



Full Length Research Paper

Assessment of agro-morphological variability among tepary bean (*Phaseolus acutifolius*) landraces collected in Botswana

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A field experiment was conducted at Department of Agricultural Research in Sebele in the 2012 to 2013 season using nine accessions that were sourced from the National Plant Genetic Resource Centre (NPGRC), Gaborone, Botswana. Multivariate statistical procedures such as clusters and principal component analysis were used on 15 selected characters to assess agro-morphological variability among tepary bean landraces collected in Botswana. Few characters were statistically significant which suggest lower genetic diversity among the Botswana tepary beans. The first three PCA accounted for 77.12% of accumulated variation. Traits which revealed significant contribution to variation among accessions were number of leaves, plant spread, pod width, 100 seed weight and seeds per pod. The dendrogram results also showed that these characters contributed significantly to the grouping of accessions into three clusters. Three accessions GK011, MTS (Motsumi) and GK012 were separated from the rest of the accessions. However, GK012 and MTS (Motsumi) with highest number of valuable traits are recommended for plant breeders to use as parents in future breeding programs.

Key words: Tepary bean, agro-morphological traits, dendrogram, principal components analysis, multivariate analysis.

INTRODUCTION

The cultivated tepary bean (*Phaseolus acutifolius* A. Gray) is a short life cycle legume originally from the deserts and semi-arid environment of northwestern Mexico and southwestern United States (Nabham and Felger, 1978). It is recognized for its resistance to heat, drought and many diseases (Salgado et al., 1994; Miklas and Stavely, 1998; Rao et al., 2013). These characteristics make it an ideal crop in parts of tropical America, the Caribbean and Africa (Porch et al., 2013)

equally so important for Botswana with a semi-arid environment. The crop has no established varieties in Botswana therefore farmers are using landraces which are usually low yielding. Since few farmers are involved in planting tepary bean, the development of new varieties could potentially encourage the growing of this crop. The crop is grown in Africa and Middle Eastern countries (Tinsley et al., 1985) where the seeds provide high protein good for human nutrition.

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Table 1. Tepary bean landraces collected from different villages from two agricultural regions of Botswana.

Entry	Accession	Collection sites	Lat.	Long.	District
1	MTS (Motsumi)	Mahalapye	23.108	26.823	Central
2	GK010	Machaneng	23.185	27.483	Central
3	GK012	Sefophe	22.182	27.961	Central
4	E70	Tutume	20.493	27.018	Central
5	GK011	Kubung	24.649	25.303	Kweneng
6	E105	Machaneng	23.185	27.487	Central
7	GK013	Thamaga	24.678	25.531	Kweneng
8	E89	Kgope	24.310	25.940	Kweneng
9	E19	Mahetlwe	24.242	25.684	Kweneng

In Botswana it is commonly known as 'Dibonkise'. It is grown by small scale farmers mainly as a source of food while the haulms are used as feed for animals. A brief survey by Karikari et al. (1995) in Botswana discovered that its production is lower than that of cowpeas, groundnut and bambara groundnut. Its relatively high protein content recorded at 24% compares well with other *Phaseolus* spp. (Bhardwaj and Hamama, 2004). Tepary beans together with other three underutilized legumes (bambara groundnut, morama bean and mungbean) were assessed for protein and mineral composition. It was found that they are a good source of protein with great potential as food crops which could contribute to improving food security in Botswana (Amarteifio and Moholo, 1998). In addition it is a high value crop as it equally fetches money such as other grain legumes through the Botswana Agricultural Marketing Board (BAMB, 2013).

Tepary bean possesses considerable variability for yield and yield related traits (Kuruvad and Valdez, 1993; Bhardwaj et al., 2002) and is superior in drought tolerance (Mohamed et al., 2005). Compared to common bean, tepary bean was shown to be superior in combining desirable traits that makes it well adapted to drought stress (Markhart, 1985). Tepary bean is a useful genetic donor of important traits such as disease, pest and stress tolerance to improve common beans (*P. vulgaris*) (Schinkel and Gepts, 1988). Little research has been conducted in Botswana environment to ascertain all the useful characteristics of tepary bean crop.

In the US, at least two varieties (TARS-Tep 22 and TARS-Tep 32) have been developed and are available to farmers especially in the production zones prone to abiotic and biotic stress (Porch et al., 2013). In Botswana the crop has not received much attention compared to other legumes probably due to low number of farmers growing the crop. Knowledge of phenotypic diversity of tepary bean accessions grown can be employed in crop improvement and in developing breeding lines (Mohammadi

and Prasanna, 2003). In order to improve the use of tepary bean, it is necessary to gain an understanding of its genetic attributes (Schinkel and Gepts, 1988). Lack of information on the genetic diversity of tepary bean has led to poor exploitation of its genetic resources. Therefore the objectives of the project is to study the morphological variability of Botswana tepary bean landraces in order to generate additional information to improve their utilization, and to identify accessions with potential to be exploited by plant breeders.

MATERIALS AND METHODS

The experimental materials for this study comprised nine tepary bean (*P. acutifolius*) accessions that were sourced from the Botswana National Plant Genetic Resource Centre (NPGRC) and originally from nine different villages and two agricultural regions of the country (Table 1). Fifteen agro-morphological characters were used to assess the variability of the accessions: Plant height (PH), number of leaves (NL), leaflet width (LW), leaflet length (LL), plant spread (PS), number of branches (NB), pods per plant (PPP), pod length (PL), pod width (PW), seeds per pod (SPP), pod weight per plant (PWP), seeds per plant (SPP), 100 seed weight (100SW), shoot dry weight (SDW) and yield per m² (YIELD) (Table 2). The morphological and agronomic traits selected were chosen from International Board for Plant Genetic Resources, IBPGR (1985) for *P. acutifolius*. Similar traits were considered important for common bean breeding programs (de Lima et al., 2012). All accessions examined were of cream coloured seeds. One of the accessions (GK010) in this project had been sent to Vienna-Austria for mutation experiments.

The experiment was laid out in a randomized complete block design using two replications in the 2012 to 2013 cropping seasons at Sebele Agricultural Research Station. The accessions were sown by hand at a spacing of 75 cm between rows and 30 cm between plants and plot length of 5 m. No fertilizers were applied but, the crops were sprinkler irrigated once a week to ensure proper plant growth. In each accession five representative plants were selected randomly and used for biometric measurements. The agro-morphological mean data were standardized to give equal weighing. The values were used to perform multivariate statistical analysis, using Multivariate Statistical Package (MVSP) software (Kovach Computing Services, UK, 2006) and NTSYS-pc Numerical

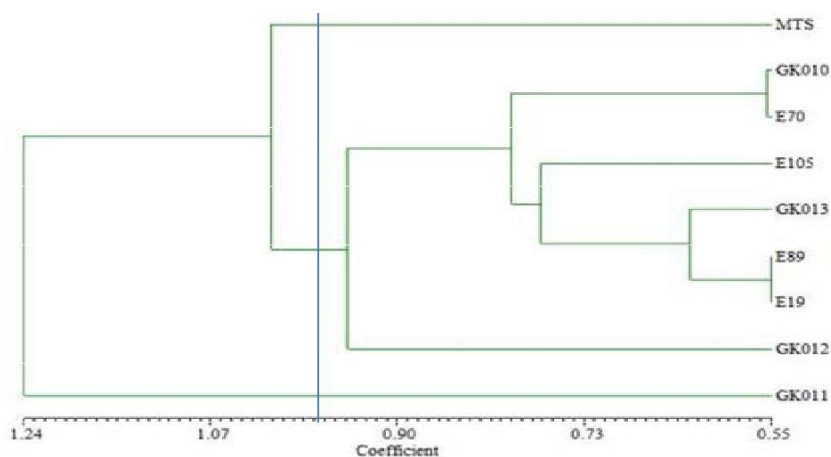


Figure 1. Dendrogram of nine tepary bean accessions showing genetic similarities based on 15 phenotypic traits, using the UPGMA cluster analysis. The test of association: Matrix correlation on NTSYS pc: ($r = 0.88$).

Table 3. Eigen values and the first three principal component axes in tepary bean diversity analysis.

Parameter	Axis 1	Axis 2	Axis 3
Plant height	0.278	-0.112	0.038
No. of leaves	0.347	0.078	0.013
Leaflet width	0.199	-0.069	-0.280
Leaflet length	0.170	0.160	-0.048
Plant spread	0.301	0.005	0.087
No. of branches	0.345	-0.171	0.135
Pods per plant	0.263	0.009	0.210
Pod length	-0.041	0.150	0.135
Pod width	0.182	0.575	0.068
Seeds per pod	0.245	-0.377	0.505
Pods weight plant	0.196	-0.087	0.174
Seeds per plant	0.253	-0.100	0.115
100seeds weight	-0.054	0.590	0.429
Shoot dry weight	0.294	0.176	-0.263
Yield m ²	0.248	0.159	-0.004
Eigen values	2.832	1.787	1.148
Percentage	37.892	23.909	15.358
Cum. Percentage	37.892	61.800	77.158

had most contributions coming from no of branches (0.345), number of leaves (0.347) and plant spread (0.301). The second variate from axis 2 had higher contributions coming from pod width (0.575), 100 seed weight (0.590), and seeds per pod (-0.377). This indicates the importance of these characters in identifying tepary bean landraces. Principal coordinate analysis (PCoA) clearly demarcated landraces GK011 and MTS (Motsumi) from the rest of the accessions; it also distinguished GK012 from the rest of the accessions

better than cluster analysis (Figure 2).

DISCUSSION

In this study we describe for the first time the diversity of tepary bean landraces grown in Botswana. Few morphological characters, number of branches per plant, 100 seed weight and number of seeds per plant exhibit significant variation, which shows low levels of genetic

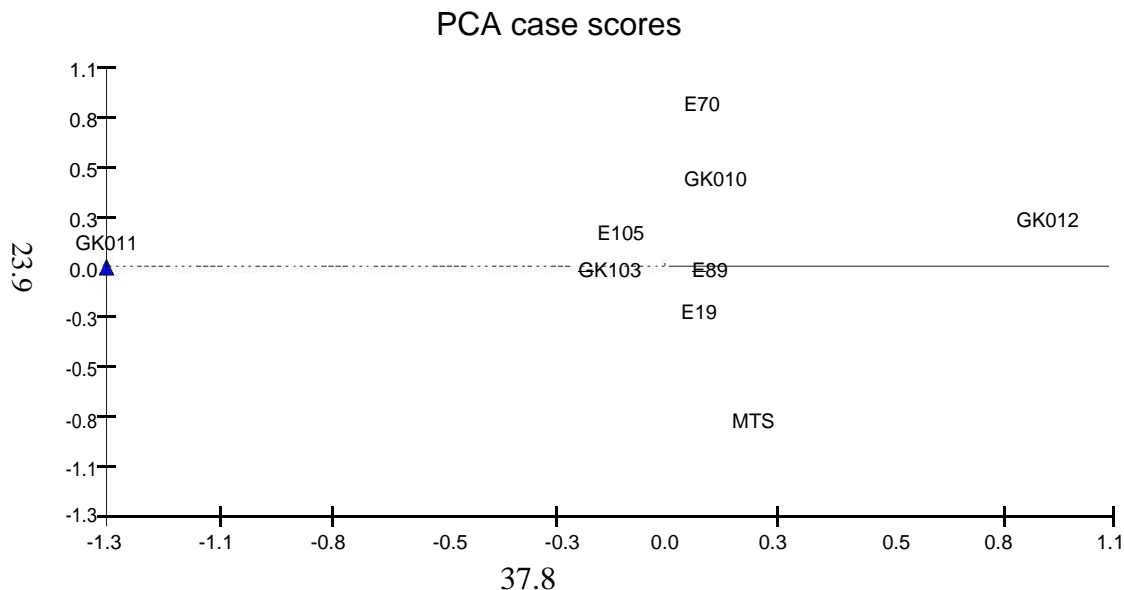


Figure 2. PCO scatter plot for nine tepary bean accessions grown in Botswana from MVSP program with a variation of 61.71%, with Axis 1 contributing 37.8% while Axis 2 explained 23.9%.

variation among the selected genotypes. Similar observations were revealed when using cluster analysis which exhibited lower differences among most of the accessions. The results generally are in accordance with the lower diversity in tepary bean observed by Schinkel and Gepts (1988) when analyzing Phaseolin among 55 wild and 8 cultivated teparies using polyacrylamide gel electrophoresis. Their results showed 15 electrophoretic Phaseolin patterns among wild forms and only one pattern in cultivars which they thought it suggest single domestication in this species.

Characters with greatest variation were yield per m², number of seeds per plant, number of leaves and podweight per plant. Similar results were observed in one important yield component in tepary bean of pods per plant with a range of (8.1 to 37.1) among sixteen accessions from five states in Mexico (Kuruvadi and Valdez, 1993). The greater variation appears to indicate that there is a potential for improvement of this crop.

The dendrogram (Figure 1) was divided into three clusters, but with a lower range among most accessions, which still shows a lower genetic diversity among the selected genotypes. The dendrogram is largely in agreement with the PCoA coordinates (Figure 2), which clearly demarcated accessions mostly on the major traits. Principal component analysis revealed those characters that are important in explaining the variation among the selected genotypes such as number of leaves, plant spread, pod width, 100 seed weight and seed per pod. Clusters can be separated mainly based on traits which contribute more variation as observed in barley (Abebe et al., 2010) and in rice (Moukoumbi et al., 2011). The clustering and scatter plots can also have a similar pattern

as in pigeon peas (Manyasa et al., 2008) and in *Arachis pinto* (Carvalho and Quesenberry, 2009).

Morphological character assessment is the first step in characterization of germplasm (Azam-Ali et al., 2001) usually breeding programmes relies on the magnitude of phenotypic variability in crops (Ghafoor et al., 2002). Morphological traits in this study were able to differentiate most of the accessions except in the case of E19 and E89, and E70 and GK10; this suggests that the accessions clearly resemble each other agronomically. Subsistence farmers in Botswana exchange seeds and these could be similar genotypes with different names. Presumably there could be some duplication which can be tested using molecular markers which are better placed to discern the accessions compared to morphological characters which are highly influenced by the environment (Smith and Smith, 1992; Hintum et al., 2000). From ten agricultural districts in Botswana the accessions were sourced from two districts (Table 1), different accessions could be discovered by the National Genetic Resource Centre when they collect more tepary germplasm to improve the genetic diversity. In general, our results revealed that the multivariate analysis used was able to differentiate the nine accessions based on the 15 characters selected. This gives an opportunity for further exploitation of the landrace since the characters with high importance in the characterization of tepary beans has been identified. However, the lower genetic diversity exposed in this study will require further addition of more materials. Currently the Department of Agricultural Research has sourced additional tepary bean lines from CIAT (Centro Internacional de Agricultura Tropical) and a mutation project is on-going with the

Vienna-Sibersdorf laboratory. These initiatives could be useful in improving the diversity among Botswana tepary beans. An initiative has also been taken to source tepary bean multiple stress tolerant germplasm released by (Porch et al., 2012). The promising accessions such as GK012 and MTS (Motsumi) could be used as parental material by plant breeders.

Conflict of Interest

The authors have not declared any conflict of interest.

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REFERENCES

- Abebe TD, Bauer AM, Leon J (2010). Morphological diversity of Ethiopian barleys (*Hordeum vulgare* L.) in relation to geographic regions and altitudes. *Hereditas* 147:154-164. doi: 10.1111/j.1601-5223.2010.02173.x
- Amarteifio JO, Moholo O (1998). The chemical composition of four legumes consumed in Botswana. *J. Food Compos. Anal.* 11:329-332. <http://dx.doi.org/10.1006/jfca.1998.0595>
- Azam-Ali SN, Sesay A, Karikari SK, Massawe FJ, Aguilar -Manjarrez J, Bannayan M, Hampson KJ (2001). Assessing the potential of underutilized crop- a case of bambara groundnut. *Experimental Agriculture* 37:433-472. <http://dx.doi.org/10.1017/S0014479701000412>
- Botswana Agricultural Marketing Board (2013). Marketing season. www.bamb.co.bw
- Bhardwaj HL, Rangappa M, Hamama AA (2002). Planting date and genotype effects on Tepary bean productivity. *HortScience* 37:317-318
- Bhardwaj HL, Hamama AA (2004). Protein and mineral composition of tepary bean seed. *HortScience* 39:1363-1365 <http://hortsci.ashspubs.org/content/39/6/1363.short>
- Carvalho MA, Quesenberry KH (2009). Morphological characterization of the USA *Arachis pintoi* Krap. and Greg. Collection. *Plant. Syst. Evol.* 277:1-11 DOI10.1007/s00606-008-0089-9 <http://dx.doi.org/10.1007/s00606-008-0089-9>
- de Lima MS, de Souza Carneiro JE, Carneiro PCS, Pereira CS, Vieira RF, Cecon PR (2012). Characterization of genetic variability among common bean genotypes by morphological descriptors. *Crop Breed. Appl. Biotechnol.* 12:76-84. <http://dx.doi.org/10.1590/S1984-70332012000100010>
- Ghafoor A, Ahmad Z, Qureshi AS, Bashir M (2002). Genetic relationship in *Vigna mungo* (L.) Hepper and *V. radiata* (L.) R. Wilczek based on morphological traits and SDS-PAGE. *Euphytica* 123:367-378. <http://link.springer.com/article/10.1023%2FA%3A1015092502466#>
- Hintum TJL, Brown AHD, Spillane C, Hodgkin T (2000). Core collection of plant genetic resources. IPGRI Technical Bulletin No. 3.
- International Board for Plant Genetic Resources, IBPGR (1985). Rome, Italy International IBPGR, *Phaseolus acutifolius*, Secretariat Rome, Italy. <http://www.biodiversityinternational.org>
- Karikari SK, Wigglesworth DJ, Kwerepe BC, Balole TV, Sebolai B, Munthali DC (1995). Country report for Botswana. In: Promoting the conservation and use of underutilized and neglected crops. 9. Proceedings of the workshop on conservation and improvement of bambara groundnut (*Vigna subterranea* L. Verdc.) 14-16 November, 1995, Harare, Zimbabwe, pp. 11-18. (Eds. Heller J., Begemann F and Mashunga J. International Plant Resource Institute, Rome, Italy.
- Kovach W (2006). MVSP-Multivariate Statistical Package version 3.1 Kovach Computing Services; Anglesey.
- Kuruvadi S, Valdez IS (1993). Range of yield components and phenotypic correlations in tepary beans (*Phaseolus acutifolius*) under dryland conditions. pp. 594-596. In: J. Janick and J.E. Simon (eds.), *New crops*. Wiley, New York.
- Markhart AH (1985). Comparative water relations of *Phaseolus vulgaris* L. and *Phaseolus acutifolius* Gray, *Plant Physiol.* 77:113-117 <http://www.ncbi.nlm.nih.gov/pubmed/16663991> <http://dx.doi.org/10.1104/pp.77.1.113> PMID:16663991 PMCid:PMC1064467
- Miklas NP, Stavelly JR (1998). Incomplete dominance of rust resistance in tepary bean, *Hort Sci.* 33:143-145 <http://hortsci.ashspubs.org/content/33/1/143.short>
- Manyasa EO, Silim SN, Githiri SM, Christiansen JL (2008). Diversity in Tanzanian pigeonpea [*Cajanus cajan* (L.) Millsp.] Landraces and their response to environments. *Genet Resour Crop Evol.* 55:379-387 <http://dx.doi.org/10.1007/s10722-077-9245-2>
- Mohamed F, Mohamed M, Schmitz-Eiberger N, Keutgen, Noga G (2005). Comparative drought postponing and tolerance potentials of two tepary bean lines in relation to seed yield. *Afr. Crop Sci.* 13:49-60.
- Mohammadi SA, Prasanna BM (2003). Analysis of genetic diversity in crop plants- Salient statistical tools and considerations. *Crop Sci* 43: 1235 -1248 doi:10.2135/cropsci2003.1235
- Moukoubi YD, Sié M, Vodouhe R, N'dri B, Toulou B, Ogunbayo SA, Ahanchede A (2011). Assessing phenotypic diversity of interspecific rice varieties using agro-morphological characterization. *J. Plant Breed. Crop Sci.* 5:74-86.
- Nabham GP, Felger RS (1978). Teparies in southwestern North America. *Econ. Bot.* 32:2-19.
- Porch TG, Beaver JS, Brick MA (2012). Registration of Tepary Germplasm with Multiple-Stress Tolerance, TARS-Tep 22 and TARS-Tep 32. *J. Plant Registrat.* 7:358-364 <http://dx.doi.org/10.3198/jpr2012.10.0047crg>
- Porch TG, Beaver JS, Debouck DG, Jackson SA, Kelly JD, Dempewolf H (2013). Use of wild relatives and closely related species to adapt common bean to climate change. *Agronomy* 3:433-461. <http://dx.doi.org/10.3390/agronomy3020433>
- Rao I, Beebee S, Polania J, Ricaurte J, Cajiao C, Garcia R, Riverra M (2013). Can tepary bean be a model for improvement of drought resistance in common bean? *Afr. Crop Sci. J.* 21:265-281 <http://www.ajol.info/index.php/acsj/article/viewFile/95291/84638>.
- SAS 9.2 (2010). SAS/GRAPH, 9.2 Reference, Second Edition, Cary, NC: SAS Institute
- Rohlf FJ (2000). NTSYS -pc Numerical Taxonomy and Multivariate Analysis system version 2.1, Applied Biostatistics, New York.
- Salgado MO, Schwartz HF, Brick MA, Pastor Corrales MA (1994). Resistance to *Fusarium oxysporum* f. sp phaseoli in tepary beans (*Phaseolus acutifolius*). *Plant Dis.* 78:357-360. <http://dx.doi.org/10.1094/PD-78-0357>
- Smith JSC, Smith OS (1992). Fingerprinting crop varieties. *Adv. Agron.* 47:85-140. [http://dx.doi.org/10.1016/S0065-2113\(08\)60489-7](http://dx.doi.org/10.1016/S0065-2113(08)60489-7)
- Schinkel C, Gepts P (1988). Phaseolin diversity in the Tepary bean, *Phaseolus acutifolius* A. Gray. *Plant Breed.* 101: 292-301. <http://dx.doi.org/10.1111/j.1439-0523.1988.tb00301.x>
- Tinsley AM, Scheerens JC, Alegbejo JO, Adan F, Krumhar KC, Butler LE, Kopplin MJ (1985). Tepary beans (*Phaseolus acutifolius* var. latifolius): A potential food source for African and Middle Eastern cultures. *Qual Plant Foods Nutr.* 35:87-101 <http://dx.doi.org/10.1007/BF01092124>