Network News

January - December 2011

Minziro Forest Reserve: Source of Crop Wild Relatives in Tanzania


Minziro Forest

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Backround

During October 2011, field trip covering Kagera region in North-western Tanzania was conducted. The team comprised of exparts from National Plant Genetic Resources Center of Tanzania, National Herbarium of Tanzania and SADC Plant Genetic Resources Center (SPGRC). On its work the team visited Minziro forest reserve, the trip was one among several, in search for Crops Wild Relatives with focus to wild *Vigna spp, Eleusine spp.* and *Pennisetum spp.* under the Collection project funded by The Global Crop Diversity Trust (GCDT) at the NPGRC-Tanzania.

The forest has been extensively logged for the large, valuable *Podocarpus* trees in the past and these are now scarce and small. Illegal logging on an unknown scale continues, as well as Agricultural activities including the escalating sugar plantations.


Vigna spp. wild relative

Minziro Forest is important because it is one of the largest forests in Tanzania. It is more important however because it represents a type of forest found nowhere else in the country and one which is more similar to the forests further west in the Congo and Guinea. It therefore contains plant and animal species that reach their eastern range limits here and occur nowhere else in Tanzania, making it an important key area in search for species, including Crop wild relatives. A total of 10 accessions were collected from Kagera region during this mission.

Geography and Climate

Minziro forest is located in Kagera Region, NW Tanzania north of the Kagera River and close to the Uganda border at 31^0 30^0 East, 1^0 05^0 South it is about 25,000 ha in size and consists of ¾ seasonal swamp forest and ¼ seasonally flooded grassland with Acacia woodland abuts the Uganda border some 20 Km inland of Lake Victoria, where it is bounded to the east by the Kagera River. It is fairly low-lying and flat but dotted with small rocky hills and large areas are regularly inundated by the flooding of the Kagera River to the south. It is essentially a southern extension of Uganda's Malabigambo Forest, which runs northwards to Sango Bay. The Kitengule/ Buhingo hills 2 Km east of the reserve at 1312m represent the highest point in the immediate area. The forest

inside

Eleusine indica

reserve is at an altitude of 1125m to 1140m with Minziro village situated on a hill in the centre of the reserve. As much of the grassland is seasonally flooded, settlement and agriculture are restricted to ground above 1140m in most areas. Coffee (*robusta)* is the major cash crop while cassava, bananas and beans are the staple food crops.

Species Richness

Minziro Forest has over 600 butterfly species - more than any other forest in Africa and has more than 245 bird species recorded in the reserve, making it an extremely alluring birding destination. It has a long list of birds recorded nowhere else in Tanzania that include forest francolin, great blue turaco, white-bellied kingfisher, shining blue kingfisher yellow-crested woodpecker, orange-throated forest robin, lowland akalat, blue-shouldered robin-chat, fire-crested alethe, white-tailed ant thrush, chestnut wattle-eye, red-headed bluebill, and at least half a dozen greenbuls (Oatley, *et. al*., 2009).

Another indication of Minziro's biodiversity is a tally of at least 500 butterfly species. Large mammals are more poorly represented, probably partially the result of local subsistence poaching, but the forest's western affiliations are manifested in three monkey species (Angola *colobus*, grey-cheeked mangabey and red-tailed monkey), as well as red-legged sun squirrel, western tree hyrax (vociferous at night) and Peter's Duiker. Buffalo and elephant visit the reserve seasonally, the bushbuck is common in the forest, and hippopotami are present but rare along the river, which also supports a substantial population of crocodiles and monitor lizards.

Collection Expedition for Wild Crop Relatives

Considering the above mentioned dangers facing the Minziro Forest Reserve and as part of the targeted collection of crop wild relatives, a team comprising of two scientists from the Tanzanian NPGRC, a taxonomist from the National Herbarium – Arusha, an information officer from the Tropical Pest Research Institute, a Senior Programme Officer from SPGRC and a driver spent three days combing in and around Minziro for the crop wild relatives.

Collectors at work

The Team expedition, mainly sponsored by the project funding agency - the Global Crop Diversity Trust, managed to collect species of Vigna, Pennisetum, and Eleusine as shown in the table below:

Genus	Species	Subspecies	District(s)
Vigna	*vexillata*	*vexillata*	Bukoba Rural, Missenyi
Vigna	*ambaensis*		Missenyi
Vigna	*unguiculata*	*dekindtiana*	Missenyi
Vigna	*oblongifolia*	*parviflora*	Missenyi
Vigna	*parkeri*	*maranguensis*	Missenyi
Vigna	*reticulata*		Missenyi, Bukoba Urban
Vigna	*luteola*		Bukoba Urban
Pennisetum	*purperium*		Bukoba Rural
Pennisetum	*polystachion*	*atrichum*	Muleba
Eleusine	*indica*		Missenyi

Some of the species were scanty and difficult to find, forewarning the danger of possible disappearance if not well maintained and conserved.

Minziro Forest Management

Minziro Forest is jointly managed by 11 villages surrounding the forest through Village Environment Committees (VECs), formed in each of these villages. The VEC members play an important role in community mobilisation, awareness-raising, information gathering and activity monitoring on environment conservation. Villagers share information about perceived values and threats to the forest; and information about NGO/CBO activity in each sub-village (Rodgers, *et. al*., und.).

The VECs are comprised of two representatives from each sub-village within a particular village, ranging from three to seven in number (Minziro Forest Report, 2002).

Threats to Genetic Diversity

Villagers cite overharvesting to be one of the main threats to Minziro Forest. *Podo*, the main timber tree in Minziro Forest, are observed on the outskirts of Minziro Forest. Mature *Podocarpus* trees are only found deep within the forest interior where access is difficult (Mulisa, 2011). Other threats include illegal harvesting without a license, fire, encroachment, inadequate management supervision and uncontrolled charcoal burning. In the dry season herds of *Ankole* cattle graze in the adjacent grasslands. These pastures are burned annually to promote new growth, but to the detriment of biodiversity.

Collection on the edges of Lake Victoria

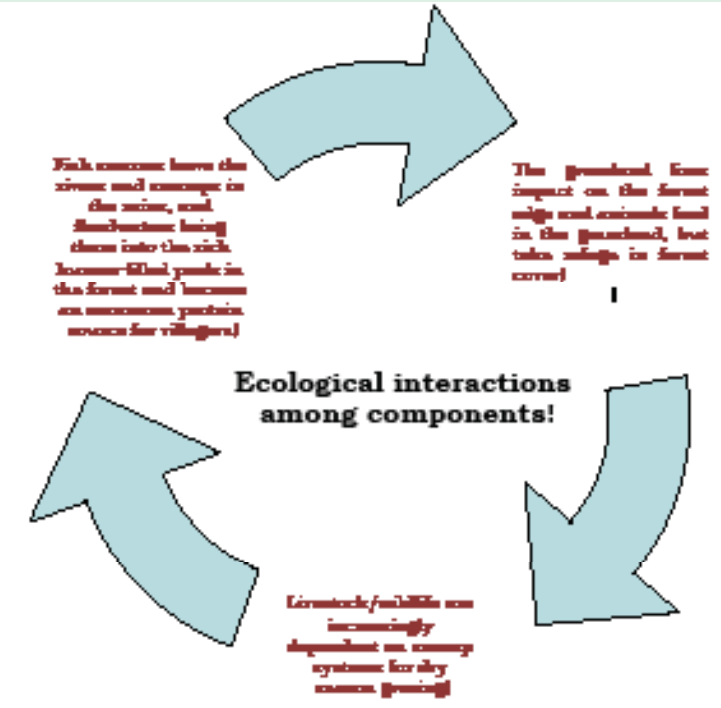
Proximity to forest edge and dependence on the forest for daily needs such as water, firewood, building poles and medicine attribute to the destruction of the forest.

The greatest value of Minziro Forest is marked as a source of firewood. Some villagers enter the forest up to 2 times a day to collect firewood, while others collect firewood

Conservation

There is a great deal of cutting of *Podocarpus* trees of which many appeared to be very small in size (< 35cm dbh) indicating that this species might be nearing commercial extinction in the area (Perkin, *et. al*., 2004).

The seasonal grazing of *Ankole* cattle in the grasslands surrounding the forest initially seems to be a sustainable activity but the levels of burning that occur to generate pasture, may be reducing the forest area. Fire damage seen on the forest edge kills many of the shrub and small trees.



Pennisetum purperium

from the forest once every 2 days. Other values of the forest include timber, medicine, building poles, water, materials for matting and rainfall.

Concluding Remarks

Urgent measures are needed to save the Minziro forest reserve in Misenyi District, Kagera Region. This follows reports of invasion by illegal timber traders in the area. Hundreds of unemployed youths have recently invaded the forest in search of timber and charcoal. Several villagers in the district are concerned over lack of conservation efforts in the area. Collaborative management (joint forest management) with clear roles, responsibilities and rights of partners might offer a way forward.

Management of natural resources - which provide food, shelter, energy and income - means maintaining their diversity at various levels, and in a manner that allows their evolutionary and ecological processes to continue. Conserving forest biodiversity means maintaining ecological conditions suitable for forest cover. If local people recognize how they benefit from the products and services provided by forests, they will be motivated to modify their resource and land use practices and to invest time and effort in forest conservation activities.

As for the SPGRC Network, it can be reckoned that the collected species from Minziro Forest are safe and will continue to be safe for a number of years to come. However, it is the opinion of the authors that more targeted collections should be made in and around the forest to rescue many more species.

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27th SPGRC Board Meeting

The 27th SPGRC Ordinary Board meeting was held at SPGRC in Lusaka, Zambia between 14th and 15th October 2010 under the chairing of Dr Gillian Maggs-Kölling who is also represents Namibian in the Board. The meeting was officially opened by the Zambian Permanent Secretary for Agriculture and Cooperatives, Mr Banda.

After welcoming the Members to the 27th SPGRC Board Meeting, Dr Gillian Maggs-Kölling reminded the members that this was the last meeting in the 5th phase of the SPGRC Project and encouraged the Board to look at the new avenues for the project instead of dwelling on the Project's past successes.

The Sida representative, Mr Pedro de Figueiredo reaffirmed ending of Sida support in 2010 and encouraged SPGRC to contribute to new challenges of Climate Change and look for funding opportunities to move the programme forward.

The Director of FANR, Mrs Margaret Nyirenda acknowledged that SADC had come a long way in battling on how to sustain the achievements that were established at SPGRC and that there was a challenge of how to go beyond this era. She said SPGRC had come a long way with the Donors and still needed them and hoped that the new strategies would take the relationship further beyond this reach. She urged SPGRC management to vigorously work on fund mobilization.

The new Tanzanian Board member, Dr Hussein Mansoor was welcomed to the Board having assumed the position of Assistant Director for Research & Development in the Ministry of Agriculture and Food Security in Tanzania.

SPGRC was directed by the Board to collect and keep the theses for the MSc Students in the library. The Network should be encouraged to publish their findings in relevant international journals – as a concrete output of the capacity building component of the network.

The Board was informed that the SADC PGR Short Course that had been taking place in Sweden over many years was to relocate to the SADC region in 2010. However, the course could not take place in June 2010 as planned because preparations for its regionalization had not been finalized. It was therefore decided by SPGRC Management in conjunction with NordGen that the course be held in the region in November/ December 2010. The Board was informed that the Technical Review and Panning Meeting endorsed this position, provided the course addressed regional priority areas of Information and Documentation, GIS and Statistical Packages.

PGRFA Policy Guidelines

Stakeholders' consultative meeting

Introduction

The SADC Plant Genetic Resources Centre (SPGRC), with financial support from the Southern African Network for BioSciences (SANBio)/Finnish-Southern Africa Partnership Programme to Strengthen NEPAD, funded by the governments of South Africa (Department of Science and Technology) and Finland has been engaged in developing plant genetic resources for food and agriculture (PGRFA) Policy Guidelines that are envisaged to provide the framework for facilitating policy coordination in PGRFA in the SADC region.

Purpose

The PGRFA Policy Guidelines set out the goal, vision, objectives, priorities as well as the policy interventions and institutional framework for addressing PGRFA issues in the region. They provide a road map for developing national policy and legislation at national level in a manner that affirms each country's national priorities and within the context of regional harmonization.

Milestones

The draft PGR policy guidelines developed in collaboration with consultants and stakeholders were presented to the network stakeholders during the annual technical review and planning meeting held in Lusaka, Zambia in September 2011. They were also presented to the SPGRC Board in October 2011 and stakeholders' comments and recommendations were incorporated in the draft document that was then presented to this stakeholders' workshop of December 2011 for finalization.

Finally, a stakeholders' workshop was held in December 2011 in Pretoria with the objective of discussing, improving on and finalize the draft PGRFA policy guidelines before they could be formally presented to the SADC Ministers Responsible for Food Agriculture and Natural Resources for approval and adoption as regional guidelines. The workshop brought together Curators from most NPGRCs. Participants discussed and commented and at the end; the draft policy guidelines had been amended and updated accordingly.

Way Forward

The finalized draft PGRFA policy guidelines were circulated to Curators for their final comments which have been incorporated in the document. It is hoped that the document will be presented to the SADC Ministers Responsible for Food Agriculture and Natural Resources early in 2012 for adoption as regional guidelines.

Upon approval, the guidelines will be translated into two other SADC working languages of French and Portuguese. Thereafter, they will be published and widely shared in the region and beyond.

2010 Annual Technical Review and Planning Meeting

The SPGRC/NPGRCs annual technical review and planning meeting was held between 6th and 10th September 2010 at the Protea Hotel – Cairo Road, Lusaka with the objective of reviewing implementation of the technical activities for the previous (2009/2010) cropping season and evaluating technical plans for the 2010/2011 cropping season. The meeting, attended by more than 30 participants, provided a forum for information sharing and exchange on technical and networking issues. Genebank staffs from all SADC Member States except Mauritius, Madagascar and Swaziland, were in attendance.

The participants were reminded about the coming to an end of the donor funding in December 2010 and therefore the Network was challenged with the future funding with no guarantee of funding by Nordic thus compelling both SPGRC and NPGRCs to strive to raise additional funds from different sources. Participants were urged to play a proactive role in writing proposals that would enhance flow of supplementary funds. Great concern was on the future funding of the planning meetings. It was agreed that ensuring continuity of these meetings it remains the responsibility of the network to mobilize funds.

The participants were also briefed on developments so far achieved in the development of the web-based SDIS, and the quest for transfer of SPGRC portal for hosting it within the region.

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Planning meeting participants

Morphological characterisation of sweet potato [*Ipomoea batatas* (L.) Lam.] accessions at the NPGRC of South Africa

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INTRODUCTION

The root and tuber crops such as potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), indigenous African potato (*Plectranthus esculentus*) and cassava (*Manihot esculenta*), amongst other crops, play an important role in food security, especially in Africa (Allemann *et al.* 2004). Sweet potato is grown for its enlarged storage roots used for human consumption and animal feed. The vines are sometimes consumed as green leafy vegetables and to a lesser extent as animal feed. In Africa, the largest producer of sweet potato is Uganda (Gibson *et al.* 2000).

In South Africa, sweet potato is of considerable economic value with marketing chains well-organised for local and export market. However, potato production and processing is larger than that of sweet potato (Allemann *et al.* 2004). The annual production of sweet potato was approximately 50 000 tons by 2007 and about 20 000 tons sold on the major fresh produce market in South Africa (Department of Agriculture 2009). The crop can be sold on small scale to generate an income, contributing to poverty alleviation (Laurie 2004).

Importance of sweet potato

Globally, sweet potato ranks seventh in production after wheat, rice, maize, potato, barley and cassava (International Potato Centre [CIP] 2008). The largest collection of sweet potato is maintained by CIP, with about 4 950 landraces, 21 wild varieties and six improved varieties. These collections were donated from other genebanks all over the world. In Eastern and Southern Africa, sweet potato is third to cassava and potato among the major food root crops, both in cultivation and consumption (Ewell & Mutuura 2004) and thus plays an important role in food security and nutrition in Africa.

Sweet potato is a good source of carbohydrates, proteins, fibre, iron and moderately rich in vitamin C (Woolfe 1992). The orange-fleshed sweet potato has high levels of beta-carotene which is a forerunner of Vitamin A, contributing much to human health and nutrition especially for children (Woolfe 1992).

Characterisation of crop germplasm

Morphological characterisation of plant species is important in the identification of duplicate accessions, detection of unique traits and also the structure of the population to be conserved, thus saving on the storage space and simplifying selection by plant breeders (Reed *et al.* 2004). Morphological diversity is assessed by measuring variation in phenotypic traits which have long been used in selecting crops that best suit needs of farmers and also led to domestication of useful plants (Gepts 2004). Morphological characterisation supplemented by molecular characterisation provides information for comparison of individual accession/variety thereby facilitating germplasm improvement and effectiveness of the collection.

The descriptors for sweet potato developed by CIP *et al.* (1991) have been widely used to assess morphological variation in sweet potato collections.

Conservation of sweet potato

Conservation of plant genetic resources is important for improving food security and nutrition for the present and future human population especially the resource poor farmers dealing in subsistence farming (Engelmann 1991). High crop diversity ensures adequate food supply and traits to improve yield, quality, resistance to pests and diseases and adaptation to changing environmental conditions. The National Plant Genetic Resource Centres (NPGRCs) serve as *ex-situ* safety mechanisms for conservation of plant genetic resources as well as restoration, and rehabilitation in areas affected by natural calamities. Although the most widely used method of conservation is seed genebanks at low temperatures (Engelmann & Engels 2002), it is suitable only for seed bearing crops (orthodox seeds) that can withstand up to five percent or less reduction in moisture content, neglecting those that cannot withstand the reduction in moisture (recalcitrant seeds) and also

crops that do not produce seeds (Engelmann 1991). Sweet potato is propagated vegetatively; its collections are conserved as clones in field gene banks and as *in-vitro* plantlets in the laboratory (Engelmann 2004). The NPGRC of South Africa conserves approximately 5 000 landrace accessions of crops listed in Annex 1 of the International Treaty for Plant Genetic Resources for Food and Agriculture (ITPGRFA), including 51 accessions of sweet potato (Department of Agriculture 2009).

Justification of research

Sweet potato production is of importance for nutritional and economic values in South Africa. It serves as a security crop for poverty alleviation and food security, especially for small-scale farmers in the rural areas (Laurie & Niederwieser 2004). Though it is not largely produced in formal commercial markets, it is a major source of income for the informal sectors. Beta-carotene together with other essential elements and nutrients found in the crop contribute to human health and nutrition for the present generation (Woolfe 1992) and will continue to do so in the future generations if conserved and utilised sustainably.

The changing climate in addition to the new diseases and pests, necessitate the genetic improvement of crop in order to counteract these effects. Traditional varieties of crops harbour genes required by plant breeders for further breeding advancement. It is important to conserve these traditional varieties of crops to ensure their availability when needed for breeding purposes. Sweet potato is one of the three crops that are vegetatively propagated and maintained as clones in tissue culture at the NPGRC of South Africa. There has been an increasing concern that sweet potato landraces in South Africa are gradually replaced by improved varieties. As mandated by FANR, all crop genetic resources need to be collected, characterised, conserved, documented and utilised to ensure efficiency of the collection.

Currently, the NPGRC of South Africa conserves 51 landrace accessions of sweet potato collected from small-scale farmers. There is little information on trait representation and description within the collection. Therefore, data needs to be collected in order to improve the usability of the accessions. Of these 51 accessions, there is a need to investigate diversity of the collection towards gap analysis and core collection development. This will improve the efficiency of the collection by eliminating duplicate accessions and also identify gaps of unique traits that are not represented in the collection.

MATERIALS AND METHODS

Plant collection

A total of 51 sweet potato landrace accessions were available at NPGRC of South Africa. These had been collected from different locations (Polokwane, Nelspruit, Pietermaritzburg, Bisho) in South Africa by NPGRC between 2003 and 2004.

The passport data captured during the collection included amongst other: accession number, depositor, collection date, province, district and village. However, the available passport data included 35 accessions from the sweet potato collection and no data were available for 16 accessions. This was due to the fact that earlier accessions were collected without passport data. Nonetheless, this study is not attempting to link certain character states to certain geographical areas.

Planting of accessions in the glasshouse

Each accession was planted in a fibre glass green house in 30 cm pots containing potting mixture made of shredded pine bark, in a randomized block of 30 cm between plants. The plants had to be re-established from tissue culture and the material was not enough to plant the replicates during this study. Multifeed fertilizer was applied once per week in a concentration of 28 g/8 L. Plants were watered by hand on every third day.

Data collection

Morphological characters of all the 51 accessions of sweet potato were scored using the standard descriptors of sweet potato described by the CIP *et al.* (1991). A set of 16 vegetative characters were scored three months after replanting in the glasshouse and 15 storage root characters were characterised after nine months in the glasshouse.

Data Analysis

All the data were analysed for the variation in each character (univariate analysis). Multivariate analyses were also done using the Numerical Taxonomy System-pc (NTSys-pc) software (Rohlf 2000) to determine variations among the different accessions. The data for each morphological character was first transformed using the STAND procedure in NTSys-pc in order to eliminate the effects of different scales of measurement. To compare the dissimilarity between accessions the distance coefficient was computed from the transformed data and the information was summarised in dendograms using Unweighted Pair Group Method using arithmetic Average (UPGMA) parameters in NTSys-pc.

Principal Component Analysis (PCA) was performed to determine the correlation on characters and the most significant traits contributing to variation in the collection, through the generation of Eigen vectors and Eigen values. The Eigen vectors with values > 0.7 and < -0.7 indicate the significance of a particular character to each component. Principal Coordinate Analysis (PCoA) was also conducted using the DCenter, Eigen and Graphics programmes as described in Rohlf (2000) to complement Cluster Analysis. Projection was done to compare objects (containing accessions) and the projection file was combined with the Eigen vector (containing characters) file using the Matrix plot option in NTSys-pc to explain the character-based grouping of accessions.

RESULTS

Univariate Analysis

Many morphological characters were scored in this study; only characters with most variability were considered in this analysis. The traits that significantly (< 60 percent) contributed to variability were vine internode length (VIL), leaf lobe type (LLT), leaf lobe number, shape of central leaf lobe, abaxial leaf vein pigmentation, storage root surface defects, storage root cortex thickness and predominant storage root skin colour.

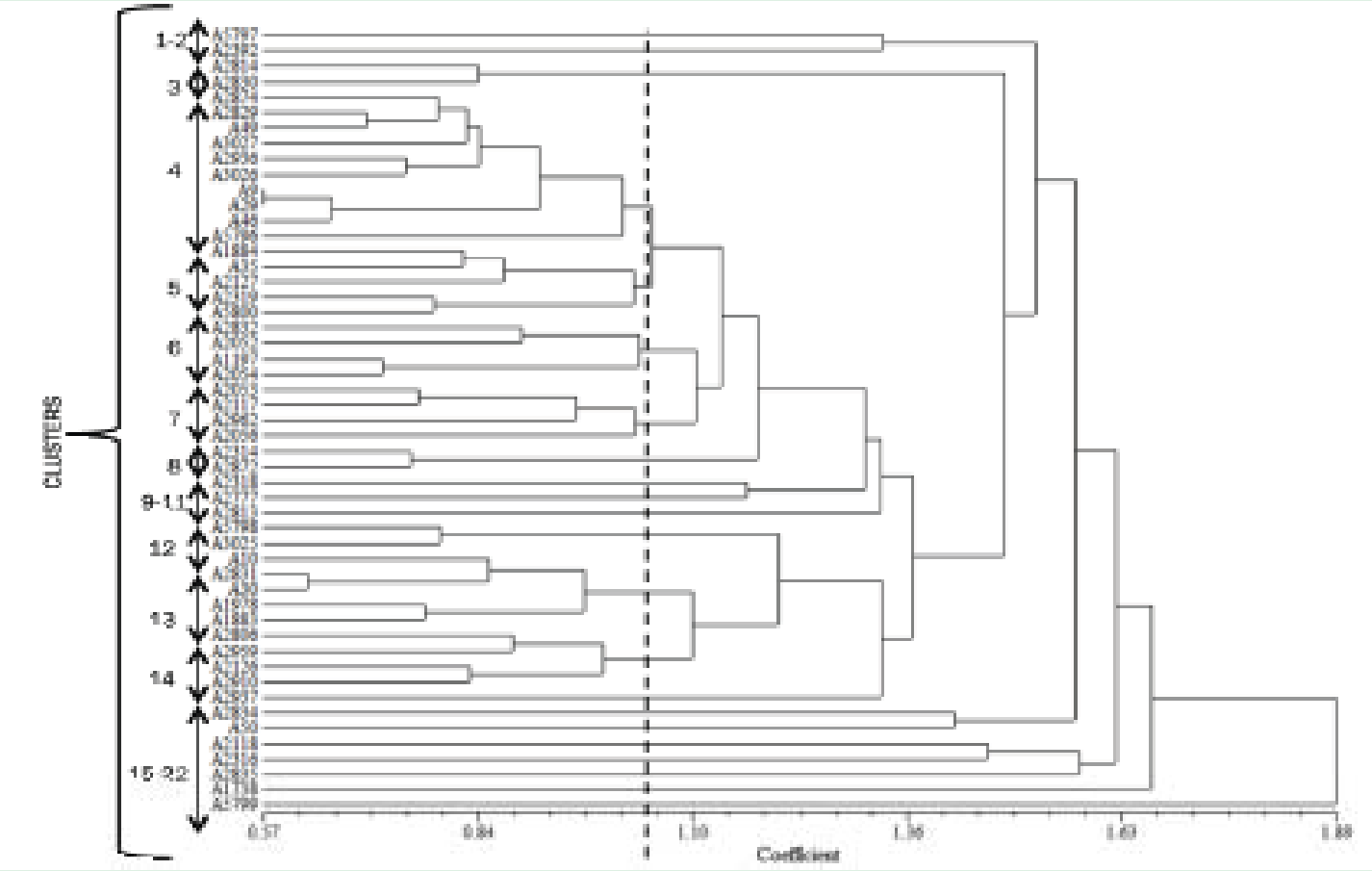

Figure 1: Hierarchical clustering using the distance coefficient. The y-axis shows the 51 accessions and 22 clusters; x-axis indicates the distance coefficient between clusters. 22 clusters at coefficient approximately 1 are shown.

Table 1: Cluster identification membership of 51 accessions of sweet potato, showing the list of accessions in each cluster and characters that made them group together

Cluster number	Cluster Identification of 51 accessions	List of Accessions
1	Ovate storage root	5797
2	Elliptic storage root, Linear-narrow central leaf lobe	2392
3	Abaxial leaf vein pigmentation green	2814, 2830
4	Green mature foliage leaf, Medium mature leaf, Five leaf lobes	2874, 2829, 49, 3027, 2936, 3026, 9, 29, 46, 5796
5	Deep leaf lobe, Five leaf lobes, Lanceolate central leaf lobe	1884, 35, 2127, 2319, 5800
6	Storage root with shallow horizontal constrictions, Very dispersed storage roots	2832, 2052, 1197, 2054
7	Vine tip pubescence absent, Erect plant	2053, 2117, 2962, 2056
8	Predominant vine pigmentation totally purple, Mature leaf lobe moderate	2314, 2872
9	Mature foliage leaf green with purple vein upper	2318
10	Large mature leaf	2777
11	Pink secondary storage root skin, Immature foliage mostly purple	2813
12	Vine tip pubescence heavy	5798, 3025
13	Triangular leaf outline, No lateral lobes, one mature leaf lobe	10, 2831, 30, 1978, 1883
14	Triangular leaf outline, one mature leaf lobe	2806, 2959, 2126, 2910
15	Oblong storage root	2937
16	Green with purple veins upper	2834
17	Short storage root stalk, Yellow Predominant Storage Root Flesh,	50
18	Slightly purple immature foliage leaf, Open cluster storage root, Yellow-green mature foliage leaf, secondary vine pigmentation with purple nodes.	2118
19	Long storage root stalk	2316
20	Slight mature leaf lobe, orange predominant storage root flesh	2835
21	Purple-red storage root skin colour, long vine internode	1738
22	Lower surface and veins of abaxial leaf totally purple	5799

Multivariate Analysis-Principal Component Analysis (PCA)

The NTSys-pc indicated the Eigenvalues measuring the degree of contribution of each component to the total variance of the collection. The first PC axis accounted for 16 percent of the total multivariate variation, while the second accounted for 11 percent and the third for ten percent. The cumulative variation reached 38 percent in the first three PC axes and 76 percent in the tenth PC axes.

The first PC axis differentiated among accessions the leaf lobe number (-0.91), leaf lobe type (-0.88), central leaf lobe shape (-0.87) and leaf outline (-0.82). The second PC axis separated predominant vine pigmentation colour (0.76) whereas the third PC axis split the number of storage roots per plant (-0.78). The characters with < -0.7 and > 0.7 contribute much in each component.

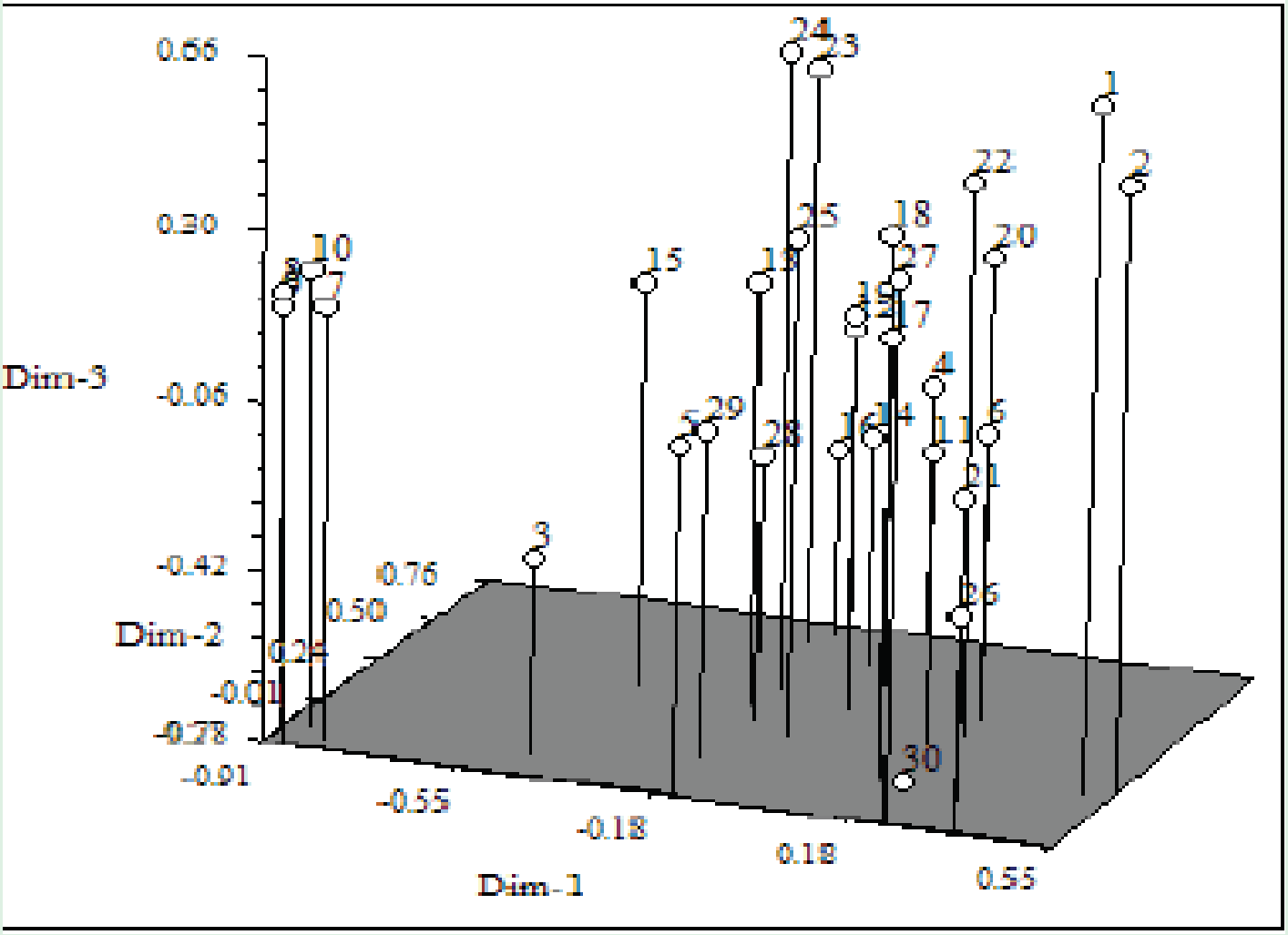

Figure 2: PCA showing the contribution of characters to the variation in 51 sweet potato accessions at NPGRC. Dim-one; two & three refer to three Principal components and their Eigenvalues Numbers, 1-30 refer to the morphological characters scored (Refer to Table 2)

The characters that influenced the first splitting of the 51 accessions were leaf lobe number and vine internode length (Fig. 2). Cluster 21 with only one accession (1738) displayed a long vine internode, while five leaf lobes were observed in Clusters four & five and only one leaf lobe in Clusters 13 & 14. The second split was attributed to predominant vine pigmentation colour and storage root formation while the third split was due to the plant type and number of storage roots per plant. Cluster eight presented totally purple predominant vine. The storage root of Cluster 18 was in an open cluster formation as compared to Cluster six with a much dispersed formation. An erect plant was observed in Cluster seven. These characters had a high magnitude in causing the splitting of accessions.

Table 2: Explanation of character numbers (1-30) shown in Figs. 2 & 4

Character No.	Trait	Character No.	Trait
1	Plant type	16	Petiole pigmentation
2	Vine internode length	17	Storage root shape
3	Vine internode diameter	18	Storage root surface defects
4	Predominant vine pigmentation colour	19	Storage root cortex thickness
5	Secondary vine pigmentation colour	20	Predominant storage root skin colour
6	Vine tip pubescence	21	Intensity of predominant storage root skin colour
7	General outline of the mature leaf	22	Secondary storage root skin colour
8	Mature leaf lobes type	23	Predominant storage root flesh colour
9	mature leaf lobes number	24	Secondary storage root flesh colour
10	Shape of central leaf lobe	25	Distribution of secondary storage root colour
11	Mature leaf size	26	Storage root formation
12	Abaxial leaf vein pigmentation	27	Storage root stalk
13	Mature foliage leaf colour	28	Variability of storage root shape
14	Immature foliage colour	29	Variability of storage root size
15	Petiole length	30	Number of storage roots per plant

Multivariate Analysis-Principal Coordinate Analysis (PCoA)

The 51 accessions of sweet potatoes were separated into 22 clusters by PCoA axes one and two. In fact, this separation was in agreement with the grouping of accessions in Fig. 11. The first PCoA contributed 17 percent and the second 13 percent to the grouping of accessions (Fig. 3). In addition the first four components cumulatively reached 50 percent.

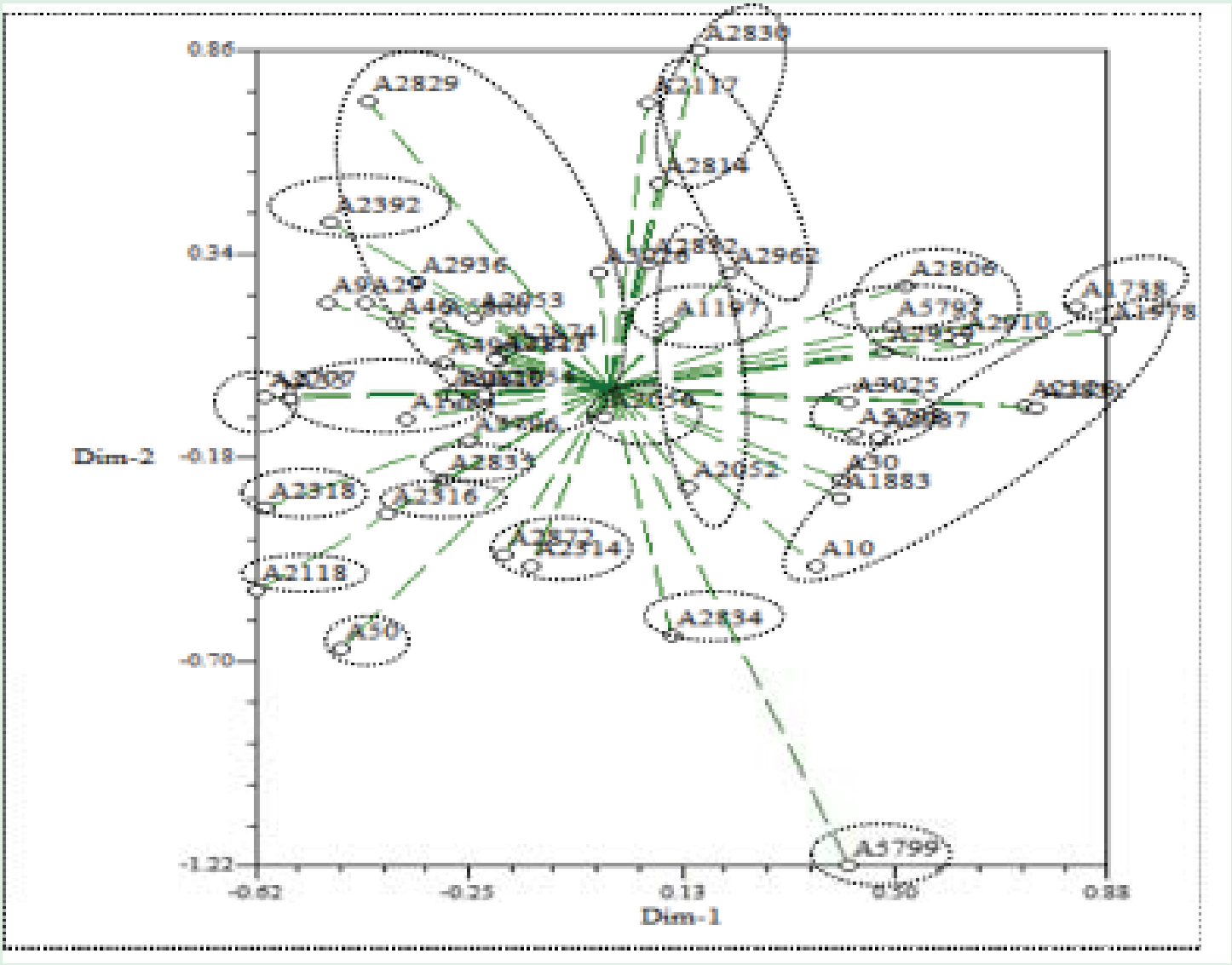

Figure 3: Plot of the first two Principal Coordinate axes (dim-1 & 2) of 51 accessions of sweet potato. The 22 groups are shown, confirming the groups observed in Cluster analysis (Fig. 1)

Multivariate Analysis-Matrix Plot

The projection matrix performed confirmed the grouping identified in Fig. 1. A combination of characters caused the grouping of the 51 accessions characterised.

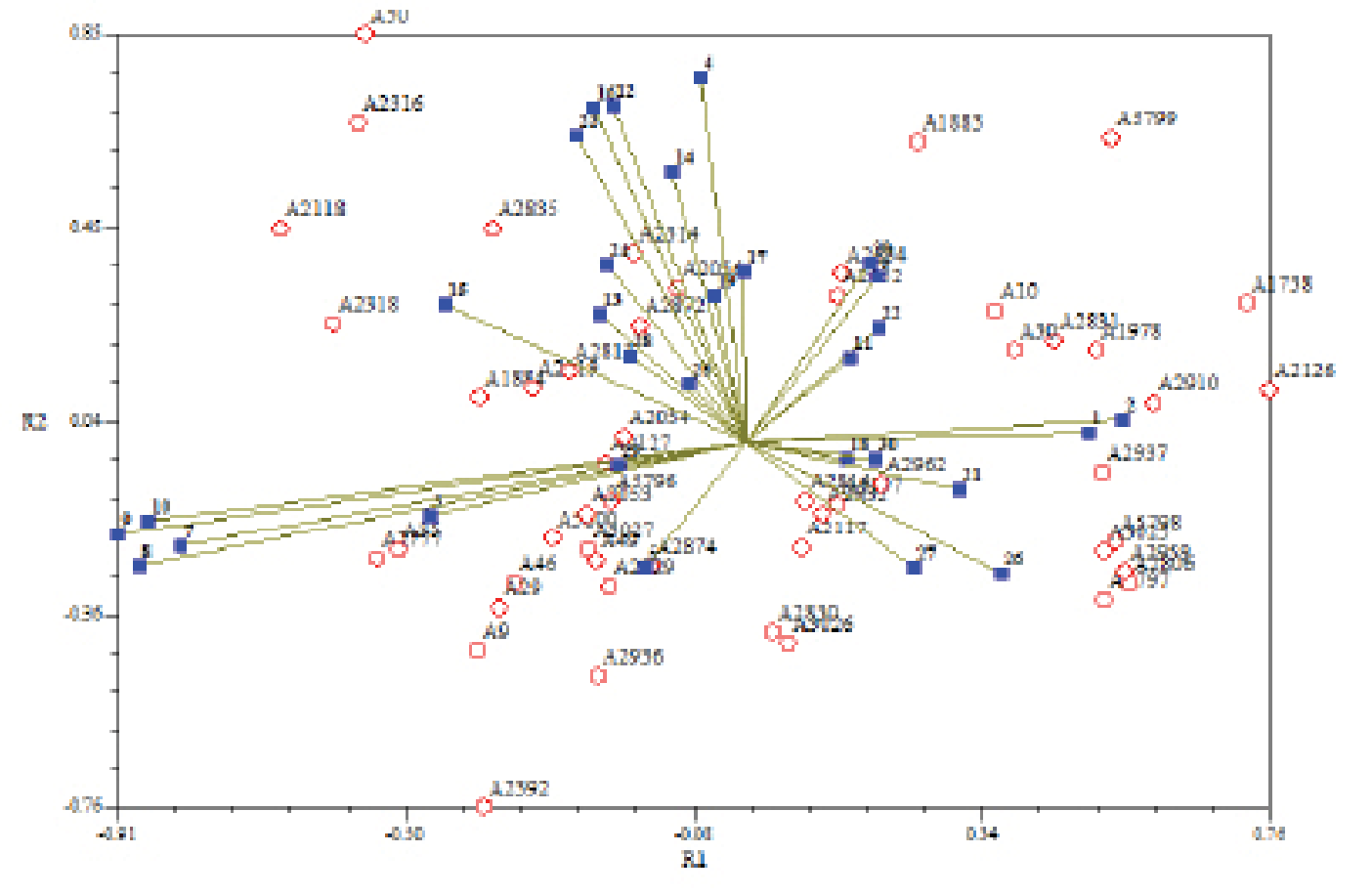

Figure 4: Matrix plot showing characters that caused the grouping of 51 accessions of sweet potato collection at NPGRC. Circles (○) represent 51 sweet potato accessions and the squares (□) represent 30 morphological characters scored (Refer to Table 2)

Discussion

The 51 accessions of sweet potato at the NPGRC of South Africa grouped into 22 clusters (Fig 1) at a distant coefficient of approximately one, which indicate a high level of morphological diversity in the collection. The coefficient of one was selected based on similar studies done by other scientists (Veasey *et al.* 2007). According to Mohammadi & Prasanna (2003) the distant coefficient that shows the largest number of groups should be considered. In this study, coefficient one gave a meaningful number of clusters. Accessions 9 and 29 were almost similar in all the characters, except for the vine internode diameter, secondary vine pigmentation colour, type of mature leaf lobe and petiole length.

Huaman (1999) identified duplicates of the same cultivar ranging from 1-99 at CIP. Furthermore, Veasey *et al.* (2007) observed seven duplicates at a similarity index ranging from 0.12-1.00, which they considered as indicative of high diversity among sweet potato accessions. Tairo *et al.* (2008) reported a distance coefficient of between 0-0.57, indicating a very low diversity among sweet potato accessions in Tanzania. In this study, the distance coefficient varying from 0.57-1.89 gives an indicator of high morphological diversity in sweet potato collection of the NPGRC.

The total number of variables (30 characters scored) determines the number of components and thus number of PC axes (30). NTSys-pc indicated the Eigenvalues measuring the degree of contribution of each component to the total variance of the collection. Sneath & Sokal (1973) highlighted that the first three PC components (Fig. 2) showing high Eigenvectors should be considered as significant because they can explain as much as up to half of the total variation in a collection. Higher coefficients or Eigenvector values for a certain character indicate the relatedness of that character to the specific PC axes (Sneath & Sokal 1973). Rohlf (2000) advocated that the Eigenvectors (characters in each component) are significant at values > 0.7 and <-0.7.

Similarly with PCA, the total numbers of accessions studied determine the total number of PCo axes. In this case, 51 accessions of sweet potato generated 51 PCo axes. PCoA, according to Rohlf (2000) complements cluster analysis. The latter is more sensitive to closely related objects; whereas, PCoA is more informative in terms of distances among major groups. The groupings of accessions as observed in Cluster Analysis were confirmed by PCoA. However, PCoA does not calculate both the accessions and characters at once. In this case, projection matrix supplemented PCoA because both matrices (accessions & characters) were projected simultaneously to determine which characters caused the accessions to group together.The projection matrix performed confirmed the grouping identified in Fig. 1.

Predominant vine pigmentation colour, vine tip pubescence, abaxial leaf vein pigmentation colour, immature foliage leaf colour, mature foliage leaf colour, mature leaf size, petiole length, petiole pigmentation, storage root shape, storage root cortex thickness, predominant storage root skin colour, secondary storage root skin colour, predominant storage root flesh colour, secondary storage root flesh colour, distribution of storage root flesh colour, and number of storage roots per plant were responsible for the groupings in Clusters 6, 8 9, 11, 17, 18, 19 & 20; and colour was the dominating aspect in these characters. Clusters 1, 3, 7, 12, 13, 14, 15, 16, 21 & 22 were linked to plant type, vine internode length, storage root surface defects, and intensity of predominant storage root colour, storage root formation, storage root stalk and variability of storage root size.

In this study, the traits that contributed to high variability (<60 percent) in the univariate analysis were vine internode length, leaf lobe type, leaf lobe number, shape of central leaf lobe, abaxial leaf vein pigmentation, storage root surface defects, storage root cortex thickness and predominant storage root skin colour. In contrast with Table 1, sweet potato collection in Vale do Ribeira presented 39 percent of its accessions with a very slight leaf lobe type (Veasy *et al.* 2007). They also observed 45 percent almost half of their collection with five leaf lobes, similarly to this study with 49 percent having five leaf lobes.

The PCoA & PCA complemented clustering method in that it confirmed the groups and it is not sensitive to closely related objects (Mohammadi & Prasanna 2003). And also, PCA depicted the relationship among the characters scored and their contribution to the total variance of the 51 sweet potato accessions. These analyses combined gave a fairly reliable output that can be used to make safe conclusions if there were replicates.

Sweet potato is a clonally propagated crop and thus there is a risk of many duplicates in the collection. Nonetheless, all the analysis performed on the morphological characterisation data obtained from sweet potato landrace accessions available at NPGRC, displayed high variation that exist in the collection. This needs however to be verified with another study with replicates for each accession. Furthermore these findings need further verifications from biochemical or molecular analysis.

Several plants of each accession need to be grown in a randomized test-design before safe conclusions can be made. Environmental factors such as light, temperature, water and pH of the soil affect anthocyanin production and the size of the leaves and storage roots. However, all accessions used in this study were grown under the same condition and treated exactly the same as is the requirement for performing characterization. Taro was grown on the edges of the 51 accessions in order to minimise the edge effect and ensure the uniform condition of the growth environment in the glasshouse. In morphological characterisation, plants on the edge of the planting site are usually not characterised because they may have been influenced by the external environmental conditions.

CONCLUSIONS AND RECOMMENDATIONS

i. Preliminary results presented here show that the NPGRC of South Africa conserves high morphological diversity of sweet potato landraces in the field and tissue culture.

ii. From the 51 accessions characterized unique traits were identified as shown in the cluster identification membership. This means that there are still gaps in trait representation in the sweet potato collection at NPGRC of South Africa. The subsequent collections of sweet potato should therefore, focus on the unique traits.

iii. Further morphological analysis but also biochemical or molecular analysis of the same set of landraces need to be performed to ascertain the findings of this study. Sweet potato landraces are gradually replaced by the improved varieties.

iv. We recommend the collection of most of the landrace diversity available and for conservation strategies to be strengthened.

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