Diversity in Tanzanian Pigeonpea [*Cajanus cajan* (L.) Millsp.] Landraces

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Abstract

A total of 123 Pigeonpea landraces were collected from four major pigeonpea production areas in Tanzania. The accessions grown at Ilonga (Tanzania) and Kabete and Kampi ya Mawe (Kenya) were characterized for diversity using 16 qualitative and 14 quantitative traits. In the Northern Highlands, pigeonpea is grown mainly as a cash crop for export. Farmers mainly rely on self saved seed, but seed is also obtained from other sources. Significant polymorphism in qualitative traits was recorded in base flower colour, pod colour, flowering pattern, streak pattern, seed colour and seed shape. Northern Highlands collections exhibited lowest diversity in these traits, an indication of selection response to market preferences. Principal component and cluster analysis separated the variability in the germplasm based on days to flower, days to maturity, plant height, number of primary and secondary branches and number of racemes/ plant. Overall, two distinct diversity clusters were evident with Coastal, Eastern and Southern accessions in one cluster and Northern Highlands accessions in another cluster. Further studies, using molecular techniques is essential to confirm the diversity groups identified and also to identify genetic markers for insect pests and disease resistance.

INTRODUCTION

Pigeonpea (*Cajanus cajan*), is the fifth most important pulse crop in the world. The crop has its primary centre of origin in India and Africa is a secondary centre of diversity (van der Maesen, 1990). Pigeonpea is the third major legume in Tanzania after beans and cowpea and is grown on over 55,000 hectares (Joshi et al., 2001), with an average production of about 38,000 tons (Shiferaw et al., 2005). The Northern Highlands is the major production region, though the crop is also extensively cultivated along the Coast, Morogoro and South of the country (Shiferaw et al., 2005). Most cultivars grown in Tanzania are landraces except for the Northern Highlands where improved long duration varieties from ICRISAT are now being adopted (Silim et al., 2005). Yields on farmers' fields are low averaging about 400-700 kg/ha due to lack of improved varieties, poor crop husbandry and losses due to insect pests and diseases (Shiferaw et al., 2005).

The knowledge of the amount, extent and distribution of genetic variations in germplasm are key to its improvement and development of effective conservation strategies (Hodgkin, 1997). No systematic collection of germplasm and characterization has been carried out in Tanzania. Yet when improved varieties are adopted by farmers, loss of diversity loss becomes real. The study of morphological and agronomic traits together with multivariate statistical procedures that characterize genetic divergence using the criterion of similarity or dissimilarity based on aggregate effect is the classic way of assessing genetic diversity (Mead et al., 2002).

The objectives of this work were to collect germplasm and primary in situ description of pigeonpea landraces from four major pigeonpea growing areas in Tanzania followed by agro-morphological evaluation so as to provide information that would enable understanding of production systems and germplasm management and use in breeding programs in eastern and southern Africa.

MATERIALS AND METHODS

Germplasm Collection and In Situ Information

Pigeonpea landraces were collected from four agro-ecologies; (i) Coastal Zone (Dar er Salaam, and parts of Mtwara and Lindi, altitude < 200m); (ii) Eastern Plains (Morogoro and Tanga regions, altitude > 200m); (iii) Southern Plains (most of collection sites in Lindi and Mtwara regions, altitude > 200m); (iv) Northern Highlands (Arusha and Dodoma Regions, altitude 1200-1700m). Structured interviews with farmers were carried out to obtain information on crop management, cropping systems, harvesting, post harvest handling and utilization.

Ex Situ Characterization

1. Genetic Material, Trial Site Description, Trial Design and Crop Management: A total of 123 pigeonpea landrace accessions plus 21 medium and long duration checks were evaluated for agro-morphological traits at two sites in Kenya: Kampi ya Mawe (1250m altitude, 1^0 57' S, mean temp. 23°C and mean annual rainfall 500-600 mm) and Kabete (1960 m altitude, $1^0$14'S and mean temp. 18^0C and mean annual rainfall 1046 mm) and in Tanzania: Ilonga (506 m altitude, 6^0 46'S and mean temp. 22^0C and mean annual rainfall 1046 mm). The 21 checks were those with known adaptation and have been released or promising lines in Tanzania, Kenya, Uganda, Malawi and Mozambique.

The cropping seasons for the trials were in 2002/03 in Tanzania and 2004/05 in Kenya. At all the sites, the accessions were planted in a 12x12 square Lattice Design with 3 replications. Plots were 4 m length and inter-row and intra-row spacing were 1.5m and 0.5m, respectively.

2. Agro-Morphological Traits and Data Collection: Data was collected on 16 qualitative and 14 quantitative traits in Kenya according to IBPGR/ICRISAT Descriptors (1993), while at Ilonga, data were taken on only 7 quantitative and 5 qualitative traits. Qualitative data was recorded on individual plants within the plot for each replication except for seed traits which were recorded on a sample from a whole plot. Data on quantitative traits was taken on 5 randomly selected plants in each plot. Pod length, pod width and number of seeds/pod were recorded on 10 pods selected randomly from 5 plants in the plot whereas pods/raceme and raceme length were recorded on 10 racemes randomly selected from 5 plants in the plot. Days to flower and days to maturity, and pod and grain yields were taken on plot basis.

Shanon-Weaver diversity indices as described by Jain et al., (1975) were calculated for qualitative traits, based on phenotypic frequencies (proportions) of each qualitative trait category to estimate phenotypic diversity among and within the accessions and within collection regions.

Analyses of variance for all quantitative traits were done using Unbalanced Design instead of the lattice design used in planting due to missing entries (failure to germinate). Principal Component Analyses (PCA) were done to determine patterns of variation and major traits contributing to the delineation (Fundora Mayor et al., 2004). Only PCs with eigen values >1 (Kaiser, 1960) were considered in determining the agro-morphological variability in the accessions. The first two PCs were plotted to enhance the dispersion of the accessions. A cluster analysis was carried out based on Euclidean distance matrix in a hierarchical way (Fundora Mayor et al., 2004) using average linkage analysis (UPMGA).

RESULTS AND DISCUSSION

Qualitative Traits

Base flower colour, flowering pattern, pod colour, pod shape, streak pattern, seed colour, seed colour pattern and seed shape were highly polymorphic among the accessions. The mean diversity indices of the qualitative traits were generally low (0.2382). Diversity indices between regions ranged from a low of 0.1665 (Northern highlands) to 0.2749 (Coastal Zone). There were no significant diversity differences in stem color, growth habit, base flower colour, pod form, pod hairiness, seed eye colour and seed eye width in the germplasm. Northern Highlands collections had lowest diversities in all traits, a manifestation of effect of selection for market preferences or recent introductions.

The accessions had predominantly green stem colour (97%), semi-spreading growth habit (93%), indeterminate flowering pattern (59%), yellow flower colour (73%), red streaks (54%), mixed pods (50%) and cream/white seeds types (94%). The frequency of plain white/cream types was highest in the Northern Highlands which is attributed to market preferences in the commercial production region (Shiferaw et al., 2005).

Quantitative Traits

There was a wide range of variability in the germplasm in all quantitative traits except seeds/pod at Ilonga. Across experimental sites, accessions from Southern Plains were earliest in flowering (103 days) and shortest in height (130cm) while highland collections were latest to flower (152 days) and were tallest (182cm). Among locations, plants flowered earliest (101 days) at Kabete and flowered late (135 days) at Kampi ya Mawe (KYM) and this agrees with Silim et al., (2005) who reported that medium and long duration pigeonpea had their phenology delayed and height increased with increase in temperature. Mean pod bearing lengths were highest at KYM (77cm) and lowest at Kabete (54 cm). Mean pod lengths were relatively similar at KYM and Kabete at 8.5 and 8.8 cm respectively. Accessions from the Northern Highlands were the tallest at all the three experimental sites (KYM-156 cm; Kabete-164 cm and Ilonga-228 cm). Accessions from the Northern Highlands took longer to flower at KYM (198 days) than at Kabete (120 days). Maturity classification of the accessions based on days to maturity (<135 early, 135-160 medium and >160 late) placed most of the Coastal, Eastern and Southern collections into the medium maturity group and most of the Northern Highlands collections into the late maturity group.

Mean pods/plant ranged from 66 at KYM to 166 at Kabete. Findings from this study reveal a high mean seed mass within the collection (mean 14 g) with Northern Highlands collections having the highest mean seed mass (16 g) at Kabete, a cool location where moisture supply during the cropping season was not limiting. Large seed mass is a manifestation of farmer and market preferences. This study confirms earlier reports (Silim et al., 2005) that east African pigeonpea landraces produce high number of seeds/pod and high seed mass and that late maturing types have highest seed mass. The highly significant phenological variability among the accessions and between accessions and environments is an indication of suitability of certain genotypes to specific environments. The differential days to flower relative to test environments was earlier reported by Silim et al., (2006) who observed that flowering in long duration types originating from high elevation is accelerated by low and inhibited by high temperature.

Principal Component (PCA) and Cluster Analysis

PC1 accounted for most of the variability with high positive loadings from days to flower and maturity, plant height, pod bearing length, number of primary and secondary branches and pods/plant (Table 1). The bi-plot of PC1 and 2 distributed the accessions into 2 major scatter distributions at all experimental sites. Accessions from Northern Highlands had strong positive scatter on PC1 (they were tall, flower and mature late, have long pod bearing lengths, higher number of pods/plant, and more primary and secondary branches). Collections from Coastal Zone, Eastern and Southern Plains tended to congregate together on the lower end of both PC1 and PC2, as they are generally shorter, early in flowering and maturity, have a fewer number of pods/plant and lower yields. The PC scatter revealed that accessions from the three regions (Coast, Eastern and Southern) are similar and diverse from the Highlands accessions. Hierarchical clustering separated the accessions into 6 clusters (Fig. 1). Clusters 1 to 4 were mainly composed of materials collected from the Coast Zone, Eastern Zone and Southern Plains plus most of the medium-duration check varieties. Clusters 5 and 6 mainly contained collections from Northern Highlands and long duration checks.

The major agronomic traits delineating the Tanzania pigeonpea germplasm were plant height, maturity duration, primary and secondary branches, pod bearing length, number of racemes/plant and pods/plant. The delineation of the germplasm into two distinct regions of genetic diversity is similar to findings by Rojas et al. (2000) who studied diversity in quinoa in Bolivia and placed the seven clusters identified into three genetic diversity areas based on altitude. As reported earlier by Silim et al., (2006), sensitivity of pigeonpea to temperature limits its adaptation to diverse altitudes with a definite separation between high and low altitude varieties. It is also evident that agro-ecological conditions in a given location usually determine farmer selection strategies and shape the diversity in the crop. The heterotic groups established in this germplasm, will be useful in crossing to generate new cultivars adapted to different pigeonpea growing environments with consumer acceptability.

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Tables

Table 1: Principal components (PC) on 14 quantitative traits recorded on 123 Tanzanian pigeonpea landraces at Kabete and Kampi ya Mawe, Kenya.

Kabete				
	PC1	PC2	PC3	PC4
Eigen value	5.902	1.639	1.371	1.112
Proportion of variance	42.16	11.71	9.80	7.94
Total variance	42.16	53.87	63.67	71.61
	Eigenvectors (loadings)			
Plant heights	0.35574	0.10630	0.17543	0.15884
Days 50% flower	0.36767	-0.04621	0.06162	0.03377
Primary branches	0.25623	0.00842	0.05123	0.22133
Seeds/pod	-0.01646	-0.48368	0.50138	-0.30082
Days to 75% maturity	0.24883	-0.04288	0.01637	-0.10670
Grain yield	0.29983	-.032501	-0.26783	-0.29159
100 seed mass	-0.03686	-0.32780	-0.30290	0.70516
Pod bearing length	0.33769	0.13384	0.15774	0.10828
Pod length	-0.04233	-0.54020	0.40827	0.32750
Pods/plant	0.32070	-0.12885	-0.22099	-0.00221
Secondary branches	0.27792	0.01336	-0.19178	0.13611
Raceme number	0.31784	0.24748	0.15395	0.06152
Pod yield	0.31885	-0.26500	-0.16558	-0.28230
Threshing %	-0.14341	-0.28222	-0.46837	-0.13963
Kampi ya Mawe				
	PC1	PC2	PC3	PC4
Eigen value	4.355	2.072	1.219	0.983
Proportion of variance	35.69	16.98	9.99	8.05
Total variance	35.69	52.67	62.66	70.71
	Eigenvectors (loadings)			
Plant heights	0.40954	-0.08960	0.06959	-0.07887
Days 50% flower	0.40729	0.07146	0.05854	-0.01317
Primary branches	0.27536	-0.05387	-0.05633	-0.15756
Seeds/pod	-0.28324	0.03143	0.04146	-0.46860
Days to 75% maturity	0.41853	0.05906	0.06244	-0.01402
Grain yield	-0.05936	-0.65248	0.02891	0.12162
100 seed mass	0.22589	-0.25007	-0.25265	-0.01960
Pod bearing length	0.30962	0.03478	0.14592	-0.11023
Pod length	-0.24387	-0.10511	-0.10475	-0.51230
Pods/plant	0.10935	-0.15114	0.60919	-0.48973
Secondary branches	0.21654	-0.02136	-0.34956	0.01074
Raceme number	0.24135	-0.06197	-0.01229	-0.14198
Pod yield	-0.06009	-0.63823	0.17174	0.21825
Threshing %	0.06771	-0.21091	-0.60254	-0.38920

Figures

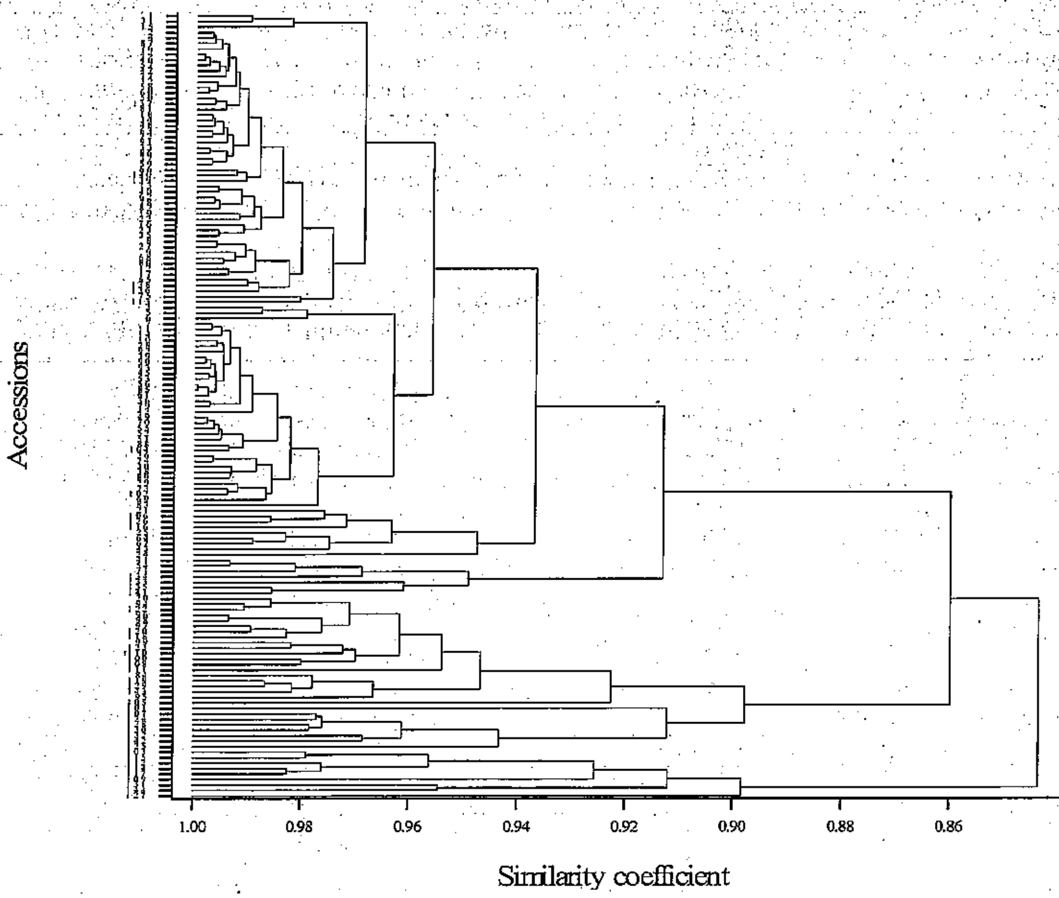

Fig. 1. Cluster analyses dendrogram for 123 accessions and 21 checks based on average linkage for the 14 quantitative traits.