 10 plants was recorded as leaf length of the plot.

Leaf width (cm)

Leaf width was assessed by measuring the width of a leaf, using a modified metric ruler from mid-way along its length for the leaf subtending the uppermost ear using 10 plants in a plot. The average measurement of 10 plants was recorded as leaf width.

100 seed weight (g)

100 seed weight was measured, using 5 groups of 100 seeds measured in each plot. The average measurement of 5 groups of 100 seeds was recorded as 100 seed weight of the plot.

Number of kernels per row

Number of kernels per row was recorded from 10 ears in a plot by counting the number of kernels per row. The average measurement of 10 ears was recorded as number of kernels per row in a plot.

Cob diameter (cm)

Cob diameter was measured using 10 ear cobs in a plot, by measuring the diameter of the uppermost ear cob. The average measurement of 10 ear cobs was recorded as ear cob diameter of the plot.

Ear diameter (cm)

Ear diameter from the central part of the uppermost ear was measured using 10 ears in a plot. The average measurement of 10 ears was recorded as ear diameter for the plot.

Ear length (cm)

Ear length was measured using 10 ears in a plot using a metric ruler from lower level to the top level of the ear. The average measurement of 10 ears was recorded as ear length of the plot.

Number of kernel rows

Number of kernel rows was recorded using 10 ears in a plot, by counting number of kernel rows in the central part

Table 1. Maize landraces used in this study.

S/N	Code	District	Village	Landraces name (Vernacular)	Meaning
1	DK-MB1	Mbulu	Bargish Uwa	-	-
2	LE-MB2	Mbulu	Bargish Uwa	-	-
3	AJ-MB3	Mbulu	Daudi	-	-
4	DA-MB4	Mbulu	Ants	-	-
5	MP-BB1	Babati	Bashnet	Kitombil	Early maturing
6	AJ-BB2	Babati	Endaw	Ikweto	Early maturing
7	BN-BB3	Babati	Gabadaw	Kitombil	Early maturing
8	MA-BB4	Babati	Endamanang	Ikweto	Our origin
9	DQ-BB5	Babati	Long	Erikwatoo	Our origin
10	JM-AR1	Arumeru	Olorien	-	-
11	DM-KR1	Karatu	Kilima Tembo	Mehhi	Coloured
12	PD-KR2	Karatu	Rhotia Kati	Mehhi	Coloured
13	AD-KR3	Karatu	Upper Kitete	Mehhi	Coloured
14	TD-KR4	Karatu	Slahhamo	Mehhi	Coloured
15	JL-KR5	Karatu	Kambi Ya Simba	Mehhi	Coloured

of the uppermost ear. The average measurement of 10 ears was recorded as number of kernel rows for the plot.

Number of tertiary branches on tassel

Number of tertiary branches on tassel was recorded using 10 plants in a plot by counting the number of tertiary branches of a tassel in each plant. The average measurement of 10 plants was recorded as number of tertiary branches on tassel.

Number of secondary branches on tassel

Number of secondary branches on tassel was counted using 10 plants in a plot, by counting the number of secondary branches of a tassel in each plant. The average measurement of 10 plants was recorded as number of secondary branches on tassel.

Number of primary branches on a tassel

Number of primary branches on a tassel was obtained from 10 plants in a plot, by counting the number of primary branches of a tassel in each plant. The average measurement of 10 plants was recorded as number of primary branches on tassel of the plot.

Tassel peduncle length (cm)

Tassel peduncle length, the length from the leaf sheath and tassel branch was measured in 10 plants in a plot using metric ruler. The average measurement of 10 plants was recorded as tassel peduncle length for the plot.

Tassel branching space (cm)

Tassel branching space, the distance between the point where tassel starts to branch to the end of the tassel branching was measured using 10 plants in a plot. The average measurement of 10 plants was recorded as plant tassel branching space for the plot.

Tassel length (cm)

Tassel length was measured with 10 plants in a plot using metric ruler from the tassel base where it starts to branch to the tip of the tassel. The average measurement of 10 plants was recorded as tassel length of the plot.

Grain yield (t/ha)

Grain yield was assessed, using two harvested rows in a plot after grain weight and moisture content was recorded using the formula in the following equation:

$$\text{Grain Yield}\left(\frac{t}{ha}\right) = \frac{10}{Pa}\ Pw\frac{(Sw - Cw)}{Sw}\frac{(100 - Sm)}{86}$$

where:

Pa = plot area (m^2), Pw = grain yield from a plot (kg), Sw = sample weight (kg), Cw = cob weight of ear samples (kg) and Sm = grain sample moisture at harvest (%).

Leaf orientation

Leaf orientation was assessed by rating the leaf orientation of the plants in each plot using 5 plants in a plot. The most occurred frequency number was recorded as leaf orientation of the plot where 1 is erect, and 2 is pendant.

Kernel type

Kernel type was assessed by observing the type of kernel of 5 plants in a plot of the uppermost ear. The kernel type that appeared the most was recorded as kernel type of the plot and rated as 1 - floury, 2 - semi-floury, 3 - dent, 4 - semi-dent, 5 - semi-flint, 6 - flint, 7 - pop, 8 - sweet, 9 - opaque, 10 - tunicate, and 11 - waxy.

Kernel colour

Kernel colour was assessed by observing colour of the kernels of 5 cobs in a plot of the uppermost ear. The kernel colour that appeared the most was recorded as kernel colour of the plot where 1 is white, 2 is yellow, 3 is purple, 4 is variegated, 5 is brown, 6 is orange, 7 is mottled, 8 is white cap, and 9 is red.

Kernel row arrangement

Kernel row arrangement was assessed by observing the kernel row arrangement of the uppermost ear of 5 plants in a plot. Kernel row arrangement shape of the ears that appeared most was recorded as the kernel row arrangement of the plot and rated as 1 if regular, 2 if irregular, 3 if straight, and 4 if spiral.

Husk cover

Husk cover was assessed by observing how good the ear leaves covered the cob of 5 plants in a plot, and rated as 3 if poor, 5 as intermediate, and 7 as good. The number that appeared most was recorded as husk cover of the topmost ear cob of the plot.

Stay green

Stay green was assessed in each plot at maturity by observing the plants that retained greenish colour and rated the intensity of greenish on 5 plants in a plot. The greenish retained was rated 3 if low, 5 as medium, and 7 as high. The number that appeared most was recorded as stay green of the accession.

Tassel type

Tassel type was assessed in each plot at milk stage by observing plant tassel arrangement of 5 plants and rated 1 as primary, 2 as primary-secondary, and 3 as primary-secondary-tertiary of 5 plants in a plot. The type which appeared the most was recorded as tassel type of the plot.

Statistical analysis

Data collected were subjected to analysis using the GenStat Discovery 15th edition computer software. Diversity studies were assessed by Shannon Weaver Diversity Index. XLstat software 2015 was used to study the pattern analysis for the relationship among landraces by cluster analysis. Dendograms were developed using the hierarchical agglomerical clustering method. Associations among landraces were identified by principle component analysis (PCA).

RESULTS AND DISCUSSION

Estimate of variation using Shannon-Weaver Diversity Index

The computed diversity indices for qualitative variables ranged from 0.95 to 0.99 for kernel row arrangement and husk cover respectively with mean diversity value of 0.98. Variation among the traits were leaf orientation (0.99), stay green (0.98), husk cover (0.99), kernel type (0.99), kernel colour (0.95), kernel row arrangement (0.95) and tassel type (0.98). Thus there was high degree of variation for the maize landraces collected. Estimation of variation of the collected maize landraces in the northern zone of Tanzania showed mean diversity index of 0.98 indicating existence of high variation within the collection. All of the quantitative characters exhibited high diversity value of 0.99. High diversity value ranged from number of tertiary branches on tassel (0.96) to 100 seed weight (0.99). High degree of variation exists within the collection for the quantitative character, as reflected by mean diversity value of 0.99 (Tables 2 and 3).

Results are different from those obtained by Siopongco et al. (1999) which was 0.54 in maize. Low diversity index obtained by Manyasa et al. (2009) was 0.32 in pigeon pea landraces. The contrasting findings could be due to differences in populations used. The variation in the current study in terms of both qualitative and quantitative characters is important in selection and crop improvement (Yoshida, 1981).

High diversity index obtained in this study could be explained by the population itself having distinct genes different among and between the landraces. Environment could have contributed to the expression of such diversity among and between the landraces collected. Conservation center for plant genetic resources could conserve this stock for further use in improvement work.

Results of cluster analysis

In this analysis, only three clusters were formed. The first cluster was identified with seven landraces (DK-MB1, DM-KR1, MA-BB4, DA-MB4, AJ-MB3, JL-KR5 and LE-MB2), the second cluster contained five landraces (DQ-BB5, PD-KR2, JM-AR1, AD-KR3 and AJ-BB2), and the third cluster was distinguished by three landraces (MP-BB1, TD-KR4 and BN-BB3) (Figure 1 and Table 4). Similar results were obtained by Khodarahmpour (2012) and Beyene et al. (2005) who found three clusters for maize. However Subramanian and Subbaraman (2010) and Ali et al. (2015) found four clusters in other studies of maize, possibly due to differential populations used. These results did not group the maize landraces

Table 2. Computed diversity indices (H) for qualitative characters.

Character	Diversity index (H)
Leaf orientation	0.98
Stay green	0.98
Husk cover	0.99
Ear damage	0.99
Kernel type	0.99
Kernel colour	0.95
Kernel row arrangement	0.95
Tassel type	0.98
Mean diversity index	**0.98**

Table 3. Computed diversity indices (H) for quantitative characters.

Character	Diversity index (H)
100 Seed weight	0.99
Grain yield	0.99
Tassel peduncle length	0.99
Tassel length	0.99
Tassel branching space	0.99
Plant height	0.99
Number of tertiary branches on tassel	0.96
Number of secondary branches on tassel	0.97
Number of primary branches on tassel	0.99
Number of kernel row	0.99
Number of kernel per row	0.99
Leaf width	0.99
Leaf length	0.99
Ear length	0.99
Ear height	0.99
Ear diameter	0.99
Days to tasseling	0.99
Days to silking	0.99
Cob diameter	0.99
Mean diversity index	**0.99**

according to the locations where maize landraces were collected implying that the Northern zone of Tanzania has distinct materials which exhibit differences from one another. However, group one was dominated with maize landraces collected from Mbulu districts. The second group displayed mixture of maize landraces, two of them from Karatu and Mbulu and one landrace from Arumeru district. The third group displayed distinct cluster with few landraces which can be further evaluated for specific traits, comprising two landraces from Babati and one from Karatu district. Farmers' preferences in the changing environment bring continuous evolving of landraces due to gene flow that farmers favor by selection of maize characteristics as reported by Ndiso et al. (2013).

Maize landraces in cluster 1 showed higher values of Gy(t/ha), TBS, NTBT, LW and ED. The second cluster comprised maize landraces having the highest values of LL, 100 SWT, and TPL. The members of the third cluster were characterized by higher values of TL, PH, NSBT, NPB, NKR, NKPR, EL, EH, DTT, DTS and CD (Table 5).

Results of principle component analysis

The computed eigen values for the variables subjected to principle component analysis together with the corresponding proportions and cumulative explained variance are given in Table 6.

The first principle component (F1) is strongly correlated with seven of the variables. The first principle component increases with increasing plant height (0.82), number of

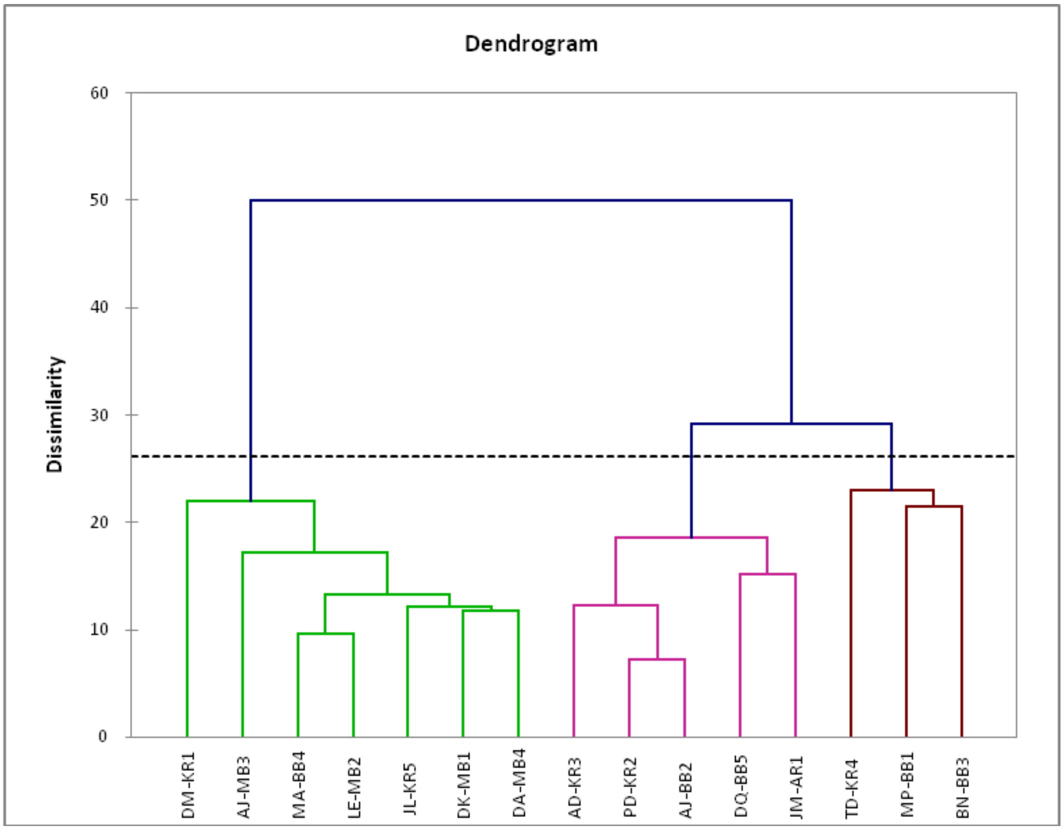

Figure 1. Dendrogram produced from cluster analysis of maize accessions using morphological data executed by UPGM method.

Table 4. Cluster membership of various maize landraces under this study.

Cluster name	No. of landraces in each cluster	Name of landraces in each cluster
Cluster 1	7	DK-MB1, DM-KR1, MA-BB4, DA-MB4, AJ-MB3, JL-KR5, LE-MB2
Cluster 2	5	DQ-BB5, PD-KR2, JM-AR1, AD-KR3, AJ-BB2
Cluster 3	3	MP-BB1, TD-KR4, BN-BB3

primary branches (0.56), number of kernel per row (0.53), ear length (0.67), ear height (0.91), days to tasseling (0.96), days to silking (0.95) and negative correlation for ear diameter (-0.59); the rest traits contributed very low either positively or negatively.

The second principle component (F2) increased with increase in leaf length (0.59), 100 seed weight (0.71), ear diameter (0.53) and cob diameter (0.56), while number of tertiary branches increased negatively (-0.62) and other traits contributing very low.

The third principle component (F3) increased with increasing tassel length (0.56), tassel branches space (0.72), number of secondary branches (0.71) and cob diameter (0.56).

The fourth principle component (F4) was explained by variation among landraces due to tassel peduncle length (0.60) and number of kernel per row (0.76).

High loading for grain yield (-0.56) and tassel peduncle length (-0.61) negatively contributed to increase in the fifth principle component (F5), while leaf width (0.62) contributed positively. The sixth component increased with increasing number of tertiary branches (0.57).

Six principle components (F6) were produced and these principle components had cumulative explained variances of 84.23%. The first principle component accounted for 29.40% of the total variation while principle components two and three accounted for cumulatives of 44.20% and 57.20% respectively. Six principle components were extracted having Eigen values of >1 out of fourteen.

Table 5. Cluster analysis of various traits in maize landraces.

Trait	Cluster 1	Cluster 2	Cluster 3
LL	96.03	97.50	92.88
100 swt(g)	53.03	53.05	50.31
Gy (t/ha)	2.45	2.35	2.27
TPL	29.07	29.77	28.44
TL	45.55	42.88	47.59
TBS	20.95	20.26	20.77
PH	278.57	308.06	322.33
NTBT	1.65	1.64	1.48
NSBT	2.09	2.22	2.33
NPB	13.30	13.82	15.66
NKR	13.14	13.18	13.26
NKPR	39.11	38.84	43.71
LW	12.09	11.52	11.69
EL	20.58	21.36	22.43
EH	145.61	171.90	189.33
ED	5.04	4.98	4.83
DTT	70.23	72.53	76.66
DTS	72.28	74.46	78.33
CD	2.88	2.85	2.89

Table 6. Factor loadings and Eigen value for component traits in principle components 1-6.

Variable/component	F1	F2	F3	F4	F5	F6
Leaf length	-0.42	0.59	0.20	-0.31	-0.31	0.09
100 seed weight	-0.34	0.71	-0.30	0.04	0.18	-0.23
Grain yield	-0.37	-0.13	-0.23	-0.06	-0.56	-0.09
Tassel peduncle length	-0.16	-0.02	-0.06	0.60	-0.61	-0.36
Tassel length	-0.12	0.07	0.56	-0.47	-0.39	-0.26
Tassel branches space	-0.34	-0.38	0.72	-0.18	-0.15	-0.20
Plant height	0.82	0.31	0.15	-0.04	-0.25	-0.18
Number of tertiary branches	-0.05	-0.62	0.08	0.07	-0.27	0.57
Number of secondary branches	-0.03	0.12	0.71	-0.29	0.09	0.39
Number of primary branches	0.56	-0.13	0.43	0.34	0.18	-0.27
Number of kernel row	-0.02	-0.31	0.39	0.76	-0.13	0.11
Number of kernel per row	0.53	-0.31	0.18	-0.41	0.09	-0.36
Leaf width	-0.43	-0.43	0.10	-0.03	0.62	-0.32
Ear length	0.67	0.49	0.02	-0.17	-0.10	0.19
Ear height	0.91	0.10	0.15	0.00	-0.26	-0.06
Ear diameter	-0.59	0.53	0.33	0.43	0.07	-0.06
Days to tasseling	0.96	0.01	-0.01	0.09	0.09	0.02
Days to silking	0.95	0.02	-0.02	0.17	0.13	0.06
Cob diameter	-0.14	0.56	0.56	0.37	0.26	0.15
Eigen value	5.58	2.82	2.45	2.11	1.79	1.23
Variability (%)	29.40	14.84	12.92	11.13	9.43	6.50
Cumulative %	29.40	44.24	57.16	68.30	77.72	84.23

Six principle components obtained after data analysis are similar with the results obtained by Ali et al. (2015) on wheat. Contrary results were obtained by Manyasa et al. (2009) and Ndiso et al. (2013) who found two principle components for maize and pigeon pea, while Ali et al. (2011) obtained seven principle components on his study in sorghum. Beyene et al. (2005), Tanavar et al. (2014) and Mustafa et al. (2015) reported four principle components from a study on maize. These differences are possibly due to environmental and populations differences used.

The current study of maize landraces accounted for 84.23% of the total variation which coincides with the results obtained by Micic et al. (2013) which was 80.86% on maize landraces in Yugoslavia. However, a study done by Siopongco et al. (1999) showed 73.99% which is slightly lower on maize. Principle components produced account for the variation occurring at farm level which is supported by the environment. The broad trait diversity evident among the maize landraces suggests ample opportunity for genetic improvement of the crop through selection directly from the landraces and/or the development of inbred lines for future hybrid production programs.

Conclusions

The broad trait diversity evident among the maize landraces suggests that there is an opportunity for genetic improvement of the crop through selection directly from the landraces and/or the development of inbred lines for future hybrid production programs.

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