# Sweetpotato breeding for northeastern Uganda:

## Farmer varieties, farmer-participatory selection, and stability of performance

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# Propositions



1. Farmer varieties can make a rapid contribution to sweetpotato improvement in Uganda and other regions where high diversity of sweetpotato landraces exists.
   (this thesis)

2. Using national germplasm resources is much cheaper than importing them from outside the country as long as there is sufficiently high genetic variation for selecting the desired traits.
   (this thesis)

3. As with many other commodities, sweetpotato is mainly grown by women as long as it is a staple food for own consumption but men take over as soon as sweetpotato becomes a cash crop.

4. It is a challenge to find ways that both science and traditional knowledge can work in a complementary fashion towards improving human well-being, not in asserting the primacy of the respective cultures out of which they have developed.
   (David Dickson, 15 September 2003, Science and Development Network)

5. Awareness of the value of indigenous knowledge – particularly its potential contribution to sustainable development and poverty alleviation – is growing at a time when such knowledge is being threatened as never before.
   (Science and Development Network, August 2002)

6. Although indigenous knowledge has proven its value in many cases it cannot, and should not, be promoted without first being critically assessed.
   (Science and Development Network, August 2002)

7. Poor people can be rich in heart and knowledge.

8. There is no limit to what a man can do or where he can go if he doesn't mind who gets the credit.
   (Robert W. Woodruff, Chairman and CEO of Coke, 1923-1985)

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# Abstract

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Between 1999 and 2001, the author conducted various studies, primarily in northeastern Uganda, aimed at rapidly assessing the potential of farmer varieties of sweetpotato (*Ipomoea batatas*) from northeastern Uganda in contributing to the varietal improvement programme in Uganda. These studies included: (i) collection of germplasm (farmer varieties) and farmer knowledge about varieties from five districts in northeastern Uganda; (ii) assessment of morphological diversity and duplication in the collected germplasm; (iii) farmer participatory on-station selection of promising varieties from the collected germplasm for on-farm and multi-locational testing; (iv) farmer-managed on-farm testing in Soroti District (northeastern Uganda) of selected farmer varieties, cultivars from the Ugandan breeding programme and local farmer varieties; (v) multi-locational testing and stability analysis of selected farmer varieties and officially released cultivars from the Ugandan breeding programme in multiple test environments (20 tests over three seasons). Additionally, the author presents results from a multi-national, multi-locational test of elite sweetpotato germplasm in eastern Africa used to study selection efficiency.

During germplasm collections, a total of 206 accessions were collected, along with farmer knowledge about them, and of these 188 were classified as distinct accessions, exhibiting considerable morphological variation. Many accessions were collected from remote locations where sweetpotato is not a commercial crop, while relatively few accessions were collected from areas where the crop is important commercially. During the on-station assessment of the collected germplasm, 11 accessions were selected for further testing from a total of 160 accessions evaluated at two sites. Nine of the 11 accessions selected by farmers were common to both sites. Farmer selection criteria were verified, with a high weighting given to fresh storage root yield, storage root number and harvest index, in addition to root dry matter content and appearance. During on-farm trials over two years, the 11 farmer varieties were generally preferred over local varieties, and cultivars from the Ugandan breeding programme. During multi-locational trials, the 11 farmer varieties on average performed better with respect to broad adaptation, specific adaptation and yield stability, than the cultivars from the breeding programme. In addition, some of the farmer varieties showed specific adaptation to local environments.

Results of the multi-national trial were analysed to generate recommendations for optimum selection efficiency, and indicated a two-step selection procedure with two locations and one replication at Selection Step 1 and five locations and two replications at Selection Step 2 (total test capacity of between 450 and 950 plots).

During the farmer participatory phases of this research, farmers were highly competent in sweetpotato varietal selection and were aware of the genotype-by-environment interactions and biodiversity. Results illustrate the potential that farmer varieties can have in the improvement of sweetpotato in Uganda and other regions where high diversity of sweetpotato landraces exists, and allowed us to recommend an approach for the rapid and efficient selection of superior genotypes from local germplasm in East Africa.

Key words: Agro-biodiversity, farmer varieties, indigenous knowledge, farmer-participatory research, genetic diversity, genotype-by-environment interaction, germplasm collection, *Ipomoea batatas*, specific adaptation, yield stability, sweetpotato, variance component estimates.

# Preface

The work described in this dissertation was conducted in Uganda from 1999 to 2001, during the time that the author was a lecturer at the Arapai Agricultural College. It would not have been possible without the support, encouragement and co-operation of a great many people, both in Uganda (one of the great sweetpotato-producing nations of the world) and elsewhere. I cannot personally thank each and every one, but I would like to mention many of the individuals that were so helpful to me during my endeavors.

I would first like to give my high appreciation to Drs. Ted Carey, Peter Ewell, Michael Hermann and Nicole Smit from the International Potato Centre (CIP). To Nicole, my thanks for suggesting that I might have the possibility of working with CIP and for introducing me to Dr. Carey. Dr. Carey and Dr. Ewell initially supported my PhD research in Uganda while Dr. Hermann continued supporting my research after Dr. Carey left for the USA in August 1999. Ted, I am very happy that you guided me in setting up the research proposal and that you continued supervising me while you have other commitments at Kansas State University, USA. Moreover, I enjoyed joining you during sweetpotato harvests in farmers' fields in Gweri and Serere-Abilaep, and at the Serere and Arapai stations. I never met a great scientist like you who did not mind to sweat under the hot sun in Uganda, to get your shoes, hands and clothes dirty, and to drink water directly from the boreholes in Gweri. I am surprised, but happy to have you as my "Guru". Peter, I am very pleased that you entrusted me to conduct this research for northeastern Uganda under your responsibility as the CIP Representative for Sub-Saharan Africa, although I was not really working for CIP or for the National Agricultural Research Organization of Uganda, but only as a collaborating researcher. Michael, I couldn't show how much my happiness was when I heard, during the regional meeting of the BMZ-project in Kampala in May 1999, of your willingness to take over CIP's financial support of my work.

Above all, I am deeply indebted to Prof. Piet Stam, who accepted my on-going research in Uganda to be put immediately under his responsibility, and also to Prof. Paul C. Struik who offered his willingness to supervise me in the process of writing the thesis and in the arrangement of this thesis to be published. Both of you are my excellent promoters, my fathers as well as my great supervisors. Though you supervised many students, you always gave your time (when I knocked at your doors without following the rules of making advanced appointments) in order to discuss the results and problems which I faced during writing. Prof. Stam always patiently listened to my explanations while Prof. Struik was always quick to send his comments to me. I

learned and gained so much knowledge and skills from both of you. I really enjoyed my learning process when finalizing the thesis. Thank you very much!

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My lovely (late) mother, who used to pray for me, continues giving her spirit of struggle to my study. As a result, I won't feel tired to cultivate more knowledge whenever I have the chance. I would like to honor this result for my sweet memoriam to you, Nang!

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Erna Abidin Wageningen, May 2004

# Contents

# CHAPTER 1

# General introduction

The work described in this thesis was conducted in cooperation with the Ugandan National Agricultural Research Organization (NARO), local agricultural extension personnel, farmers, and the International Potato Center (CIP). It was aimed at assisting the Ugandan sweetpotato breeding efforts to select superior varieties for farmers in northeastern Uganda. Specifically, I used farmer participatory methods during the collection and selection of regional germplasm to rapidly identify promising varieties for local farmers, and I assessed the stability of these varieties over a number of sites or environments in comparison with elite varieties recently released by the Ugandan national breeding programme. This work is reported in five chapters of the thesis. This introductory chapter describes the sweetpotato, its role in traditional and commercial agriculture, and the challenges faced by sweetpotato breeding programmes attempting to serve farmers using low-input systems. Next, I describe the situation of sweetpotato and sweetpotato improvement in Uganda, and lay out the rationale and objectives of this thesis research.

## The sweetpotato crop

### *Origin, distribution, and diversity*

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is a dicotyledonous plant which belongs to the family Convolvulaceae. Amongst the approximately 50 genera and more than 1000 species of this family, only *I. batatas* is an important food crop (Purseglove, 1991; Woolfe, 1992).

Sweetpotato is a hexaploid (2n = 90) (Jones, 1964). It has been suggested that it was derived by amphidiploidy from a tetraploid (2n = 60) and a diploid (2n = 30) to produce a triploid (2n = 45), followed by subsequent doubling of the chromosomes to produce the hexaploid (Purseglove, 1991). The number of wild *Ipomoea* species is estimated at more than 400, but *I. batatas*, a 'cultigen', is not found in the wild; nor, so far, has a direct ancestor of this species been positively identified (Woolfe, 1992).

Sweetpotato is of American origin. Austin (1988) postulated that the centre of origin of *I. batatas* was somewhere between the Yucatán Peninsula of Mexico and the mouth of the Orinoco River in Venezuela. The 'cultigen' had mostly likely been spread by local people to South America by 2500 BC. Zhang *et al.* (1998a) provided strong supporting evidence that the geographical zone postulated by Austin is the primary centre of diversity. The much lower molecular diversity found in Peru-Ecuador suggests that this region should be considered as a secondary centre of sweetpotato diversity.

The crop was spread widely by Portuguese explorers to Africa, India and the East Indies in the 16th century (Yen, 1974; Huamán and Zhang, 1997). At present, the sweetpotato is an important low-input crop in many places in Sub-Saharan Africa (Ewell and Mutuura, 1994; Bashaasha *et al.*, 1995; Kapinga *et al.*, 1995; Tayo, 2000). Sweetpotato production throughout the region is mainly based on large numbers of landraces (Carey *et al.*, 1998). On the basis of numbers of landraces and the adaptation of the varieties to local conditions, including resistances to regionally important diseases and pests, eastern Africa is considered to be a secondary centre of sweetpotato genetic diversity (IBPGR, 1981; Huamán and Zhang, 1997; Mwanga *et al.*, 2001a).

The crop is genetically unstable and has the tendency to mutate (Hernandez *et al.*, 1964; Collins and Cannon, 1983); it also has an obligate outcrossing nature and a capacity to flower and set seed (Miller, 1937, 1939; Hernandez and Miller, 1964; Jones, 1965 a, b). These natural characteristics give rise to large numbers of landraces grown by farmers under traditional agricultural systems in several areas of Asia, Africa and Oceania (Yen, 1974; Carey, 1996; Carey *et al.*, 1998). Woolfe (1992) stated that there is more diversity in the sweetpotato than in, for example, cassava (*Manihot* spp.), yam (*Dioscorea* spp.) or cocoyam (*Colocasia* spp.). Cultivars differ from one another in the colour of the root skin (white, cream, yellow, brown, red and purple) or flesh (white, cream, yellow, orange or reddish-purple), in the size and shape of the roots and leaves, in the depth of rooting, the time to maturity, the resistance to diseases and in the texture of the cooked roots.

### *Ecology*

The crop is widely grown in tropical, sub-tropical and temperate areas between 40° N and 32° S (Purseglove, 1991; Woolfe, 1992; Ahn, 1993). A wide range of cultivars are suitable for different soils and climates. Sweetpotatoes are grown on a variety of soils, but well-drained light and medium textured soils with a pH range of 4.5-7.0 are more favourable for the plant (Woolfe, 1992; Ahn, 1993). It is unnecessary to apply lime unless the soil has a high aluminium concentration. Sweetpotatoes are very sensitive to aluminium toxicity and will die about 6 weeks after planting if lime is not applied at planting in this type of soil (Woolfe, 1992). Best growth is obtained with temperatures above 24 °C, abundant sunshine and warm nights. Annual rainfalls of 750 - 1000 mm are considered most suitable, with a minimum of 500 mm in the growing season. The crop is sensitive to drought at the tuber initiation stage 50 - 60 days after planting and is not tolerant to water-logging, as it may cause tuber rots and reduce growth of storage roots if aeration is poor (Ahn, 1993).

There have been indications that nitrogen-fixing bacteria of the *Azospirillum* genus are found in association with the roots of sweetpotato (Hill *et al.*, 1983). Nitrogenase activity varies among different cultivars (Woolfe, 1992). Evaluation and enhancement of microbial associations promoting nitrogen-fixation in sweetpotato roots could be an alternative to the use of expensive chemical fertilizers for increasing plant production. This might also provide an explanation for the capacity of the crop to perform reliably under conditions of low soil fertility.

***Uses***

The edible storage roots of sweetpotato are important food for resource-poor farmers in many countries (Woolfe, 1992; Carey, 1996; Carey *et al.*, 1998; CIP, 1998). Sweetpotato produces two useful food types from the same plant, namely fleshy storage roots and green tops (vines consisting of stems and leaves). Both can be used as a nutritious food for human and animal feeding.

Apart from its use as a staple food, sweetpotato is being made into a wide variety of products. Among these are a tropical spinach or salad green, a sweet dessert, a variety of convenient processed products, fast or snack foods (fries and chips), multi-purpose flour, alcoholic or non-alcoholic drinks, starch, animal feed or a basic industrial raw material. It has high provitamin A content which could make it a valuable tool for combating widespread vitamin A deficiency, particularly among children in the developing world (Woolfe, 1992; http://www.cipotato.org/VITA.htm; Hagenimana *et al.*, 2001). Yamakawa and Yoshimoto (2002) claim that sweetpotato can play an important role in activating some physiological functions of the human body in order to prevent serious diseases such as diabetic sickness, cancers, liver injury, blood pressure, etc.

***Constraints***

Woolfe (1992) explained that the low status of the crop is due to its image as a subsistence crop, a 'poor man's food' or something to be eaten only in times of dire need such as famine or war. So, this low status may have been a limiting factor for this crop in its exploitation as foods of highly nutritional quality. Pre- and postharvest losses, resulting in excessive waste, have increased prices to levels unattractive to those searching for a low cost nutritious substitute for more expensive, but prestigious, foods. In many areas, the lack of cultivars with characteristics catering to consumer preferences for colour, texture, flavour and low fibre levels, combined with the difficulties of handling and storage of a highly perishable commodity under tropical conditions of elevated temperatures and humidities, has frequently resulted in the sale of inferior quality sweetpotatoes. The high levels of sweetness and the strong flavour associated with many cultivars may have reduced its popularity as a staple food, and make it difficult to combine with other foods in a variety of dishes. Sweetpotato leaves and tips are often considered to be tough and too strongly flavoured in comparison with other green leafy vegetables. These factors have helped to reduce the esteem of the sweetpotato in the eyes of the consumer. Furthermore there is little available as yet in the developing countries with respect to new, tasty, interesting and nutritious processed forms of sweetpotato, appropriate to local dietary preferences, which would help to promote and raise its status in the eyes of those who would benefit most from increased intakes. The bulkiness of sweetpotatoes, their relatively low cash value per unit of weight, and difficulties associated with their storage and transportation in tropical conditions have resulted in a very low level of importance in international trade; thus the bulk of the crop is still used or sold for domestic purposes.

***Research challenges***

In the Far-East including China, Japan and Taiwan the sweetpotato has evolved from being a food security crop, to being important for animal feed, starch production for sugar syrups, alcohol and other value-added products (Woolfe, 1992; Yamakawa and Yoshimoto, 2002). Breeding has been successful in many places (USA, Japan, China and Peru), but has been somewhat less successful in places where sweetpotato has retained its character of "subsistence" crop (Woofle, 1992). Often sweetpotato breeding was neglected in the past due to the non-commercial nature of the crop. Recent efforts, particularly in Sub-Saharan Africa have been promoted by international agricultural research centres in collaboration with national programmes. The challenges include selecting for marginal environments, as well as ensuring adequate attention to quality, necessary adaptations and resistances to biotic and abiotic constraints. To be most successful, the breeding efforts need to be accompanied by concerted efforts at seed dissemination.

## Farmer participatory breeding

It is now over 20 years since the farming system approach was initiated in southern Africa, and now research is primarily conducted on-farm (Snapp, 2002). Farmer involvement in the selection process is seen as a tool for enhancing the efficiency and effectiveness of plant breeding efforts, particularly for variable and marginal environments where adoption of improved varieties from plant breeding programmes has been limited (Sperling *et al.*, 1993). Nepalese farmers selected chilling-tolerant rice cultivars from $F_5$ bulk families (Sthapit *et al.*, 1996). Mulatu and Belete (2001) reported that participatory varietal evaluation of sorghum in Ethiopia was a means for enhancing adoption and increasing genetic diversity. Ceccarelli *et al.* (2001) concluded that it is possible to organize a plant breeding programme in which farmers become major actors in the selection of new cultivars.

Franzel and Coe (2001) classified three types of on-farm trials, depending on the objectives of the trials, who designs it, and who manages it. Type 1 trials are researcher-designed and -managed and their objective is to assess biophysical responses. Type 2 trials are researcher designed and farmer managed, i.e., farmers agree to implement a common design. They are useful to get farmer feedback on specific prototypes or for conducting economic analyses. Type 3 trials are farmer designed and managed where farmers can experiment on their own. The objective of this type of trial is to assess farmer innovation and acceptability of new technology. Witcombe *et al.* (1996) distinguished between participatory varietal selection and participatory plant breeding. In participatory varietal selection, farmers evaluate near-finished or finished products whereas participatory plant breeding is the selection by farmers of genotypes from segregating populations.

There has been limited adoption of improved seed and farming technologies by smallholder farmers in many regions of the world. According to the participatory research literature, one of the major barriers to adoption has been insufficient attention to understanding farmer priorities and perceptions (Chambers *et al.*, 1989; Ashby and Sperling, 1995). Farmers' production priorities are often assumed to focus on maximizing yields or financial returns, while in reality they may concentrate on gaining the best return from a very small cash investment, or on maximizing food security (Snapp, 2002). Lilja and Ashby (http://www.prgaprogram.org/participatory.htm; 2002) provided an example of feedback and cost impacts (i.e., project and participants) gained from the participatory plant breeding. Feedback led to a more effective and efficient research process, increased adoption, and improved the social, capital, and the empowerment of farmers. The cost impacts related to the change in costs and cost structures, and the time over which they occurred as compared to conventional breeding. Meanwhile, the participant costs were (i) the opportunity cost of their time and (ii) the other resources used of the participants.

In Sub-Saharan Africa, there have been numerous instances of farmer participatory research for sweetpotato variety selection (Kapinga *et al.*, 2000; Ndolo *et al.*, 2001; Shamebo and Belehu, 2000). This work has been stimulated in part because of national variety release requirements for breeders to test varieties on-farm for consumer acceptance before release. In most of these cases, the second type of trial design described by Franzel and Coe (2001) was used.

**Genotype-by-environment interactions and farmer-participatory research**

Participatory methods have been widely adopted by researchers working on applied agricultural problems including crop breeding. Using any models of farmer participation has implications for the design and analysis of methods used. Data from on-farm trials take many forms, from crop yields measured on individual plots to the reported consensus of participants at a group meeting. Any set of data comprising multiple observations that are not all identical will require some sort of statistical analysis to summarize the common patterns.

Genotype-by-environment (G×E) interaction is the differential response of genotypes (cultivars) to changing environmental conditions. Strong G×E may lead to different rankings of cultivars in different environments. Thus, the assessment of genotype-by-environment interaction, which tells whether a cultivar is adapted to specific growing conditions or is broadly adapted to a wide range of environmental conditions, is of extreme importance to a plant breeding programme.

Methods to document the biological performance and yield potential of varieties and technologies are widely known. For example, it is highly recommended that on-farm trials be conducted at representative, well characterized sites, so that results can be extrapolated to recommendation domains. In some cases researchers use trial designs on-farm similar to those conducted at research stations, with replicated plots per treatment and a randomized complete block design. Generally farmers are treated in a contractual manner, and this trial design can be an effective means for evaluating technology performance under edaphic conditions typical of a farming community (Snapp, 2002).

Another widely used approach is to conduct a large number of on-farm trials to evaluate technology performance across a wide spectrum of environments (Fielding and Riley, 1998; Mutsaers *et al.*, 1997). This takes into account the variability of the heterogeneous environment that characterizes many smallholder regions (Snapp, 2002). A trial design where each site acts as a replicate is one approach that allows many environments to be sampled (Mutsaers *et al.*, 1997). Adaptability analysis and related statistical tools can use data from the many sites to evaluate performance across different environments. This may make it possible to detect which varieties perform best in a weedy environment or on acid soils, for example (Snapp, 2002). Another recently developed tool for multi-environment trial data is the framework of multiplicative mixed models, which can be used to model genetic variances and covariances in terms of response to environmental factors. These statistical approaches are illustrated by van Eeuwijk *et al.* (2001) for participatory breeding and variety selection in barley.

**Sweetpotato in the agricultural systems in Uganda**

In Uganda crop cultivation and livestock husbandry are based on the peasant farmers who ingeniously use one natural environment for a meagre living. The peasant farmer is a small holder with access only to limited land which is the means of his livelihood. The farmer uses mainly family labour in farm production and only engages in markets when surplus is realized.

Uganda is Africa's largest producer of sweetpotato with production over 2.5 million tonnes on 572,000 hectares (http://www.fao.org; 2002). Sweetpotato is a major co-staple crop in Uganda, where per capita consumption is around 100 kg per year. It is important for food security, and increasingly, as a cash crop (Bakema *et al.*, 1994; Scott *et al.*, 1999). The storage roots of the crop are widely consumed in fresh-boiled or steamed form throughout Uganda, but the long dry season in northeastern Uganda, and accompanying weevil (*Cylas* spp.) infestations, have led farmers to develop sun-dried products, such as amukeke (dry-sliced form) and inginyo (dry-chunk form) (CIP, 1998; Owori and Hagenimana, 2000).

Sweetpotato fits well in the farming and food systems of Uganda (Mwanga *et al.*, 2001b). Production is mainly concentrated in the densely populated, mid-altitude regions between 1000-2000 m above sea level (Hakiza *et al.*, 2000). The crop is mostly grown in small plots, < 0.5 ha, by subsistence farmers (Bashaasha *et al.*, 1995) mostly in low input agricultural systems (Carey *et al.*, 1998).

In most places the women play a major role in cultivating the sweetpotato crop (Bashaasha *et al.*, 1995) and they are able to distinguish the varieties (Hakiza *et al.*, 2000).

In Uganda, sweetpotato ranks third among the starchy staple crops after cassava (*Manihot esculenta* Crantz) and banana (*Musa* sp.) (Mwanga *et al.*, 2001b). However, the crop is second after banana in western and central regions, and to finger millet (*Eleusine coracana* (L.) Gaertn.) in the northern and eastern regions (Mwanga *et al.*, 2001b; Bashaasha *et al.*, 1995).

In Uganda most farming systems have undergone profound changes in recent years. In particular, in northeastern Uganda sweetpotato has become more important. In this area the factors that have contributed to such changes are civil strife, decimation of cassava, another important staple crop, by the African Cassava Mosaic Virus (ACMV), cattle depopulation, decline in cotton marketing systems and population increase. Adverse climatic variability is now widely perceived to be a driving force of change in the farming systems (Musiitwa and Komutunga, 2001).

**Farmer sweetpotato varieties in Ugandan agriculture**

In almost every district the number of varieties grown is large (Bashaasha *et al.*, 1995).

Often, a plot contains a mixture of varieties (Ewell and Mutuura, 1994), sometimes completely intermixed, but usually each variety is planted in a separate section of the plot (Hakiza *et al.*, 2000). Many of these varieties have been reported to be relatively low yielding, narrowly adapted, and susceptible to diseases and pests (Bashaasha *et al.*, 1995).

In any one village the relative popularity of individual cultivars changes with time (Hakiza *et al.*, 2000). There are lists of sweetpotato varieties currently grown or dropped by farmers in the districts of Apac, Arua, Mbale, Mpigi, Gulu, Iganga, Kabale, Kabarole, and Luwero (Bashaasha *et al.*, 1995). In Kabale district, Low (1996) listed 46 varieties being grown by farmers while 41 had been dropped. Another situation was noted that popular cultivars may disappear from cultivation due to so called 'degeneration' attributed to a progressive increase in virus infection (Mwanga *et al.*, 1991) or depletion of soils (Low, 1996, 1997).

Regardless of the large numbers of sweetpotato landrace varieties, and their importance for sweetpotato production in Uganda, there is little representation of Ugandan sweetpotato germplasm in global sweetpotato genebanks (Huamán and Zhang, 1997; Singer online database, http://www.ipgri.org). Indeed, there is little representation of germplasm from eastern and southern Africa in germplasm collections.

**Sweetpotato breeding for Uganda**

In Uganda, as is the case in many developing countries, little research attention was historically paid to sweetpotato. It was not until 1982, when collaborative work between the Ugandan's Ministry of Agriculture and the International Institute for Tropical Agriculture (IITA) was initiated, that sweetpotato research was begun (Hakiza *et al.*, 2000). Research to improve the production and productivity of sweetpotato was started at Serere Research Station in Eastern Uganda in 1984. The work was moved to Namulonge Research Station in central Uganda in 1986. Since that time significant progress has been made, and breeding efforts are set up for the varietal improvement through germplasm collection, evaluation and breeding (Hakiza *et al.*, 2000).

The main breeding activities have included evaluation and testing of local and introduced germplasm, generation and screening of breeding populations and multi-locational and on-farm testing of advanced clones and superior cultivars in different agro-ecological zones (AEZs). The main targeted AEZs are warm, sub-humid of the Short-grasslands agro-ecological zone, where weevils (*Cylas* spp.) and drought are important; the warm, moist of the Tall-grasslands agro-ecological zone, where viruses are most severe; and the cool, moist southwestern highlands where *Alternaria* stem blight and low soil fertility are major constraints to production of the crop (Hakiza *et al.*, 2000).

Breeding populations have been generated from local and introduced germplasm by recurrent mass selection followed by sequential selection schemes (Figure 1). Large populations are generated by polycrosses that are open-pollinated, and seed is also generated by hand crosses of specific male and female parents with desirable traits (Hakiza *et al.*, 2000). The generated populations are screened and advanced through seedling nursery, clonal evaluation, preliminary, intermediate, advanced, multi-locational and on-farm trials before release. Five superior cultivars, Tanzania (TZ), Tororo3, New Kawogo, No. 29 (Bwanjule), No. 39 (Wagabolige) and one breeding line, No. 389a (Sowola) from the national programme were released by the Variety Release Committee in 1995 (Mwanga *et al.*, 1995). Another six varieties, i.e., NASPOT 1, NASPOT 2, NASPOT 3, NASPOT 4, NASPOT 5 and NASPOT 6 were released in 1999. Outstanding characteristics of these varieties are high root yield of more than 21 t $ha^{-1}$, high level of resistance to sweetpotato virus disease (SPVD), high dry matter content (above 29%), and high consumer acceptability (Mwanga *et al.*,

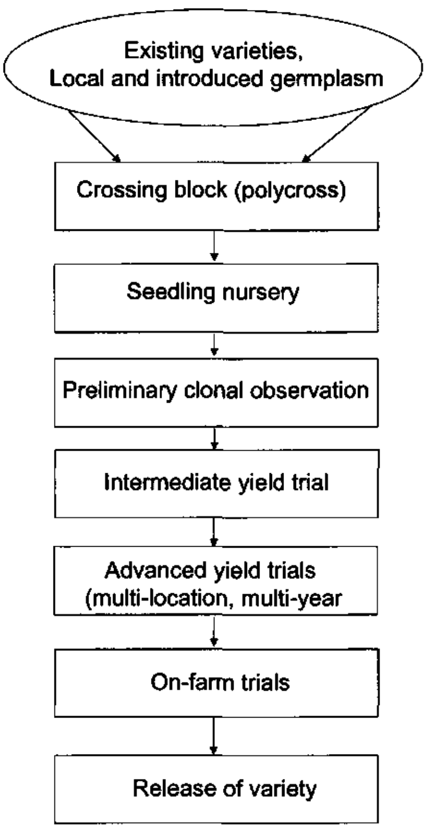


Figure 1. A routine sweetpotato breeding work in Uganda (Source: Wilson *et al.*, 1989).

2003). Three of the varieties, Tanzania, Wagabolige and Bwanjule, are already on the CIP (International Potato Center) pathogen-tested list for distribution to institutions or countries that request those (Hakiza *et al.*, 2000). Although the released varieties have been multiplied and distributed to farmers in some districts, the demand for these elite varieties is too high for the research institutes to meet. As such there is need to develop a multiplication and distribution system for dissemination of new improved clones, because the current informal farmer-based system is slow (Mwanga and Sengooba, 1996).

**Importance of local knowledge**

In modern agriculture, research has been focused on the local knowledge. Many social scientists intensively studied this local knowledge. These scientists have tried to find out if the local knowledge could play an important role in agricultural research and development programmes.

Campilan (www.scidev.net/dossiers/indegenous_knowledge/ikpolicy_campilan.html; 2002) indicated that local knowledge is a source that develops, becomes shared, and is used by a particular social group (for example a farming community, social network or ethnic group) in the pursuit of certain goals and interests. It generally emerges from people's direct experiences as they learn – deliberately or by chance – about their biophysical and social environments. It may also include knowledge handed down from previous generations, shared by other communities, and acquired from external research institutions. Thus, it forms a body of knowledge that usually extends beyond the indigenous, traditional and technical. Since it is shaped by particular social, cultural, physical and temporal contexts, local knowledge is inherently diverse.

Local knowledge has historically served as an important resource for farming communities in managing their livelihoods, and in continuously adapting to changes in their environment. Gaining a full understanding of the knowledge that exists in a local community is therefore a necessary first step for agricultural research and development programmes.

Local knowledge about diversity of sweetpotato cultivars is important in Uganda. Maintenance of this diversity helps to ensure that specific cultivars are available when and where farmers need them. On the other hand, knowledge of farmers is very important for ensuring that crop breeding programmes are selecting for what farmers need. To achieve this, local knowledge is an essential resource for identifying, cultivating, utilizing and maintaining different cultivars for different purposes. However, increased market orientation and new livelihood opportunities have reduced this diversity, mainly threatening those cultivars that have no immediate economic value (Bashaasha *et al.*, 1995; Low, 1996, 1997).

**Research aims and structure of the thesis**

The overall aim of this research project on sweetpotato germplasm in northeastern Uganda was to assist with the efforts of the Ugandan sweetpotato breeding programme through exploitation of local genetic diversity, farmer participation, understanding the stability of bred and selected local varieties, and verification of varietal requirement for dissemination. A series of studies was carried out in Uganda. The results of these studies are presented in Chapters 2 through 6. Chapter 7 supplements the studies in optimizing resource allocation in sweetpotato breeding for East African conditions.

The first aim was to collect sweetpotato germplasm using a participatory rural appraisal approach. Farmers' knowledge of varieties and the sweetpotato farming systems in northeastern Uganda were identified. This work also aimed to clarify the level of indigenous knowledge of farmers from northeastern Uganda about their sweetpotato landraces. Detailed analyses of the germplasm collection, farming systems and farmers knowledge of varieties will be found in the second chapter of this thesis.

The second aim was to determine the degree of morphological diversity in the germplasm collected from northeastern Uganda. Chapter 3 provides the result of the morphological characterization. The passport information and morphological characterization was deposited in the database of the International Potato Center (CIP)'s library in Lima, Peru (Abidin, 2001). A number of early research works were reviewed to understand the source of diversity which could contribute to the high variation on sweetpotato varieties noted in northeastern Uganda.

The third aim was to compare researchers and farmers' selection criteria in a large scale of initial assessment. Chapter 4 provides detailed information on this work.

The fourth aim was to study the performance of the tested genotypes on-farm. A farmer managed and designed trial was practised. However, some guidance was given to farmers in order to make it easy for the researcher to collect the yield data at harvest. The yield data were analysed to assess genotype-by-environment interactions. The capability of farmers in a varietal selection on farm was further studied. The result of this work is presented in Chapter 5.

The fifth aim included the following objectives (i) to analyse the stability of the tested genotypes initially selected by farmers on station (Chapter 3) and a number of nationally released cultivars in multi-locational on-station trials, over three consecutive rain seasons; (ii) to compare the stability of yield performance among these landrace genotypes selected by farmers in the initial selection with a number of nationally released Ugandan cultivars; (iii) to define a specific adaptation for a number of genotypes. Chapter 6 presents results of this work.

Finally, in Chapter 8, the major findings of the studies are synthesized and their implications for sweetpotato improvement in northeastern Uganda, for the Ugandan breeding programme, and for sweetpotato improvement elsewhere in Africa are discussed.

# CHAPTER 2

# Sweetpotato (*Ipomoea batatas* (L.) Lam.) germplasm from northeastern Uganda.
# I. Germplasm collection and farmers' knowledge of varieties[1]

Putri E. Abidin, Paul C. Struik, Piet Stam, Michael Hermann and Edward E. Carey

**Abstract**

Sweetpotato germplasm and associated farmers' knowledge of sweetpotato varieties and farming systems were collected at sites in Lira, Soroti, Katakwi, Kumi and Pallisa districts of northeastern Uganda. Farmer participatory methods were used to collect 206 sweetpotato accessions with 129 vernacular names. Farmers showed detailed knowledge of their varieties and identified the following agronomic attributes as important: relative earliness or lateness of production, resistance to pests and diseases, drought tolerance, suitability for cultivation on sand or clay soils and keeping quality. They considered root dry matter content important for culinary reasons. Many more accessions were collected from relatively remote rural areas than from areas with good access to main roads, where a few commercially important varieties were dominant. All accessions were planted in a multiplication nursery at Arapai Agricultural College in the Soroti District for further assessment. Indigenous knowledge about sweetpotato varieties could assist breeders to identify promising varieties and traits for improvement by plant breeding programmes.

Key words: Farmers' knowledge, germplasm collection, *Ipomoea batatas*, sweetpotato.

[1] Some information of this chapter was presented in the 98$^{th}$ International Conference of the American Society for Horticultural Science (ASHS), 2001. A slightly modified abstract could be read in: Abidin, P.E. and E.E. Carey 2001. Sweetpotato genetic diversity in North-eastern Uganda: Germplasm collection, farmer knowledge, and morphological characterization. HortScience 36(3): 487.

## INTRODUCTION

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is of American origin. The crop was spread widely by Portuguese explorers to Africa, India and the East Indies in the 16$^{th}$ century (Yen, 1974; Huamán and Zhang, 1997). At present, the sweetpotato is an important low-input crop in many places in Sub-Saharan Africa (Ewell and Mutuura, 1994; Bashaasha *et al.*, 1995; Kapinga *et al.*, 1995; Tayo, 2000). Sweetpotato production throughout the region is mainly based on large numbers of landrace varieties (Carey *et al.*, 1998). On the basis of numbers of landraces and the adaptation of the varieties to local conditions, including resistances to regionally important diseases and pests, Eastern Africa is considered to be a secondary centre of sweetpotato genetic diversity (IBPGR, 1981; Huamán and Zhang, 1997; Mwanga *et al.*, 2001).

With a production over 2.5 million tonnes on 572,000 hectares, Uganda is Africa's largest producer of sweetpotato (http://www.fao.org). Information about sweetpotato, and sweetpotato varieties, in the farming systems of southwestern, southeastern, north-eastern and central Uganda has been documented (Bashaasha *et al.*, 1995; Low, 1997), but there is limited literature describing the farming systems and sweetpotato varieties of northeastern Uganda, and the changing role of sweetpotato in them. In northeastern Uganda, farmers used to depend on cattle and cotton. However, the civil war during the 1980s resulted in crop destruction and cattle rustling decimated herds. Shortly after the war, a virulent mosaic virus devastated the cassava crop. The parasitic witchweed (*Striga* spp.) attacked the sorghum and maize crops. Hence, the sweetpotato was a fallback crop that helped many people to survive, and has now become a very important crop (Bakema *et al.*, 1994). In 1992, when the civil war ended, the area cropped to sweetpotato in the districts of Pallisa, Kumi, Soroti and Katakwi was reported to be 48,000 ha. Subsequently, the area cropped to sweetpotato increased tremendously with an average annual increase from 1992 to 1997 of 52,000 ha (MAAIF, 1998). Scott *et al.* (1999) reported that the crop was important for food security, and increasingly, as a cash crop.

Bakema *et al.* (1994) described the rainfall pattern of northeastern Uganda as bi-modal, with a long rainy season from March to June and a shorter, less reliable season from August to November. Annual rainfall decreases going from south-west to north-east. The long rainy season supports the growing of all major crops. Crop failures during the short rains are quite common. Smit (1997) found some constraints in this climate to sweetpotato cropping, particularly weevils (*Cylas* spp).

Sweetpotato is widely consumed in fresh-boiled or steamed form in Uganda, but the long dry season in northeastern Uganda and accompanying increases in weevil infestations, have led to the development of traditional sun-drying and processing techniques. Amukeke consists of dried slices while inginyo is made by drying crushed sweetpotato pieces. Waragi is a gin distilled from dried sweetpotatoes. Inginyo is usually milled into flour for making other types of food, e.g., local bread (atapa) (CIP, 1998; Owori and Hagenimana, 2000). The use of sweetpotato flour as a wheat flour substitute in recipes (to make chapatti (pancake), mandazi (doughnut), buns and cakes) has recently been investigated (Hagenimana and Owori, 1997; Owori *et al.*, 1997) and promoted in northeastern Uganda (Owori and Hagenimana, 2000).

Regardless of the large numbers of sweetpotato landraces, and their importance for sweetpotato production in Uganda, there is little representation of Ugandan sweetpotato germplasm in global sweetpotato genebanks (Huamán and Zhang, 1997; Singer database online, http://www.ipgri.org). In the 1980s, the Ugandan national programme had a collection of 450 accessions maintained at the Serere Research Institute in the Soroti District of northeastern Uganda which was duplicated at the Namulonge Research Institute in Mpigi District of Central Uganda (Hakiza *et al.*, 2000; Mwanga *et al.*, 1991, 2001). However, many of them were lost due to viral incidence at Namulonge (Hakiza *et al.*, 2000; Mwanga *et al.*, 1991) and due to civil war at Serere (Peter Esele, personal communication). In the 1990s, a study on sweetpotato farming systems in some regions of Uganda resulted in a list of 183 vernacular names of genotypes grown by farmers (Bashaasha *et al.*, 1995).

The Ugandan national sweetpotato breeding programme develops improved cultivars, and has released selected farmer varieties and bred cultivars, following a programme of multi-locational and on-farm testing (Mwanga *et al.*, 1995, 2001, 2003). Yet, this effort has not been enough to satisfy the needs of farmers for superior varieties with broad adaptation to Ugandan conditions or specific adaptation to certain production regions. At least in northeastern Uganda, it appears that farmers still largely rely on local varieties. Furthermore, for much of Sub-Saharan Africa, successful variety selection efforts have relied on the selection of elite varieties from existing farmer sweetpotato varieties. Examples include the varieties Mugande in Rwanda, SPN/O in Tanzania, Kenya and Uganda, and New Kawogo in Uganda (Ndamage *et al.*, 1992; Mwanga *et al.*, 2001).

Brown *et al.* (1995) have developed a basic sampling strategy for collecting plant germplasm, setting guidelines for number and location of sampling sites, individual plants sampled at a site, choice of individual, and number and type of propagules per plant. Huamán *et al.* (1995) laid out a specific strategy for collecting vegetatively propagated crops, especially roots and tubers. They recommended that local knowledge is useful for guiding collectors and having some ideas about numbers of distinct cultivars available in a given area, their names, appearance and properties. According to Nabasa *et al.* (1995) and NRI (1996), the knowledge of farmers can be best elicited through informal discussions, using "participatory rural appraisal" (PRA) techniques. In addition, Huamán *et al.* (1995) suggested to make use of markets as important sources of information on the varieties grown in the area, though not all varieties grown would be found on market stalls.

Despite the presence of many sweetpotato accessions in global germplasm collections, little information was obtained from farmers at the time of germplasm collection. For instance, many sweetpotatoes were listed that are grown by farmers in Kenya (Abubaker, 1992), in Rwanda (Ndamage *et al.*, 1992), in Uganda (Bashaasha *et al.*, 1995), and in Tanzania (Kapinga *et al.*, 1995), but little information was acquired from the farmers' indigenous knowledge of varieties. Thus, little information from farmers is available for most accessions in *ex situ* collections including national collections and those of the International Potato Center (CIP), and of the United States Department of Agriculture (USDA). However, a few authors have described collecting the indigenous knowledge while collecting sweetpotato germplasm. For example, Prain *et al.* (1995) collected the germplasm in Irian Jaya together with indigenous knowledge and Yen (1974) studied the sweetpotato in the Oceania and collected information on farmers' knowledge of varieties as he collected them.

The present work was conducted in 1999, when we made an effort to collect and to evaluate sweetpotato germplasm from Lira, Soroti, Katakwi, Kumi and Pallisa districts of northeastern Uganda. The districts mentioned above had not been surveyed during the fieldwork of Bashaasha *et al.* (1995) due to the civil war at that time. The results of collecting sweetpotato germplasm and associated indigenous knowledge of varieties and farming systems, and the initial characterization of the germplasm are reported in two chapters of the thesis. In this chapter, the process of germplasm collection, the farmers' knowledge of the varieties and the farming system are described. The third chapter of this thesis describes the morphological characterization and diversity of the sweetpotato germplasm collection.

## MATERIALS AND METHODS

Sweetpotato farmer varieties from the Lira, Soroti, Katakwi, Kumi and Pallisa districts of northeastern Uganda were collected and the farmers' knowledge of varieties was recorded through group discussions using a participatory rural appraisal (PRA) approach.

### Description of collection sites

Germplasm was collected between 3$^{rd}$ February and 8$^{th}$ June 1999. Figure 1 shows collection sites and the agro-ecological zones (AEZs) of Wortmann and Eledu (1999) at those sites. For Kumi and Pallisa, the areas were situated in the same AEZ. The areas of collection of germplasm in Lira, Soroti and Katakwi differed in agro-

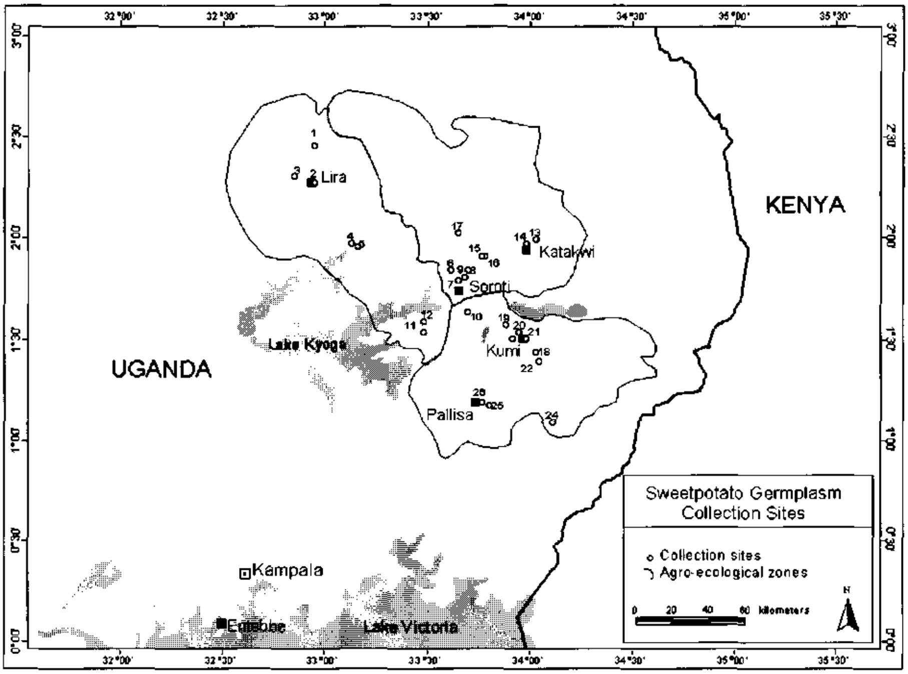


Figure 1. Locations in northeastern Uganda where sweetpotato germplasm was collected (C. Bussink and H. Juarez, Geographical Information Systems and Natural Resources Management, International Potato Center (CIP), Lima, Peru). The agro-ecological zones are indicated in Table 1.

ecological conditions. However, based on the Uganda Working Group 9A, Agricultural Policy Committee (1991), the areas of germplasm collection are commonly situated in the Short Grassland AEZ.

Sweetpotato germplasm was collected at sites in 26 villages in 18 sub-counties of 10 counties in the five districts. Table 1 provides the detailed information on the locations of sites, number of farmers participating, number of accessions collected, the AEZs at those sites, and relative importance of sweetpotato in the farming system at each site.

According to Rabwoogo (1997), the maximum air temperatures for all areas of collection were relatively similar (above 30 °C) but the rain distribution patterns varied moderately. The annual rainfall in the districts of Lira and Soroti, Katakwi, Kumi and Pallisa was 1000-1500 mm, 850-1500 mm, and over 1500 mm, respectively. The altitude of the sites was between 900 to 1200 m above sea level.

Table 1. Names and locations of sweetpotato germplasm collection sites in 5 districts of northeastern Uganda. Numbers of accessions collected and numbers of farmers participating in group interviews, agro-ecological zones (AEZs) and ranking of sweetpotato in the farming system at each site are also presented.

| District | County | Location | | Latitude (N) | Longitude (E) | AEZ[1] | Farmers[2] (#) | Rank[3] | Accessions[4] (#) |
|---|---|---|---|---|---|---|---|---|---|
| | | No. | Name | | | | | | |
| Lira | Erute | 1 | Acan Pe Winyo Abwete | 2°26' | 32°55' | 1 | 6 | 2 | 5 |
| Lira | Erute | 2 | Ayago | 2°15' | 32°55' | 1 | 5 | 2 | 7 |
| Lira | Erute | 3 | Owiti | 2°17' | 32°49' | 1 | 8 | 1 | 14 |
| Lira | Dokolo | 4 | Rego-Rego Akolodong | 1°57' | 33°06' | 1 | 40 | 3 | 11 |
| Lira | Dokolo | 5 | Araki | 1°56' | 33°08' | 1 | 35 | 3 | 6 |
| Soroti | Soroti | 6 | Amoru Agwete | 1°49' | 33°35' | 2 | 6 | 1 | 10 |
| Soroti | Soroti | 7 | Mugana | 1°46' | 33°37' | 2 | 10 | 1 | 4 |
| Soroti | Soroti | 8 | Abalang | 1°49' | 33°40' | 2 | 21 | 1 | 5 |
| Soroti | Soroti | 9 | Aloet Central | 1°47' | 33°39' | 2 | 16 | 1 | 7 |
| Soroti | Soroti | 10 | Aukot | 1°37' | 33°40' | 3 | 10 | 2 | 8 |
| Soroti | Serere | 11 | Abilaep | 1°31' | 33°27' | 1 | 14 | 1 | 12 |
| Soroti | Serere | 12 | Okulonyo | 1°34' | 33°27' | 1 | 30 | 1 | 15 |
| Katakwi | Usuk | 13 | Aparisia | 1°58' | 34°00' | 2 | 16 | 1 | 8 |
| Katakwi | Usuk | 14 | Aloogok | 1°57' | 33°57' | 2 | 16 | 1 | 6 |
| Katakwi | Amuria | 15 | Aterai | 1°53' | 33°45' | 2 | 25 | 1 | 14 |
| Katakwi | Amuria | 16 | Olianai | 1°53 | 33°44' | 2 | 37 | 1 | 8 |
| Katakwi | Amuria | 17 | Opolin | 1°60' | 33°37' | 2 | 40 | 2 | 10 |
| Kumi | Kumi | 18 | Atiar | 1°29' | 33°53' | 3 | 15 | 1 | 1 |
| Kumi | Ngora | 19 | Mukura | 1°33' | 33°51' | 3 | 25 | 1 | 8 |
| Kumi | Kumi | 20 | Kabata | 1°31' | 33°55' | 3 | 6 | 2 | 1 |
| Kumi | Kumi | 21 | Osiada | 1°29' | 33°57' | 3 | 20 | 2 | 4 |
| Kumi | Kumi | 22 | Kapokena | 1°22' | 34°01' | 3 | 14 | 3 | 5 |
| Kumi | Kumi | 23 | Atutur | 1°25' | 34°00' | 3 | 15 | 1 | 7 |
| Pallisa | Budaka | 24 | Kamongkoli | 1°04' | 34°05' | 3 | 30 | 2 | 11 |
| Pallisa | Pallisa | 25 | Boliso Central | 1°09' | 33°46' | 3 | 20 | 2 | 8 |
| Pallisa | Pallisa | 26 | Pallisa Town-Council Eastward | 1°10' | 33°44' | 3 | 8 | 1 | 11 |
| Total: 5 | 10 | 26 | | - | - | - | 488 | - | 206 |

[1] Agro-ecological zones (AEZs) at the sites as follows: 1. The Northern Moist Farmlands AEZ; 2. The Northcentral Farmbush Land with Sandy soils AEZ; 3. The Southern and Eastern Lake Kyoga basin AEZ (Wortmann and Eledu, 1999).

[2] Number of farmer participants in the group interview; the extension officer and member of PADEC were not counted unless they were farmers from that area.

[3] Rank of sweetpotato in the food system.

[4] Number of accessions collected.

## Methodology of collecting farmers' knowledge and germplasm

### *Site identification and interviews with farmers*

In each district, collection sites were identified, and collection activities were conducted in close consultation with the District Agricultural Offices and extension workers of the Ugandan Ministry of Agriculture, Forestry and Fisheries. Important sweetpotato production areas were targeted for collection. Then, meetings with farmers at collection sites were scheduled. District extension officers in consultation with local farmer representatives (Parish Development Councils or PADECs) requested farmers in the target village and surrounding areas to bring cuttings of all of their sweetpotato cultivars to a central location, in order to discuss them and contribute to the germplasm collection. On the day of germplasm collection, farmers (from 5 to 40) assembled at the designated collection site, along with the senior author, an assistant (general agriculture specialist), extension officers, members of parish development councils, local elders and Local Council members (local government). Discussions were held with the assistance of an interpreter at each location, to ensure that details of farmers' descriptions of sweetpotato cultivars and farming systems were captured accurately.

During group discussions, a standard checklist of topics was used to ensure that the following topics were covered at each location: the sweetpotato farming system, pest and disease incidence, market situation, and information on each variety including its history, agronomic characteristics, and postharvest attributes including suitability for different forms of utilization. Farmers were encouraged to contribute freely to the discussion in order to try to capture the full range of farmers' opinions and information about sweetpotato varieties and farming systems at each location. Open questions were used to cover the items on the checklists. The discussion and germplasm collection at each location took about 3 hours.

### *Sweetpotato germplasm collection*

Farmers came with bundles of ten cuttings of each of their varieties to the central collection points. As the collection was conducted during the dry season, the source of cuttings was from nurseries maintained in farmyards or swamps and not directly from production fields. Accessions with the same name and appearance (both at particular sites and across sites) were not collected multiple times but were noted. Accessions about which group discussions did not yield consensus on names and varietal characteristics were also not collected. Cultivars developed by the Ugandan national sweetpotato breeding programme were encountered at three sites but were not collected. Since the germplasm collection was essentially a community affair, the names of individual farmers donating varieties at each site were not noted. Instead, the name of the group leader at each location was recorded for passport documentation.

As accessions were collected, they were assigned collection numbers, and standard passport information was recorded. The following key morphological characteristics were noted to assist with identification: leaf shape, leaf colour, pubescence, petiole colour, vine pigmentation, skin and storage root flesh colour (reported by farmers) (CIP, AVRDC, IBPGR, 1991).

## RESULTS AND DISCUSSION

### Number of accessions collected and their maintenance

A total of 206 accessions were collected from the Lira, Soroti, Katakwi, Kumi and Pallisa districts in northeastern Uganda (Table 1). Because collecting was done during the dry season, planting material was not available for a number of varieties reported by farmers during group discussions at some locations, and so these were not collected. In 67 cases, accessions reported by farmers during discussions were not collected, either due to lack of planting material, or because farmers failed to reach a consensus during their discussions of these varieties. Conclusion about the true numbers of varieties collected must await confirmation of identity through determination of morphological characteristics, and are reported in the third chapter of this thesis.

Passport information and other details of the collection were given to sweetpotato researchers at the Namulonge Agricultural and Animal Research Institute (NAARI) under the National Agriculture Research Organization (NARO) for registration of the germplasm in the Ugandan national genebank. Passport information and morphological descriptors of germplasm collected were also deposited at the library of the CIP in Lima, Peru, where they are available on file (Abidin, 2001). Accessions collected were planted for maintenance and multiplication at the Arapai Agricultural College, near Soroti and at a backup site in a farmer's field in Kidetok, Serere County, Soroti District.

### Sweetpotato farming system in northeastern Uganda

The group interview process provided an ideal opportunity not only to collect farmer sweetpotato varieties and information about them, but also to obtain general information about the role of sweetpotato in the farming systems of northeastern Uganda. That information is presented here.

#### *Ranking in the food system*

Farmers reported that sweetpotato was an important crop in the farming system at each site surveyed (Table 1). In Soroti and Katakwi, farmers ranked sweetpotato as their primary food crop, with the exception of Aukot and Opolin where sweetpotato was ranked second after cassava. In Kumi, farmers ranked the crop either first or second place, except at Kapokena. In Lira, farmers ranked the crop from second to third, except at Owiti. In Pallisa, they ranked the sweetpotato as the second crop after cassava or millet, except at Pallisa Town-Council Eastward. Millet and/or cassava were ranked as the primary food crops by the majority of farmers in Pallisa, Lira, and parts of Kumi and Soroti. Smit *et al.* (1996) previously reported that in Soroti District sweetpotato was ranked first as a food crop and third as a cash crop. Also, Mudiope *et al.* (2000) reported that sweetpotato was a major crop in the farming system of Kumi District.

### *Cultural practices*

Farmers throughout the region grew sweetpotatoes on mounds, conical heaps of soil of variable size spaced roughly 60 to 100 cm apart. Mostly, farmers planted two cuttings per mound. Monoculture was predominant in the five districts of Lira, Soroti, Katakwi, Kumi and Pallisa (488 respondents). However, a few farmers particularly those living in towns or trading centres, reported intercropping sweetpotato with cereals or beans.

At only two sites, Aukot (Soroti District) and Kamongkoli (Pallisa District), farmers reported applying pesticides or inorganic/organic fertilizers to the sweetpotato crop. Pesticides and inorganic fertilizers were rarely available in the markets of the trading centres, and if available, the price was often too high for farmers to afford them. Most cattle disappeared from the areas during the civil war, so farmers could not make use of cow dung as manure to increase the fertility of the soils.

Cultural practices like weeding and hilling up of the soils were done only once during the growing season. Farmers gave the following reasons for not weeding twice: (i) the sweetpotato foliage already covered the soil ground so weed growth was controlled, (ii) farmers did not want to disturb the early initiation of storage roots by the time a second weeding was needed (352 respondents for reasons 1 and 2), and (iii) lack of manpower (80 respondents).

### *Commercial versus subsistence farmers*

Farmers reported on the commercial importance of sweetpotato in their districts (Table 2). Kumi District is one of the more important commercial production areas of sweetpotato in Uganda. During the peak season, much of the sweetpotato available in the markets of Kampala comes from Kumi. In contrast, Pallisa District although situated along the road between Kampala and Kumi, is primarily an area of subsistence production. All respondents from Pallisa explained that there was no market for selling

Table 2. Some details of sweetpotato cultivation in northeastern Uganda by district.

| District | Type of farming | Cropping season | Gender of sweetpotato farmers | Origin of planting material |
|---|---|---|---|---|
| Lira | Commercial & Subsistence | May-October | Men and Women | Swampy areas, homestead nurseries, volunteers from previous gardens |
| Soroti | Commercial & Subsistence | April-October | Men and Women | Mostly volunteers from previous gardens |
| Katakwi | Subsistence | May-October | Men and women | Mostly volunteers from previous gardens |
| Kumi | Commercial | February/March -October | Men and women | Mostly homestead nurseries and volunteers from previous gardens |
| Pallisa | Subsistence | April-August | Women | Mostly swampy areas and homestead nurseries |

their sweetpotato because their areas were not targeted by the sweetpotato buyers who went directly from Kampala to Kumi District. Since a commercial variety, Tanzania, was grown in Pallisa, this district may have the potential to become a commercial area since a new main road from Kampala to Kumi was recently built through the district. In some parts of Soroti and Lira, farmers planted sweetpotato for home consumption and/or local market sales.

In relatively remote areas, farmers utilized the crop only for home consumption due to lack of transportation to take their produce to the trading centres. In many cases they reported losing much of the crop due to rots following a major harvest. Katakwi District located in a relatively remote area of Uganda mainly had subsistence farmers who only used the sweetpotato to feed their families.

### *Gender of sweetpotato farmers*

In some parts of Uganda, sweetpotato production is mainly done by women (Mutuura *et al.*, 1992; Bashaasha *et al.*, 1995). We found this only to be true for Pallisa. In four districts of northeastern Uganda both men and women were involved in sweetpotato production (Table 2). Men mainly prepared the fields but men and women planted the sweetpotato vine cuttings, and women weeded and hilled up the fields. Both reported participating in harvest and postharvest activities (e.g., making amukeke and inginyo).

In the commercial areas, oxen were used to open the land and then both sexes prepared the mounds. In Kapokena (Kumi District), only men uprooted the storage roots at harvest, perhaps indicating a shift toward male predominance as the crop gains commercial importance.

***Source of planting material***

In the tropics, sweetpotato is propagated from vine cuttings, which farmers mostly obtain from their own or neighbours' fields (Gibbon and Pain, 1985; Ewell and Mutuura, 1994). Planting material in Soroti and Katakwi was collected from volunteer plants in the fields of the previous season. In Kumi, besides volunteer plants, farmers also obtained material from nurseries maintained near their homesteads. In Lira, farmers obtained vines from homestead nurseries, swampy areas and volunteer plants. In Pallisa, farmers obtained planting material from the nurseries maintained in swampy areas or at the homesteads (Table 2).

When the region is affected by a long dry spell, farmers may buy the planting material from the market. However, this is rare, and mainly reported by farmers who live in trading centres. Not all varieties grown in the villages would be available in the markets. Some common varieties such as Osukut, Ateseke, Osapat, Araka Red and Araka White (Teso), and Tedo Oloo Keren, Lira-Lira and Tanzania (Lira) may be sold during the planting season.

***Planting season***

The first rainy season usually starts in March and the second one in August. In general, the sweetpotato crop was planted from February to October. Planting time depended on the rain distribution of the sites (Table 2). Nevertheless, in some sites, such as Owiti, Aloet Center, Serere Abilaep, Okulonyo, Aparisia, Aterai, Olianai, Boliso Central, Kapokena, Boliso Central and Kamongkoli, farmers preferred to plant the crop only during the first rainy season as the rainfalls in the second season are erratic. Most farmers in Kumi District preferred to plant early (February/March).

At many other locations, however, farmers did not plant sweetpotato at the beginning of the rainy season. Reasons for later planting, indicated during the interviews, were ranked and summarized in Table 3. The most important reason was that farmers wanted to plant their main rainfed-crops in time. The second reason was the lack of availability of sweetpotato planting material at the start of the rainy season. The third reason was that farmers wanted to be sure that soil moisture was adequate to prepare mounds. Also, lack of labour in the beginning of the rainy season and attacks

Table 3. Reasons given by farmers to delay planting of sweetpotato in northeastern Uganda (total number of interviewed farmers: 488).

| Reasons | # Respondents |
|---|---|
| Priority given to the main rainfed crops: millet, groundnut and sorghum | 296 |
| Planting material not ready | 128 |
| Need to know whether rainfall is enough | 73 |
| Lack of labour | 35 |
| Soil pest attack (e.g., millipedes) | 14 |

by soil pests, particularly millipedes, were mentioned as reasons for planting late.

***Utilization***

Generally, farmers in all districts (488 respondents) preferred fresh consumption of sweetpotato as opposed to processed sweetpotato. In Katakwi and Kumi, all varieties were also grown to produce amukeke and inginyo, even though in Kumi they sell most for fresh consumption in Kampala. Amukeke and inginyo are the typical foods for the dry season in Lira, Soroti, Katakwi and Kumi districts. In contrast, in Pallisa, farmers traditionally eat fresh, steamed banana, so they preferred to consume fresh, steamed sweetpotato as well. Dried sweetpotatoes were not important in this area.

Two types of alcoholic drinks, local beer and distilled potent gin, were traditionally produced from millet and cassava in northeastern Uganda. When the cassava mosaic virus disease occurred, sweetpotato was used to produce alcoholic drinks instead. Most Iteso farmers (from Soroti, Katakwi and Kumi districts) prepared a potent gin from sweetpotato, but this was not reported in Lira and Pallisa.

Apart from the utilization of the storage roots, at some locations in Teso (Amoru Agwete, Abalang, and Aparisia) farmers reported eating the fresh young leaves of some varieties as fresh vegetable.

**Some constraints to the sweetpotato production**

The interviews yielded some information on abiotic, biotic and economic constraints to the sweetpotato farming system (Table 4). Abiotic constraints were related to climate and weather; biotic constraints included pest damage; economic constraints included lack of capital, the market situation and availability of planting material. Farmers ranked these problems.

### *Abiotic constraints*

The main abiotic constraint was drought, although in Aparisia (Katakwi) also waterlogging was reported. Abiotic constraints were reported to be important by 153 out of 488 respondents.

### *Biotic constraints*

In general, farmers mentioned three major pests which created problems in sweetpotatoes: weevils (*Cylas* spp.) (267 out of 488 respondents), rats (240 out of 488 respondents), and millipedes (order *Diplopoda*) (192 out of 488 respondents). Grazing domestic animals (cows, goats and pigs) as well as termites and monkeys also were said to be causing damage. Particularly in Acan Pe Winyo Abwote, Araki, Aterai, Atiar, and Pallisa Town-Council Eastward, grazing animals were a major problem.

### *Economic constraints*

The most important economic constraints were lack of capital, the unfavourable market situation and the lack of planting materials (Table 4).

The civil war resulted in severe poverty for farmers in the districts surveyed (SDDP, 1994) while Uganda is already noted as one of the world's poorest and least developed countries (World Bank, 1998/99). Therefore, lack of capital is commonly experienced in the region. Typically, farmers could only afford to have a hand hoe for cultivating their crops. Consequently, they could not prepare a large area for cropping the sweetpotato; 488 respondents reported to prepare only between 2000 and 4000 square metres per household.

Since every household grew sweetpotato, storage roots were abundantly available in the region by the time of the main harvest (in July/August or December/January). As a result, there was no market available for selling sweetpotato in the village. In trading

Table 4. Economic constraints of sweetpotato cultivation in northeastern Uganda.

| Items | # Respondents (n = 488) |
|---|---|
| Lack of capital[1] | 347 |
| Market situation[2] | 243 |
| Planting materials[3] | 198 |
| Others[4] | 83 |

[1] For agricultural inputs such as oxen, tools, labour, etc.

[2] Included low prices, lack of transportation, no buyers.

[3] Including adequate quantities of preferred varieties.

[4] Limited land, low fertility, post harvest pest, lack of knowledge of utilization.

centres the price is very low. In the relatively remote areas, farmers had problems taking their produce to the market because of lack of transport or bad roads during the rainy season.

In Kumi, traders who came to the villages offered the sweetpotato against a very low price. Hence, the lack of a profitable market can be a major bottleneck for sweetpotato growers in the region. The sweetpotato market problem has been described previously by Low (1997) and Bashaasha (2000).

**Germplasm collection approach**

Roughly 78 hours of interviews allowed us to contact more than 488 farmers at 26 sites, representing a large number of farms surrounding each of those sites (Table 2). In addition, it was worthwhile that the senior author was a resident of the region so she was able to take time to make the logistical arrangements for the collection visits and had the trust and cooperation of the local farmers and authorities.

The methodology used in our collection of sweetpotato germplasm from north-eastern Uganda differed from standard procedures, in which germplasm is collected directly from the fields of individual farmers. In general, collecting sweetpotato germplasm is therefore very expensive work and time-consuming. However, in our case, the accessions and information were collected at central sites allowing the participation of many individual farmers from surrounding areas, and eliminating the need for visits to individual farms.

The areas of collection were selected on the basis of advanced information from the district administration. The district authorities were also knowledgeable about this important crop. Largely, the approach was effective especially in terms of time and budget spent. Above all, farmers appreciated our visits and the fact that the approach acknowledged their knowledge on sweetpotato varieties. Prain (1993) reported some constraints in using rapid rural appraisal to collect germplasm in western Java, Indonesia particularly because of increased costs, and ongoing genetic erosion associated with cultural erosion. Nevertheless, Prain (1993) felt that the extra costs were justified by the increased potential value to crop improvement programmes of germplasm collected along with indigenous knowledge.

In Uganda, the value of collecting indigenous knowledge appears to be very high, as the crop is very important. Farmers showed detailed knowledge of varietal characteristics and were willing to talk about them during the interviews. Varieties which were clearly recognized by farmers during the group discussions were included in the collection.

Collecting the farmer varieties along with knowledge about them was based on group discussions. Thus, if farmers were really familiar with the accessions collected the information about the varieties could be quite accurate. However, there are some aspects of the information that will require some time to be confirmed – such as information about adaptation to certain conditions. For example, the variety Icok Opito Bala Mogo (in Ayago, Lira), which farmers only recently began planting, was believed to have been brought from the Democratic Republic of Congo. Farmers were actually not very sure about its local adaptability but expected it to yield well. Furthermore, in the cases where there was disagreement among farmers about the characteristics of particular varieties, these were not collected, perhaps resulting in inadequate sampling of germplasm, but also reducing requirements for germplasm maintenance and assessment following collection.

A concern with group discussions is that dominant individuals may bias discussion, leading to skewed results. Nevertheless, farmers demonstrated an in-depth knowledge of their sweetpotato varieties during the interviews, and generally produced consistent information. In the few cases where there was a lack of consensus among farmers about particular varieties, these varieties were not collected. The presence of the PADECs as moderators of the group discussions may also have tended to facilitate consensus, though it is possible that a dominant PADEC might have biased discussions in some ways but this last case did not come up during our germplasm collection.

Table 1 shows that at Atiar and Kabata (Kumi District) the number of farmers was higher than the number of accessions collected. In fact, at these sites farmers only grew one variety Osukut, so we only collected one accession from there. In contrast, at the sites Owiti (Lira) and Amoru Agwete (Soroti) every farmer at least brought one accession. The value of the obtained farmers' knowledge may have depended on the numbers of farmers (5-40) participating in the discussion: five farmers may be too few but 40 farmers may be too many for an ideal group discussion.

The accessions, which were collected, were not registered from individual farmers but were registered on behalf of the farmers' leader at each location site. Thus precise passport data describing farm location were not taken for each accession, and varieties might be difficult to trace if required in the future. This may be a disadvantage of this collecting method.

The areas of collection were targeted and this may give imprecise information on the distribution of sweetpotato germplasm in the region. However, the knowledge of many farmers was collected together with their varieties so we feel confident that our methods provided a rapid and effective means of collecting sweetpotato germplasm and information about it for the five districts surveyed in northeastern Uganda.

**Farmers' sweetpotato varieties in northeastern Uganda**

***Availability of varieties and market orientation***

Farmers commonly reported planting a number of different varieties in the same plot but each variety was grown separately in each mound. Both availability of planting material and market demand appeared to have an effect on the number of cultivars grown by farmers in an area (Table 5). In northern Katakwi where long dry spells are frequent, farmers had only a small number of varieties (e.g., 2) per household while in Okulonyo and Aukot surrounded by the swamp areas of Lake Kyoga in Soroti district every household might have eight varieties. In areas along the main road to Kampala (the capital city of Uganda) in Kumi District, farmers planted only one commercial variety, the regionally important Osukut, also known as Tanzania. The Kampala market required them to grow a certain type of variety with white skin, yellow flesh and a sweet taste. Local markets, such as those in Amoru Agwete and Rego-Rego Akolodong, were not so demanding with respect to skin and flesh colour, but did demand sweetness.

From the present study, two distinct types of areas with commercial orientation emerge. Good roads and distance to Kampala may influence the possibility of selling sweetpotato to the Kampala traders (i.e., Pallisa, Kumi, Soroti and Katakwi). From our experience in Kumi District, at the sites along the Kampala road (i.e., Atiar and Kabata) farmers only grew one commercial variety, Osukut, while at the sites far from the main road to Kampala (i.e., Osiada, Kapokena and Atutur) grew many varieties (Table 5). In addition, farmers living in Katakwi, parts of Soroti and even in Pallisa districts, only grew sweetpotato for home consumption. The reason was that their areas were remote and difficult to reach by the Kampala traders, except for a few sub-counties of Pallisa. Consequently, in these remote areas and/or in subsistence areas, a relatively high diversity of sweetpotato germplasm was observed.

According to literature, farmers also planted many varieties in their gardens because they were short of their favourite planting material (Ewell and Mutuura, 1994; Smit, 1997). During our group discussions at most collecting sites, farmers gave a number of reasons for growing different varieties, including food security, lack of planting material of preferred varieties, culinary attributes (e.g., fresh-steamed storage roots, amukeke, and inginyo) and trying out new varieties recently obtained from elsewhere. In many cases, both early and late maturing varieties were planted in the same plots in order to provide a continuous food supply for the household over an extended production season.

In this study, the highest ranking was given to reasons associated with continuous food supply and trying out new varieties (146 respondents). This is indicative of the

Table 5. Numbers of varieties of sweetpotato found at selected remote and/or subsistence sites and commercial sites.

| District | Site | Varieties collected (#) | Commercial varieties (#) | Where to sell |
|---|---|---|---|---|
| *Remote site* | | | | |
| Katakwi | Aparisia | 8 | Nil | Nowhere |
| | Aloogok | 6 | Nil | Nowhere |
| | Aterai | 14 | Nil | Nowhere |
| | Olianai | 8 | Nil | Nowhere |
| | Opolin | 10 | Nil | Nowhere |
| *Subsistance site* | | | | |
| Lira | Acan Pe Winyo Abwote | 5 | Nil | Nowhere |
| Soroti | Serere Abilaep | 12 | Nil | Nowhere |
| | Okulonyo | 15 | Nil | Nowhere |
| Pallisa | Boliso Central | 8 | Nil | Nowhere |
| | Pallisa Town-Council Eastward | 11 | Nil | Nowhere |
| | Kamongkoli | 11 | Nil | Nowhere |
| *Commercial site* | | | | |
| Lira | Owiti | 14 | 8 | Local market* |
| | Ayago | 7 | 5 | Local market |
| | Rego-Rego Akolodong | 11 | 11 | Local market |
| | Araki | 6 | 3 | Local market |
| Soroti | Amoru Agwete | 10 | 10 | Local market |
| | Aukot | 8 | 1 | Kampala market |
| | Abalang | 5 | 5 | Local market |
| | Mugana | 4 | 4 | Local market |
| | Aloet Central | 7 | 7 | Local market |
| Kumi | Mukura | 8 | 1 | Kampala market |
| | Atiar | 1 | 1 | Kampala market |
| | Kabata | 1 | 1 | Kampala market |
| | Osiada | 4 | 1 | Kampala market |
| | Atutur | 7 | 1 | Kampala market |
| | Kapokena | 5 | 1 | Kampala market |

* Local market: trading centres and boarding schools.

farmers' interest and willingness to experiment with the introduced varieties. A shortage of planting material ranked second (114 respondents). The seven locations (not shown) where this reason was mentioned, were not located near swamps, and some of them also reported problems with roaming animals.

***The importance of vernacular names by farmers***

In Uganda, it was likely that a vernacular name was important to sweetpotato growers because the name influenced the demands of a cultivar in the Kampala markets (i.e., Osukut type). In northeastern Uganda, names of sweetpotato varieties could reflect many morphological variations of the sweetpotato. Sometimes, the name characterized the cultural method to grow the cultivar or the method to utilize the storage roots. For instance, the name of the variety Icok Opito Bala Mogo means you must plant the vine cuttings completely under the soils, and Tedo Oloo Keren means even Keren does not know how to cook the storage roots in a proper way (the storage roots are hard). Table 6 illustrates the naming of sweetpotato varieties in northeastern Uganda by classifying names based on the translation of some vernacular names into English.

Out of 206 accessions, however, only 129 unique names were recorded. The same name was used on a number of occasions for morphologically distinct accessions. For example Tanzania, Osukut, Araka and Ateseke appeared several times in the collection, but inspection revealed that they represented accessions, which differed in appearance (cf. Chapter 3 and Abidin, 2001).

Varieties with names of people or clans or places were the most common. Next came names reflecting specific agronomic or morphological characteristics. Especially early maturity, yield performance and other yield-related information were frequently reflected in the names (Table 6).

***Farmers' perception of varietal origin***

Farmers classified a number of varieties into original, old, new, and introduced varieties. Old and original varieties were grown since the time of their grandparents in the early 1950s. An old variety may not necessarily be an original variety from the area and may have been introduced 40 to 50 years ago. Anam-Oyito collected from Ayago in Lira was reported to have been introduced by a British scientist 50 years ago. The name of the variety also reflected to somebody from far away. Table 7 provides the reported history of selected varieties, which occur in the region.

Farmers had some experiences with new varieties, which had appeared spontaneously in their gardens. These new varieties were (1) Mary/Imery, (2) Osukut-b, both in Serere Abilaep, (3) Araka 3 in Atutur, (4) Kamongkoli 'unknown' in Kamongkoli, (5) Ateseke-b in Aloet Center, and (6) Odupa-b in Aterai. Farmers believed that the new

Table 6. Vernacular names of some sweetpotato varieties in northeastern Uganda.

| English translation | Vernacular name |
|---|---|
| After a person or a clan | Mary, Imery, Ibety, Nora, Onait, Emadirait, Kilara, Ros, Wilson Odyek, Opiowor, Ekola Charles, Atwau, Odupa, Orode, Ikala, Malisa, Ajeso, Anam-Oyito, Anamoyitu, Oleke, Okelaaji. |
| The name of a place | Bale Acol (from Mbale District), Lira-Lira (from Lira District), Ekampala and Kampala (from Kampala), Kenya (from Kenya), Ekido (came from an island in Lake Kyoga) and Mukura (a place in Kumi District), Tanzania (from Tanzania), Oyirodege (it was brought by aeroplane), and Bombo Icok, Emuganai, Namuganda (from Buganda). |
| Early maturity | In Teso area: Odiopelap, Araka, IgangAmalayan and Iwela; in Lira: Dwe'achel and Pamdero; in Pallisa: Mwezigumu and Mpaenfumbiro. |
| Hairy | Ayer |
| Brittle and with soft vines | Ateseke |
| Colour of the foliage or storage roots | Purple, Muyambi white, Ejumula, Araka white, Araka red, Araka Nakwangan |
| The back of an old woman (means: rough skin of storage roots) | Epura Amojong, Epura Imat, Epura Kemat |
| It makes the granary full (means: high yielding) | Opong Bur, Pamdero (Lira), Owayunai, Dowery (Teso), Paluku, Bunduguza, Muyambi, Laka (Pallisa) |
| Easily growing vines and it can fight against weevils | Intalo |
| Sweet taste | Owiny, Emeketa, Etamu |
| Even Keren can't cook the storage roots easily | Tedo Oloo Keren |
| A poor man is hard working (means: drought tolerance) | Acan Kome Tek |
| Storage root arrangement and shape | Akungurodere, Akerekokolak, Ocakamani, Elanikokolak, Ookot, Inego |
| You plant the cuttings under the soil | Icok Opito Bala Mogo |
| Miscellaneous | Osapat, Etelepat (it means young man), Latest, New Araka (latest varieties), Mbio-Mbio (means running, the variety found during the insurgency of running away from the village), Dowery and Igang Amalayan (occasion for the brides). |

plants distinctly differed in their performance of the foliage and storage roots compared to the existing varieties in their fields. However, farmers did not propose an explanation as to the source of these varieties.

Table 7. The history of original places of some sweetpotato germplasm in northeastern Uganda as reported by farmers.

| Vernacular name | Grown in | Came from |
|---|---|---|
| Ajeso | Amuria, Katakwi | Pallisa |
| Anyara | Serere, Soroti | Otuboi, Lira |
| Araka 3 | Atutur, Kumi | Mbale |
| Asira | Usuk, Katakwi | Usuk, Katakwi |
| Asira | Ngora, Kumi | Kaberemoido, Soroti |
| Atwau | Wera, Katakwi | Serere, Soroti |
| Bale Acol | Erute, Lira | Mbale |
| Bombo Icok | Erute, Lira | Buganda* |
| Bugwere | Pallisa town, Pallisa | Buganda |
| Daga-Daga | Pallisa | Busoga** |
| Ecola Charles | Dokolo, Lira | Moroto |
| Ekano, Elobat | Usuk, Katakwi | Usuk, Katakwi |
| Ekido, Iwela, Ecici and Kaiga | Amuria, Katakwi | Lake Kyoga |
| Emadirait | Serere, Soroti | Arapai, Soroti |
| Emuganai | Serere, Soroti | Buganda |
| Esamiat | Soroti and Katakwi | Tororo |
| Epura Amojong | Serere, Soroti | Serere, Soroti |
| Icok Opito Bala Mogo | Erute, Lira | D.R. Congo |
| Ikala | Kumi, in Kumi | Kumi, Kumi |
| Itemokedula | Atutur, Kumi | Atutur, Kumi |
| Kampala | Pallisa | Busoga |
| Kawogo | Puti-Puti, Pallisa | Buganda |
| Kawogo | Budaka, Pallisa | Mugwere, Pallisa |
| Kibandula/Kyabandula | Lira and Pallisa | Buganda |
| Kilara | Erute, Lira | Jinja |
| Kenya | Pallisa | Kenya |
| Malisa | Ngora, Kumi | Kaberemoido, Soroti |
| Mbio-Mbio | Atutur, Kumi | Serere, Soroti |
| Mukurah | Kumi, in Kumi | Ngora, Kumi |
| Namuganda | Puti-Puti, Pallisa | Buganda |
| Nora | Dokolo, Lira | Buganda |
| Nora | Wera, Katakwi | Ngora, Kumi |
| Nora | Dokolo, Lira | Buganda |
| Nora | Amuria, Katakwi | Amuria, Katakwi |
| Naidoko | Budaka, Pallisa | River in Pallisa |
| Ocakamani | Serere, Soroti | Serere, Soroti |
| Odeochani | Erute, Lira | Apac |
| Odiopelap | Gweri, Soroti | Tanzania (1967) |
| Odiopelap | Serere, Soroti | Serere, Soroti |
| Odukuldere | Amuria, Katakwi | Amuria, Katakwi |
| Odupa | Amuria, Katakwi | Serere, Soroti |
| Omakira | Serere, Soroti | Serere Soroti |
| Omoding | Ngora, Kumi | Kaberemoido, Soroti |
| Onait | Serere, Soroti | Kyere, Soroti |
| Opejo | Wera, Katakwi | Kumi |

Table 7. Continued.

| Vernacular name | Grown in | Came from |
|---|---|---|
| Orode | Aterai, Katakwi | Serere, Soroti |
| Orode | Olianai, Katakwi | Kapellebyong, Katakwi |
| Osapat | Arapai, Soroti | Arapai, Soroti |
| Osukut | Serere, Soroti | Serere, Soroti |
| Osukut | Aukot, Soroti | Tanzania |
| Osukut | Usuk, Katakwi | Usuk, Katakwi |
| Owiny | Ngora, Kumi | Ngora, Kumi |
| Tanzania/Osukut | Lira, Soroti, Katakwi, Kumi, and Pallisa | Uganda→Tanzania→Uganda |
| Tanzania | Amuria, Katakwi | Tanzania |
| Wunduguza | Pallisa town and Budaka, Pallisa | Busoga |

* Buganda area: Mukono, Kampala, Mpigi, Masaka, Mubende, Rakai, Luweero, Kalangala, Kiboga, Mityana, and Nakasongola

** Busoga area : Inganga, Jinja, Kamuli and Bugiri

## Knowledge of varieties

### *Important criteria for preference and preferred varieties*

Criteria used by farmers to select preferred varieties were recorded and ranked. In group discussions, the first ranking was high yielding, early maturing and sweet taste (488 respondents), followed by culinary attributes and market demand (341 respondents). In addition, varieties which do not rot easily were among the preferred varieties (241 respondents).

Osukut was a widely grown variety and it was preferred by most farmers in the five districts (451 respondents). Asira was the best variety in Katakwi district (109 respondents out of 134). The taste of this variety was sweet and similar to banana. Tedo Oloo Keren was the favourite variety in Lira (88 respondents out of 94), followed by Lira-Lira (the remainding 6 respondents). The promotion of new forms of utilization in Lira was finding acceptance with farmers. These two varieties (Tedo Oloo Keren and Lira-Lira) were also selected for making cakes, mandazi and chapati. Most farmers in Soroti preferred Osapat (72 respondents out of 107) followed by Araka Red (25 respondents out of 107). Osapat and Araka Red were considered to be the highest yielding varieties in the district. Osapat had a sweet taste similar to Osukut. The remaining respondents in Soroti district preferred Osukut, New Araka or Ateseke. Kyebandula was chosen by farmers in Pallisa (50 respondents out of 58). Interestingly, this old variety has been abandoned by farmers in Luwero, Mpigi and Iganga districts further south (Bashaasha *et al.*, 1995). Farmers in Kumi planted only one variety

Osukut but according to some farmers, it was likely that Osapat would be adopted as a second variety with commercially desirable attributes.

***Characteristics related to utilization***

The storage roots of at least 95% of the varieties collected in the five districts were consumed as fresh-steamed product. Some varieties like Elanikokolak (ERA071), Temtedule (ERA099), Tanzania (ERA161), and Ateseke (particularly in Soroti and Katakwi) were preferably eaten fresh-steamed by farmers. More than 80% of the varieties collected in Lira and Soroti could also be used for food in a dried form. Most of the varieties were specially selected for this utilization especially in the Teso area (336 respondents). Thus, most available varieties had high dry matter content. The farmers judged this trait by their experiences in processing or cooking the storage roots. Specifically, varieties considered to have superior processing quality, such as Tedo Oloo Keren (ERA096) and Lira-Lira (ERA102), were hard in peeling of the skin, were floury and required much water for boiling/steaming.

Farmers reported that some varieties had a high dry matter content: from (i) Lira Tedo Oloo Keren (ERA076,096), Icok Opito Bala Mogo (ERA078), Purple (ERA083), Wilson Odyek (ERA085), Twonggweno (ERA098,109), Temtedule (ERA099), Tanzania (ERA107, 112), Bale Acol (ERA080), Kisumu (not in the collection) and Lira-Lira (ERA102, 110); (ii) Soroti: Emadirait (ERA047), Araka Red (ERA059), Latest (ERA060), Daweri/Anyara (ERA061), and Abokoro (ERA005); (iii) Katakwi: Osukut (ERA075) and Nora (ERA101); (iv) Kumi: Ekampala (ERA196) and Itemokedula (not in the collection); and (v) Pallisa: Muwogo (not in the collection), Laka (ERA171) and Kawogo Mugwere (ERA146). Some farmers in Kumi indicated that Osukut was not suitable for slicing and drying. In addition, some varieties with low dry matter content were noted: Ros (ERA086), Dwe'achel (ERA100, 113), Pamdero (ERA104) (from Lira), Mwezigumu (ERA175), Intalo (ERA165), and Imery (ERA159) (from Pallisa). The advantages of low dry matter content were not discussed in detail by farmers but they mentioned that these required less water and firewood for cooking.

In Soroti, 62% of the varieties collected were reported to be suitable for making a traditional potent gin. Emeketa (ERA004) was believed to produce a good quality distilled gin (respondents from Aukot).

Osukut, Osapat, Latest and Ateseke could be eaten as leafy vegetable (respondents from Amoru Agwete, Abalang, Aloet Central, Serere Abilaep and Okulonyo).

***Disease and pest incidence, drought tolerance and perishability***

No serious sweetpotato diseases were recognized by farmers in the five districts of northeastern Uganda. This information was confirmed by the observations later in 1999, i.e., during the morphological assessment of 206 germplasm accessions (Chapter 3), during the initial assessment (Abidin *et al.*, 2002). Yet, stem blight (*Alternaria* spp.) incidentally attacked a few accessions of Ateseke at the nursery of Arapai in the long dry-season of 2000, suggesting that the lack of serious diseases was more associated with a lack of conditions that favour development of diseases rather than with high levels of resistance in the germplasm of northeastern Uganda.

From experience, weevil infestation was a serious problem in the region, so the interviews emphasized the farmers' knowledge on this pest. The results presented here were based on the daily experiences of farmers in their fields. From the information given by Talekar (1987) resistance to weevils is not present in sweetpotato germplasm. However, data from Collins *et al.* (1999) indicate that the resistance levels are low and sweetpotato reactions are inconsistent and unstable across environments. Farmers from the districts of Lira, Kumi and Katakwi reported a moderate to low percentage of varieties which were resistant to weevils (56%, 46% and 39% respectively). Pallisa was noted to have the highest percentage (93%). Intalo (ERA165) (respondents at Boliso central, Pallisa) was identified as resistant against weevils. The weevil incidence is possibly determined by the rainfall distribution pattern (Smit, 1997). In Pallisa, weevils were less of a problem, perhaps due to higher rainfalls. Soroti had the lowest one (15%): this information from farmers in Soroti stated with the lowest perceived level of resistance may need to be confirmed.

The main characteristic of drought tolerance noted during group discussions was that the crop could grow vigorously throughout a dry spell and could produce storage roots under drought. All varieties in Pallisa were believed to be drought tolerant; only around 50% of varieties were reported to be drought tolerant in Lira and Kumi, and 85% of varieties in Soroti and Katakwi. For Pallisa it was possible that there was not enough drought stress to enable growers to identify this characteristic. In contrast, a variety not tolerant to drought was Ayer (ERA106) (respondents at Rego-Rego Akolodong, Lira).

Rots were discussed with respect to in-ground and post-harvest observations. Rotting may result from sun-burn and secondary infections after storage roots are damaged. Damage may be caused by weevil infestation or by careless work at harvest or at weedings (Onwueme, 1978). However, most farmers did not recognize rot as an important disease but rather indicated that rot was caused by sun-burn. Some varieties which did not rot easily were recorded in the five districts. Soroti had the highest percentage (79%) followed by Katakwi (70%), Lira (63%), Pallisa (53%) and Kumi (42%). Varieties which rotted fast were Kenya (ERA154) and Kampala (ERA160) (respondents from Kamongkoli and Boliso Central and Pallisa Town-Council

Eastward in Pallisa) and Emekenyit (ERA054) (respondents at Okulonyo, Soroti).

Four varieties, Anam-Oyito (ERA082) and Icok Opito Bala Mogo (ERA078) (respondents at Ayago, Lira), Aleso (ERA063) (respondents at Aparisia, Katakwi) and Bulemwezi (ERA138) (respondents at Owiti, Lira), were identified by farmers to be resistant to both weevils and drought. On the contrary, varieties which were not resistant to either weevils or drought were Lira-Lira (ERA102, 110) (respondents from Rego-Rego Akolodong and Araki in Lira) and Emeketa (ERA004) (respondents at Aukot, Soroti). Osukut (all respondents in five districts) and Bale Acol (ERA080) (respondents at Ayago) were not resistant to any of the three constraints.

***Maturity of varieties***

Early maturing varieties are important for farmers in northeastern Uganda since most of the areas in this region had some experiences with a short period of rainfall. The varieties: Acan Kome Tek (ERA077), Ayer (ERA106), Bale Acol (ERA080), Ejumula (ERA123), Ekola Charles (ERA108), Elobat (ERA069), Emeketa (ERA004), Kampala (ERA160, 176), Ekampala (ERA194, 196), Old Kawogo (not collected), Kenya (ERA154), Lira-Lira (ERA102, 110), Odeocani (ERA136), Osapat (all accessions), Osukut (all accessions), Temtedule (ERA099) and Twonggweno (ERA098, 109) were reported by farmers to mature within 3 to 4 months after planting. On the other hand, late maturing varieties were grown in certain areas of Lira, Soroti, Katakwi and Pallisa, including Oleke (ERA084, 103, 111, 137), Tedo Oloo Keren (ERA076, 087), Anyara (ERA043), Elanikokolak (ERA071), Nora (ERA101, 134) Ocakamani (ERA058, 207), and Samagali (ERA169).

Most farmers of the five districts practised piece-meal harvesting, the successive harvesting of large storage roots from individual mounds over an extended harvest period. In most cases, the sweetpotatoes were ready for initial harvesting three months after planting. However, piece-meal harvesting was not recommended for Bale Acol (ERA080) (Ayago, Lira District) till its storage roots reach maturity to avoid having fewer storage roots. On the contrary, the storage roots of Twenggweno (ERA098) (Rego-Rego Akolodong, Lira) might be bigger if farmers practised this method. These characteristics appear to be rare in the sweetpotato germplasm; breeders may consider them for further testing.

***Specific adaptations with respect to suitability for soil type and planting season***

Twelve varieties reported by farmers could be grown in the dry period (showing drought tolerance). Two varieties reportedly could only be planted in the first rainy season. Six varieties apparently needed to be grown in specific soil types: Emekenyit and Nylon/Silik preferred sandy-loam whereas Aleso, Dowery, Ookot and Opejo grew

Table 8. Varieties reported by farmers in northeastern Uganda to have specific adaptation to soil and seasonal conditions.

| Farmers' variety and the District | Can be grown in: Dry period | Sandy loam only | Clay loam only | First season only |
|---|---|---|---|---|
| Acan Kome Tek (ERA077) (Lira) | x | | | |
| Anam-Oyito (ERA082)(Lira) | x | | | |
| Muyambi (ERA167) (Pallisa) | x | | | |
| Twonggweno (ERA098, 109) (Lira) | x | | | |
| Temtedule (ERA099) (Lira) | x | | | |
| Tedo Oloo Keren (ERA076, 096)(Lira) | x | | | |
| Odukuldere (ERA020, 051) (Soroti) | x | | | |
| Odeocani (ERA136)(Lira) | x | | | |
| Elobat (ERA069) (Katakwi) | x | | | |
| Ekola Charles (ERA108) (Lira) | x | | | |
| Anyara (ERA043) (Soroti) | x | | | |
| Aleso (ERA063) (Katakwi) | | | x | |
| Anam-Oyito (ERA082) (Lira) | x | | | |
| Emekenyit (ERA054) (Soroti) | | x | | |
| Nylon/Silik (ERA155) (Pallisa) | | x | | |
| Dowery (ERA022) (Soroti) | | | x | |
| Ookot (ERA068) (Katakwi) | | | x | |
| Opejo (not collected) (Katakwi) | | | x | |
| Abokoro (ERA005, 205) (Soroti and Katakwi) | | | | x |
| Odupa (ERA132, 212) (Soroti and Katakwi) | | | | x |
| Total | 12 | 2 | 4 | 2 |

well in clay-loam soil. Abokoro and Odupa were known by farmers to be planted merely in the first rainy season (Table 8).

## CONCLUSION

The farmer participatory rural appraisal approach used during our germplasm collection activities in northeastern Uganda was successful with respect to allowing the relatively rapid collection of a large selection of farmer varieties from this region along with farmers' knowledge about the varieties and farming systems. Two hundred six sweetpotato accessions with 129 vernacular names were collected from north-eastern Uganda. Detailed farmers' indigenous knowledge was recorded on various agronomic and culinary attributes of the varieties. This information will have to be confirmed through further study.

Subsistence farmers and those who lived in the relatively remote areas maintained more sweetpotato varieties than farmers who lived in the commercial areas. So, high diversity of sweetpotato could be found in these areas. This information may be helpful to breeders in searching diversity of sweetpotato germplasm that is potentially useful for cultivar improvement.

The knowledge of farmers may help breeders in their preliminary selection of sweetpotato germplasm to be used as breeding materials. Furthermore, the implication of the findings may also be useful for sweetpotato germplasm conservation.

# CHAPTER 3

# Sweetpotato (*Ipomoea batatas* (L.) Lam.) germplasm from northeastern Uganda. II. Morphological assessment of duplication and diversity[1]

Putri E. Abidin, Paul C. Struik, Fred A. van Eeuwijk, Piet Stam, Michael Hermann, and Edward E. Carey

**Abstract**

Farmers in Uganda grow many sweetpotato landraces. Two hundred six accessions were collected at sites in the Lira, Soroti, Katakwi, Kumi and Pallisa districts of northeastern Uganda. The accessions were grown for evaluation at the Arapai Agricultural College in Soroti District, Uganda, with initial grouping based on similarity of morphological descriptors in farmers' fields and vernacular names. Observations of morphological descriptors of above-ground plant parts and storage roots were taken at 90 days after planting. Similarity of accessions was assessed using multivariate analysis to generate a dendrogram. Of the 206 accessions assessed 18 were classified as identical or nearly identical, while the remaining 188 were classified as distinct accessions, exhibiting considerable morphological variation. The large number of sweetpotato varieties present in northeastern Uganda is assumed to have arisen in the absence of serious disease pressure from a combination of varietal introductions from outside of the region, the selection of volunteer seedlings in farmers' fields, and spontaneous somatic mutations in existing varieties.

Key words: Duplicate identification, genetic diversity, hybridization, *Ipomoea batatas*, sweetpotato, spontaneous somatic mutation.

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[1] Some information of this chapter was presented in the 98th International Conference of the American Society for Horticultural Science (ASHS), 2001. A slightly modified abstract could be read in: Abidin, P.E. and E.E. Carey 2001. Sweetpotato genetic diversity in North-eastern Uganda: Germplasm collection, farmer knowledge, and morphological characterization. HortScience 36(3): 487.

## INTRODUCTION

Farmers in Eastern Africa grow many sweetpotato varieties (Ewell and Mutuura, 1994; Bashaasha *et al.*, 1995; Kapinga *et al.*, 1995; Carey, 1996). The varieties are often well-adapted to local conditions, having attributes that farmers desire (Abidin *et al.*, 2002). However, when commercial opportunities increase (and when breeding programmes are successful) farmers can quickly adopt a single variety over a large area, leading to abandonment of many of the old cultivars (Low, 1997; Bashaasha *et al.*, 1995; Zhang *et al.*, 1998) and the potential for genetic erosion. It is important not to significantly lose genetic diversity since it is important for breeding progress, and some of the abandoned cultivars may also be useful to farmers in the future.

Adequate collection, characterization, conservation and utilization of germplasm present a challenge for sweetpotato breeding programmes, since resources are limited, and because the vegetative nature of the crop makes conservation of genotypes expensive, requiring *in vitro* conservation and protection against infection by viruses in field genebanks (Carey, 1996). The crop is a poor farmers' crop in countries with very limited resources to dedicate to improvement (Carey, 1996; Carey *et al.*, 1998; CIP, 1998). Sweetpotato is genetically instable and has the tendency to mutate (Hernandez *et al.*, 1964; Collins and Cannon, 1983). This results in new genotypes, but also presents a challenge for the maintenance of genetic identity in germplasm banks.

Conservation of crop genetic resources requires an understanding of the genetic variation present in the gene pool, and adequate sampling to ensure that diversity is not lost (Carey, 1996). Sweetpotato originated in Central to South America (Yen, 1974; Huamán and Zhang, 1997; Zhang *et al.*, 1998), but has become an important crop in many places around the world. Its tendency to mutate readily, as well as its obligate outcrossing nature and its capacity to flower and set seed (Miller, 1937, 1939; Hernandez and Miller, 1964; Jones, 1965 a, b) have given rise to large numbers of landraces grown by farmers in several areas of Asia, Africa and Oceania (Yen, 1974; Carey, 1996; Carey *et al.*, 1998; Abidin and Carey, 2001). In these secondary centres of genetic diversity (IBPGR, 1981; Huamán and Zhang, 1997; Mwanga *et al.*, 2001) the crop is exposed to selection pressures (diseases, pest, climatic conditions and market forces) that may not exist in the centre of origin, and locally adapted genotypes and populations may emerge.

There is currently little representation of sweetpotato germplasm from Sub-Saharan Africa in global sweetpotato germplasm collections (Huamán and Zhang, 1997). In the past, sweetpotato germplasm collection was a rather indiscriminate process, involving comprehensive collection of cultivars over large areas and incorporation of these into genebanks with little attention given to levels of duplication present during collections (Carey, 1996). As a result, sweetpotato genebanks have become congested, and cumbersome to manage effectively (Carey, 1996). Addition of new germplasm to genebanks, such as that from Sub-Saharan Africa, which is currently under-represented, will require careful selection of genotypes for conservation, and an understanding of the genetic diversity being conserved (Carey, 1996).

Some farmers in Uganda (Bashaasha *et al.*, 1995; Smit, 1997) and those from northeastern Uganda (cf. Chapter 2) use volunteer plants from previous fields as their planting material, whereas other farmers prepare nurseries in swamp areas or in homesteads or under trees. Volunteer plants originate from botanical seed and may contribute to the genetic variation as sweetpotato is outcrossing and self-incompatible.

The work described here was a follow-up to a farmer-participatory sweetpotato germplasm collection effort conducted in five districts of northeastern Uganda where sweetpotato is an important crop (Chapter 2). During the collection effort, 206 accessions were collected. At the time of collection, we could not confirm that varieties collected were in fact distinct accessions, and indeed, we expected to find a relatively high number of duplication across collection sites. We characterized the germplasm in order to assess levels of duplication and to determine the range of morphological variation present in the germplasm grown by farmers in northeastern Uganda and collected in 1999.

## MATERIALS AND METHODS

Collection sites and methodology of the sweetpotato germplasm collection were described in Chapter 2 of this thesis.

### Morphological characterization

Two hundred six sweetpotato accessions collected from northeastern Uganda were planted at the Arapai Agricultural College in Soroti District on 3rd July 1999 to identify duplicates. Five cuttings of each accession were planted. The genotypes with the same names and those with similar foliage (i.e., leaf shape, size and colour) were planted side by side. Ninety days after planting the morphological characteristics of foliage and storage roots were assessed according to sweetpotato descriptors of CIP, AVRDC, IBPGR (1991). Traits recorded were twining, plant type, the length and diameter of vine internodes, primary and secondary vine pigmentation, pubescence, mature leaf shape, vein colour and size, mature and immature leaf colour, length and pigmentation of petioles; shape and defects of storage roots, storage root formation, and skin and flesh colour of storage roots. Passport information and morphological descriptors of the 206 accessions from northeastern Uganda are on file at the library of the International Potato Centre (Abidin, 2001). All accessions were healthy at planting; disease and pest incidence were not found during the assessment.

**Data processing**

Similarities were calculated among accessions as follows. For nominal traits Jaccard similarities were calculated (joint absence of a character state will not contribute to similarity), for ordinal traits rank distances were linearly translated into similarities (Gordon, 1980). An average similarity over all traits was then calculated. Calculations were done in Genstat (Genstat 5 committee, 1993). Cluster analysis was performed by MEGA version 2.1 (Kumar *et al.*, 2001).

First, a tree was generated by the unweighted pair-group method using arithmetic averages (UPGMA). Clusters resulting from this dendrogram were compared for morphological trait values. For ordinal data, medians were calculated, while for nominal data the most frequent values (modes) were determined. Medians were calculated for plant type (erect, semi-compact, spreading and extremely spreading), stem internode length and diameter, petiole length, type of leaf lobes, number of lobes, leaf size, and root skin intensity. Modes were assessed for vine tip pubescence, stem pigmentation such as predominant and secondary colour, petiole pigmentation, leaf general outline, shape of central lobes, abaxial leaf vein pigmentation, mature and immature leaf colour, root shape, root shape arrangement, storage root skin predominant and secondary colour, storage root flesh predominant, secondary and distribution colour.

## RESULTS AND DISCUSSION

### Morphological diversity of some sweetpotato farmer varieties collected from northeastern Uganda

Figure 1 presents the dendrogram generated by the MEGA analysis of the morphological descriptors.

***Identical and/or nearly identical varieties***

Eighteen accessions were assessed as identical and/or nearly identical genotypes (Table 1), and the remainder of the accessions were distinct. Two accessions of Cluster 3 (Figure 1): ERA112 (Tanzania) and ERA130 (Osukut)) had exactly the same morphological descriptors (see Abidin, 2001). This suggests that these two accessions were identical. The other pairs of the 16 genotypes were classified as nearly identical, as some differences occurred. For example, in Cluster 1 the two genotypes ERA033 (Esamiat) and ERA072 (Esamiat) differed in vine tip pubescence and petiole pigmentation. Moreover, in Cluster 3 ERA062 (Osukut) and ERA055 (Osukut big leaf) differed in vine pubescence and shape of central lobe of their leaves. Table 1 provides detailed information on the degree of similarity of these accessions.

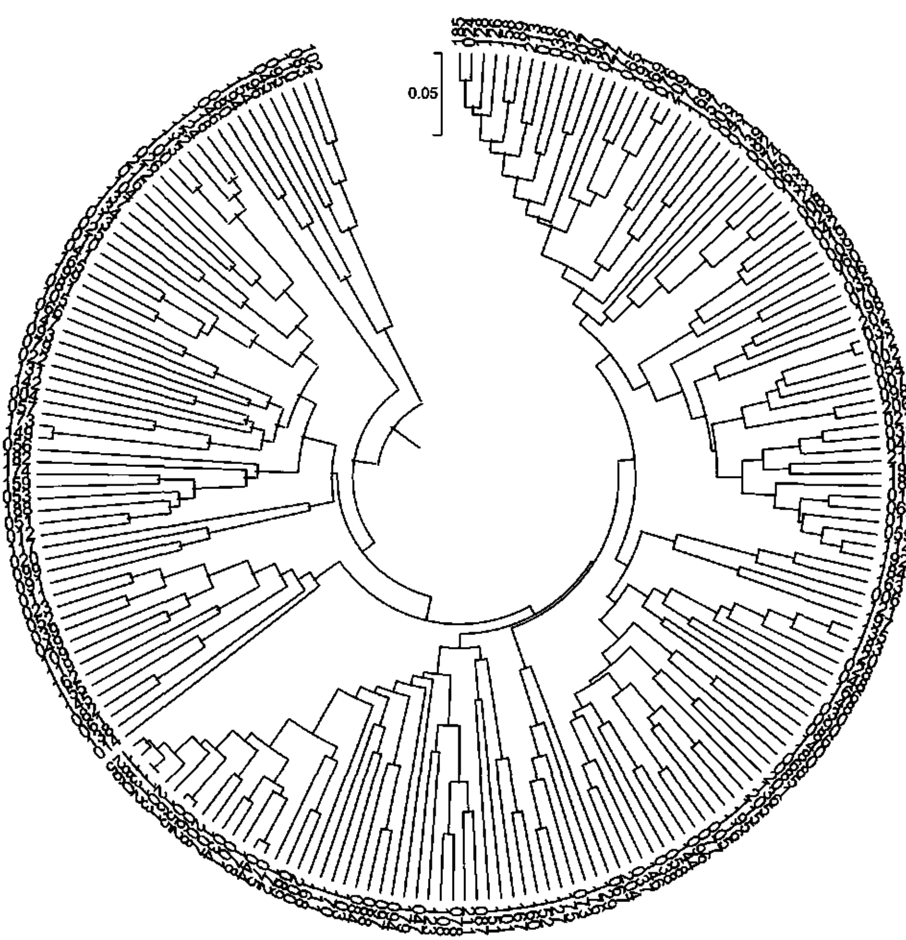

Figure 1. Dendrogram of the 206 sweetpotato accessions from northeastern Uganda. The names and short descriptions of the accessions can be found in Abidin (2001). The three letters "ERA" should be added in the front of each code number of accessions.

*Cluster analysis*

Seven clusters were obtained from the dendrogram which were taken from the 206 sweetpotato germplasms collected. Each cluster had several sub-clusters. Cluster 1 (s = 0.8605) had 96 accessions starting from accession No. 185 (original code ERA185 = Osukut) and ending at accession 204 (ERA204 = Ateseke). Cluster 2 (s = 0.8651) had 6 accessions, starting from ERA067 (Asira) and ending at ERA127 (Asira). Cluster 3 (s = 0.8455) had 38 accessions, starting from ERA152 (Daga-Daga Kikondo) and ending at ERA125 (Osukut). Cluster 4 (s = 0.8586) had 14 accessions, starting from

Table 1. The degree of similarity of some farmer sweetpotato varieties from northeastern Uganda based on the dendrogram.

| Cluster | Accessions | Collected from | Degree of similarity | Differed in |
|---|---|---|---|---|
| 1 | ERA076 (Tedo Oloo Keren) and ERA209 (Alweo) | Ayago, Lira; Opolin, Katakwi | Nearly identical | Vine tip pubescence |
| | ERA033 (Esamiat) and ERA072 (Esamiat) | Abalang, Soroti; Aloogok, Katakwi | Nearly identical | Vine tip pubescence and petiole pigmentation |
| | ERA185 (Osukut) and ERA024 (Latest) | Atiar, Kumi; Amoru Agwete, Soroti | Nearly identical | Plant type and vine pubescence |
| | ERA135 (Ateseke) and ERA183 (Ateseke) | Olianai, Katakwi; Mukura, Kumi | Nearly identical | Plant type and stem internode diameter |
| 3 | ERA112 (Tanzania) and ERA130 (Osukut) | Araki, Lira; Olianai, Katakwi | Identical | None |
| | ERA062 (Osukut) and ERA055 (Osukut big leaf) | Aparisia, Katakwi; Okulonyo, Soroti | Nearly identical | Vine tip pubescence and shape of central lobe of the leaf |
| | ERA075 (Osukut) and ERA044 (Osukut big leaf) | Aloogok, Katakwi; Abilaep, Soroti | Nearly identical | Vine tip pubescence and shape of central lobe of the leaf |
| | ERA186 (Osukut) and ERA125 (Osukut) | Kabata, Kumi; Aterai, Katakwi | Nearly identical | Petiole length, vine tip pubescence and leaf general shape |
| 5 | ERA173 (Bunduguza) and ERA149 (Muyambi white) | Pallisa Town-Council Eastward, Pallisa; Kamongkoli, Pallisa | Nearly identical | Stem internode diameter |

ERA014 (Mary/Imery) and ending at ERA011 (Inego). Cluster 5 (s = 0.8408) had 42 accessions, starting from ERA091 (Abejatar) and ending at ERA118 (Odupa 2 big leaf). Cluster 6 (s = 0.8072) had only one accession, ERA046 (Purple). Cluster 7 (s = 0.8431) had 9 accessions, starting from ERA080 (Bale Acol) and ending at ERA102 (Lira-Lira).

Table 2 provides information on the variation within each cluster based on the medians and most frequent values (modes) of the 24 variables mentioned in the sweetpotato descriptors (CIP, AVRDC, IBPGR, 1991).

Phenotypic variation among clusters was large, especially with regard to plant type (V1), type of leaf lobes (V4), number of leaf lobes (V5), and petiole length (V7). Moderate variation was observed in the stem internode diameter (V3) and the storage root skin intensity colour (V8). For the stem internode length (V2), the variation was not so high and only six cases were found, which differed from the medians (data not shown but referred to in Abidin, 2001). In the trait mature leaf size (V6), Cluster 3 typically differed from the other clusters (Table 2).

For the most frequent values in Table 2 a high variation was displayed especially for some traits like shape of central lobe of the leaf (V13), abaxial leaf vein pigmentation (V14), and petiole pigmentation (V17). Moderate variation was found in stem pigmentation predominant colour (V9), vine tip pubescence (V11), general outline of the leaf (V12), immature leaf colour (V16), storage root skin predominant colour (V20), and storage root flesh predominant colour (V22). Little or no variation was found for traits like stem pigmentation secondary colour (V10), mature leaf colour (V15), storage root shape (V18), storage root arrangement (V19) and storage root skin secondary colour (V21), storage root flesh secondary colour (V23) and storage root distribution colour (V24).

The most frequent values for predominant colour of the stem pigmentation were green (scored 1) with the exception of the Clusters 6 and 7. Only one accession of Cluster 6 had green vine pigmentation with many purple spots (scored 4) while in the accessions of Cluster 7, the most frequent values for vine pigmentation was totally dark purple (scored 9). The secondary colour of stem pigmentation in almost all clusters was absent (scored 0) except in Cluster 7. For more detailed information see Table 2.

An adequate assessment of diversity in East Africa germplasm will require comparison with other global sweetpotato populations. However, there is considerable morphological diversity observed in accessions from northeastern Uganda, and certainly a number of genotypes and genes (seed) warrant conservation in regional and global genebanks.

**The implication of the findings**

From the dendrogram it can be concluded that the morphological variation of the 206 sweetpotato germplasms collected from northeastern Uganda, was relatively high, although all accessions were related to each other to some extent (Figure 1). Breeders can try to select some elite varieties from this region. Many of these varieties had a

Table 2. Median and most frequent values (modes) scores of the 24 variables* based on the 7 clusters (Cl).

| Cl. | Median scores for variables (V1 to V8) | | | | | | | | Most frequent values (modes) for variables (V9 to V24) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | V9 | V10 | V11 | V12 | V13 | V14 | V15 | V16 | V17 | V18 | V19 | V20 | V21 | V22 | V23 | V24 |
| 1 | 7 | 5 | 4 | 7 | 6 | 5 | 4 | 3 | 1 | 0 | 3 | 6 | 6 | 8 | 2 | 3 | 4 | 8 | 3 | 2 | 0 | 1 | 0 | 0 |
| 2 | 6 | 5 | 5 | 4 | 4 | 5 | 8 | 1 | 1 | 0 | 3 | 6 | 4 | 8 | 2 | 3 | 5 | 8 | 5 | 8 | 3 | 4 | 0 | 0 |
| 3 | 3 | 5 | 3 | 6 | 7 | 7 | 6 | 2 | 1 | 0 | 0 | 6 | 6 | 2 | 2 | 3 | 1 | 8 | 3 | 2 | 0 | 4 | 0 | 0 |
| 4 | 6 | 3 | 5 | 9 | 5 | 5 | 4 | 3 | 1 | 0 | 3 | 7 | 5 | 8 | 2 | 3 | 4 | 8 | 3 | 2 | 0 | 1 | 0 | 0 |
| 5 | 7 | 3 | 4 | 1 | 6 | 5 | 6 | 3 | 1 | 0 | 3 | 4 | 2 | 8 | 2 | 2 | 5 | 8 | 3 | 2 | 0 | 1 | 0 | 0 |
| 6 | 5 | 3 | 5 | 5 | 5 | 5 | 3 | 3 | 4 | 0 | 3 | 6 | 4 | 3 | 2 | 7 | 4 | 8 | 5 | 7 | 0 | 2 | 5 | 3 |
| 7 | 7 | 3 | 3 | 5 | 5 | 5 | 5 | 1 | 9 | 2 | 5 | 6 | 4 | 7 | 2 | 3 | 9 | 8 | 5 | 8 | 0 | 4 | 0 | 0 |

*V1: plant type: 3 = erect, 5 = semi-compact, 6 = between semi-compact and spreading types, 7 = spreading type

V2: stem internode length: 3 = short, 5 = intermediate

V3: stem internode diameter: 3 = thin, 4 = between thin and intermediate, 5 = intermediate

V4: type of leaf lobes: 1 = very slight (teeth), 4 = between slight and moderate, 5 = moderate, 6 = between moderate and deep, 7 = deep, 9 = very deep

V5: number of leaf lobes varied from 4 to 7

V6: mature leaf size: 5 = medium, 7 = large

V7: petiole length: 3 = short, 4 = between short and intermediate, 5 = intermediate, 6 = between intermediate and long, 8 = between long and very long

V8: storage root skin intensity colour: 1 = pale, 2 = intermediate, 3 = dark

V9: stem pigmentation predominant colour: 1 = green, 4 = green with many purple spots, 9 = totally dark purple

V10: stem pigmentation secondary colour: 0 = absent, 2 = green tip

V11: vine tip pubescence: 0 = none, 3 = sparse, 5 = moderate

V12: general shape of the leaf: 4 = triangular, 6 = lobed, 7 = almost divided

V13: shape of central lobe of the leaf: 2 = triangular, 4 = semi-elliptic, 5 = elliptic, 6 = lanceolate

V14: abaxial leaf vein pigmentation: 2 = green, 3 = purple spot at base of main rib, 7 = all veins partially purple, 8 = all vein mostly or totally purple

V15: mature leaf colour: 2 = green

V16: immature leaf colour: 2 = green, 3 = green with purple, 7 = mostly purple

V17: petiole pigmentation: 1 = green, 4 = green with purple on both ends, 5 = green with purple spots throughout petiole, 9 = totally or mostly purple

V18: storage root shape: 8 = long elliptic

V19: storage root arrangement: 3 = open cluster, 5 = disperse

V20: storage root skin predominant colour: 2 = cream, 7 = red, 8 = purple red

V21: storage root skin secondary colour: 0 = absent, 3 = yellow

V22: storage root flesh predominant colour: 1 = white, 2 = cream, 4 = pale yellow

V23: storage root flesh secondary colour: 0 = absent, 5 = pink

V24: storage root distribution colour: 0 = absent, 3 = scattered spots.

potential to be high yielding in a low input agricultural system (Abidin *et al.*, 2002). Along with a good knowledge of farmers in that region (Abidin and Carey, 2001; Chapter 2), some varieties may readily serve breeders to develop some superior varieties for Uganda and elsewhere.

In Eastern and Southern Africa, sweetpotato is an important crop, and large numbers of landraces have developed over the years, possessing resistances, adaptation and quality attributes required in by this region's farmers (Carey *et al.*, 1998). Furthermore, some genotypes from northeastern Uganda could be useful for the regional (i.e., *ex situ* and *in situ* conservations) and global conservations (e.g. genebanks). Nevertheless, it may require careful selection of genotypes to avoid duplications in the genebanks.

**Sources of variation of sweetpotato germplasm in northeastern Uganda**

Farmers observed that "new" varieties suddenly appeared in their gardens but they did not discuss the source of those new varieties (Chapter 2). Some morphological variations of sweetpotato from northeastern Uganda may be caused by somatic mutations or hybridizations resulting in polymorphisms. These matters will be discussed below.

***Somatic mutation***

Sweetpotato varieties were found to have a fairly high frequency of mutations in the skin and flesh colour of the roots (Hernandez *et al.*, 1964). The spontaneous somatic mutation was apparently also noted in a few accessions of the sweetpotato germplasm collected from northeastern Uganda. This mutation was observed during the maintenance of the germplasm in the nurseries of Arapai and Serere, in the Soroti district.

Two varieties were recorded to obtain mutations, i.e., Ejumula (ERA123) and Muyambi (ERA167). These two genotypes produced two more different genotypes in our collection in the Soroti district. A mutant from Ejumula (ERA123) had a bright orange-flesh with brownish-orange skin colour while the original one according to farmers from Katakwi had a pale yellow storage root flesh colour with white skin (Abidin, 2001). In contrast, Collins and Cannon (1983) described the mutation which occurred in the cultivar Jewel in North Carolina, USA to have some changes in the storage root flesh colour from orange to white and/or light orange. With regard to Muyambi, its mutant was different in the skin colour but not in the flesh colour. The skin colour of its mutant was white, whereas, the skin colour of the original one was dark red. Rosa (1926) found a similar mutant in the Red Bermuda variety grown in Virginia and Missouri, USA.

Normally, the sweetpotato mutants found by Rosa (1926) in California, USA and Yen (1963) in New Zealand had a smaller number of edible roots produced and they were somewhat reduced in root size. This characteristic was also recognized in the mutant derived from Muyambi but not in the mutant from Ejumula. On the contrary, the performance of the storage roots of the mutant from Ejumula was quite promising, and there were no changes in yielding ability compared to the original one, consistent with the observations by Hernandez *et al.* (1964) in the cultivar Unit I Porto Rico from Louisiana, USA.

***Hybridization***

Farmers tend to grow many varieties in their fields (Ewell and Muutura. 1994; Chapter 2) and take volunteer plants from the previous fields as source of planting material for the next season (Carey, 1996; Smit 1997; Chapter 2). This situation could give some chances of outcrossing among the compatible varieties in the farmers' fields and may result in new genetic variation (Hernandez and Miller, 1964; Jones, 1965 a, b). It was recorded that more than 55% of sweetpotato accessions grown at the Arapai nursery produced flowers and botanical seeds (detailed information not shown).

The cluster analysis showed that there are some varieties which have the same name but are slightly different in their morphological characteristics, for example: Osukut (ERA185) of Cluster 1 and Osukut (ERA034) of Cluster 3 or other Osukut types found in the Clusters 4 and 5 (data not shown but see Abidin, 2001). Another case was the following two varieties collected from the same location site of Owiti in Lira District: Opong Bur A (ERA092) and Opong Bur B (ERA139). They slightly differed in their morphological characteristics particularly in the foliage performance (Cluster 1) although farmers still kept the same name for the two genotypes.

Morphological variations of the 206 sweetpotato accessions were relatively high but they ended up in one common root of the dendrogram (s = 0.7933) (Figure 1) because of only a slight difference in their performance. This slight difference may be due to mutations or hybridizations resulting in polymorphisms. Nevertheless, the process of having a high genetic variation might continue in the region as long as there are no serious threats caused by pest and disease pressure.

## CONCLUSION

At least 18 sweetpotato accessions were found to be identical or nearly identical among each other and the remaining 188 accessions collected from northeastern Uganda could be distinct genotypes.

Somatic mutations or hybridizations might have influenced the degree of morphological variation in the region.

Farmers played a role in the development of the sweetpotato diversity of the germplasm from northeastern Uganda. The sweetpotato morphological diversity was found to be relatively high in this region. The large numbers of these distinct varieties could present some challenges for efficient utilizations and conservations in regional and global genebanks. Furthermore, a network of *in situ* conservation may be considered to take place in the region which can be supported by knowledgeable farmers on the varieties.

# CHAPTER 4

# On-station initial evaluation of sweetpotato (*Ipomoea batatas* (L.) Lam.) germplasm from northeastern Uganda through a farmer-participatory approach[1]

Putri E. Abidin, Fred A. van Eeuwijk, Piet Stam, Paul C. Struik, Michael Hermann and Edward E. Carey

**Abstract**

In Uganda, farmers grow many sweetpotato landraces, but many of these are relatively low yielding, or narrowly adapted and susceptible to pests. The objective of the present research was to involve farmers in a large-scale assessment of Ugandan landraces in order to rapidly identify accessions with superior yield performance and consumer acceptance. One hundred and sixty distinct accessions collected from the Lira, Soroti, Katakwi, Kumi and Pallisa districts of northeastern Uganda were evaluated in on-station trials. Trials were conducted at two sites (Serere Agricultural and Animal Research Institute and Arapai Agricultural College) in Soroti District in the second rainy season of 1999. Twenty-five farmers from surrounding areas voluntarily participated in the selection at each site. At harvest, fresh storage root yield, number of storage roots, foliage yield, harvest index, and root dry matter content were determined by researchers. Farmers observed a number of characteristics and rated each entry with respect to the following variables: general impression, storage root dry matter content, pests, and defects. A strong positive correlation was observed between farmers' general impression and yield, number of storage roots per variety and harvest index. Farmers selected 10 superior varieties from each trial for further multi-environment, on-station and on-farm trials. Nine of the selected varieties were common to both sites. Farmers' selection criteria are discussed.

Key words: Farmer participatory variety selection, farmers' perception, farmer varieties, sweetpotato.

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## INTRODUCTION

Sweetpotato (*Ipomoea batatas* (L). Lam.) is a major crop in Uganda, where per capita consumption is around 100 kg per year (http://www.fao.org). It is important for food security, and increasingly, as a cash crop (Scott *et al.*, 1999). Sweetpotato is widely consumed in fresh-boiled or steamed form throughout Uganda, but the long dry season in northeastern Uganda, and accompanying increases in weevil (*Cylas* spp.) infestations, have led farmers to develop sun-dried products, such as amukeke (dry-sliced form) and inginyo (dry-chunk form) (CIP, 1998; Owori and Hagenimana, 2000).

In Uganda, as in other locations in eastern and southern Africa, farmers grow many different local varieties, mostly in low input agricultural systems (Carey *et al.*, 1998). Sweetpotato crop has a tendency to mutate readily, as well as having an obligate outcrossing nature and a capacity to flower and set seed (Miller, 1937, 1939; Hernandez and Miller, 1964; Jones, 1965 a, b). These characteristics have given rise to large numbers of landrace varieties in several areas of Asia, Africa and Oceania (Yen, 1974; Carey, 1996; Carey *et al.*, 1998). Many of these varieties have been reported to be relatively low yielding, narrowly adapted, and susceptible to diseases and pests (Bashaasha *et al.*, 1995). However, the expression of these negative characteristics may depend on the agro-climatic conditions where the crop is grown. For example, viral incidence, which is serious in some parts of Uganda, is not a serious problem in northeastern Uganda (Gibson *et al.*, 1997; Aritua *et al.*, 1998).

The Ugandan national sweetpotato breeding programme, based in Namulonge in Mpigi District in the Lake Victoria Crescent agro-ecological zone (AEZ) (Wortmann and Eledu, 1999), is developing improved cultivars. The programme released selected farmer varieties and bred cultivars following a multi-year programme of selection and multi-location testing (Mwanga *et al.*, 1995, 2001, 2003). Selection criteria are well established and include virus resistance, storage root yield, and high dry matter content which is strongly related to eating quality. As multi-location testing is expensive, it is a challenge for the national programme to effectively select superior cultivars for all the major environments where sweetpotato is important. Performance of the newly released cultivars has not proven to be consistently superior at sites in northeastern Uganda (farmer leader of Abilaep, Soroti District; personal communication) where farmers continue to rely on landraces and to express interest in obtaining new and superior cultivars.

Farmer participation in plant breeding has proven effective in a number of crops and environments (Sperling *et al.*, 1993; Sthapit *et al.*, 1996; Weltzien *et al.*, 1998; Joshi and Witcombe, 1998; Mulatu and Belete, 2001; Ceccarelli *et al.*, 2001; Courtois *et al.*, 2001). Farmer involvement in the selection process is seen as a tool for enhancing the efficiency and effectiveness of plant breeding efforts, particularly for variable and marginal environments where adoption of improved varieties from plant breeding programmes has been limited (Sperling *et al.*, 1993). Sperling *et al.* listed several advantages that can be gained from involvement of farmers in the selection process. First a greater number of promising varieties are selected. Better adapted varieties are thus identified which give higher yields on-farm. Secondly, promising varieties can be identified early, saving several seasons of on-station testing plus research expenses. In Rwanda, farmers selected a number of bean cultivars from a wide range of cultivars from on-station trials, and grew them in their fields for further on-farm trials (Sperling *et al.*, 1993). Sperling and Berkowitz (1994) indicate that farmers can evaluate germplasm meaningfully when hundreds of cultivars are involved. Nepalese farmers selected chilling-tolerant rice cultivars from $F_5$ bulk families (Sthapit *et al.*, 1996). In India, farmer participatory research was used to identify pearl millet cultivars suitable for Rajasthan (Weltzien *et al.*, 1998), and to identify rice, cowpea and maize cultivars for Gujarat (Joshi and Witcombe, 1998). Mulatu and Belete (2001) reported that participatory varietal evaluation of sorghum in Ethiopia was a means for enhancing adoption and increasing genetic diversity. Ceccarelli *et al.* (2001) concluded that it is possible to organize a plant breeding programme in which farmers become major actors in the selection of new cultivars. Courtois *et al.* (2001) compared rankings made by breeders on-station and by farmers on-farm in order to evaluate rainfed rice cultivars suitable for low-input environments in eastern India. A good agreement between farmers' and breeders' mean rankings was found in about two-thirds of the trials.

In sweetpotato breeding efforts elsewhere in eastern Africa, farmer participation has led to quick selection and dissemination of new varieties, many of them superior selections from regional germplasm (Anshebo *et al.*, 2000; Shamebo and Belehu, 2000; Munga *et al.*, 2000; Chirimi *et al.*, 2000; Kapinga *et al.*, 2000; Ndolo *et al.*, 2001).

The work described here was conducted as part of an effort by the senior author to use farmer-participatory methods to collect, evaluate and select superior varieties from regional sweetpotato germplasm in northeastern Uganda. During germplasm collection, farmers demonstrated detailed knowledge of the characteristics of their varieties (Abidin and Carey, 2001). This region was found to have a large number of farmer varieties: of 206 sweetpotato accessions collected, 188 were identified as distinct genotypes (Abidin and Carey, 2001). During the work described here, farmers participated in initial on-station trials of 160 sweetpotato accessions to evaluate and select a few varieties for further testing. In this study farmer selection criteria were evaluated and were compared with reported selection criteria which are usually applied in the Ugandan breeding programme. Performance of a number of accessions in these trials was compared with information reported by farmers at the time of germplasm collection. The selected genotypes from these trials were subsequently evaluated in a series of on-farm and on-station trials (Chapters 5 and 6) aimed at determining their varietal potential and yield stability in comparison with varieties released by the Ugandan breeding programme.

## MATERIALS AND METHODS

### Site characteristics

One hundred and sixty morphologically distinct Ugandan farmer varieties were planted at Serere Agricultural and Animal Research Institute (SAARI) and Arapai Agricultural College (AAC) on 11$^{th}$ and 14$^{th}$ October 1999, respectively. Both sites are in Soroti District and both have sandy loam soils. The sites' agro-ecological conditions are, however, somewhat different. According to the Uganda Working Group 9A, Agricultural Policy Committee (1991) both sites are in the Short Grassland AEZ, while Wortmann and Eledu (1999) classify Arapai as Northern-Central Farm-Bushlands and Serere as Northern Moist Farmlands. Both sites have poor soil fertility although Serere soil condition was better than Arapai. At Arapai, the land was intensively used for growing food crops, with cassava grown immediately prior to the trials there. At Serere, the experimental field was fallow for 5 to 6 years prior to the trial. The low soil fertility condition of the trials, including the cropping systems and the fallow practices, were generally similar to what farmers experience in their own fields.

### Crop cultivation

Ten cuttings of each variety were planted in single-row plots with a between-row distance of 100 cm and a within-row spacing of 30 cm. This spacing is commonly used by farmers in the region. A randomized complete block (RCB) design with 3 replicates was used. No fertilizers or pesticides were applied. Harvest was done 4 months after planting (mid-February 2000) during the dry season.

### Measurements by researchers

Data on disease incidence (e.g., viruses and *Alternaria* spp.), fresh storage root yield, fresh foliage weight, number of plants harvested, number of storage roots per plot (i.e., 10 plants per plot), and dry matter content of storage roots, were collected by researchers at harvest. The sets of data collected were based on the routine work of the sweetpotato breeding programmes in Uganda. For dry matter determination, medial sections of roots from each plot were chopped and a sample of about 200 g was oven-dried at 60 °C for 72 h or until constant weight.

**Farmer evaluation**

At each site a different group of volunteer farmers from nearby communities was invited to participate and evaluate the trials at harvest. Names of varieties were not given to farmers so as to avoid bias based on name recognition.

A checklist was designed to give farmers free rein in evaluating the general performance of each variety according to their own criteria and to allow researchers to gather precise information.

Evaluation was done at each of both sites in two cycles (initial and final selection). From the group of approximately 25 farmers a group leader was appointed.

After plants of each plot had been uprooted, farmers went along the 160 plots with two replicates, and a common group opinion on each variety was formulated, while researchers, who did not interfere in this discussion, recorded the criteria by which farmers judged the varieties. The farmers group also rated 'general impression', dry matter content, pest (weevil) damage and defects on a 5-point rating scale. These rating scales were adopted from the regular measurements in the sweetpotato variety trials. For each variety they also indicated whether or not they would select it for growing in their own fields. In this initial selection farmers were not given an indication of the number of varieties that were to be selected, so that they would have completely free rein in their evaluations. This initial selection resulted in 43 and 45 selected varieties at Serere and Arapai, respectively.

Since for the future multi-location testing we had to reduce the number of selected varieties to ten, a second cycle of farmers' selection was done. To this end the plots from which the initially selected varieties had been acquired were marked with a peg and farmers were asked to select from these the ten varieties they preferred most. By going along the marked plots and examining the items once more the top ten varieties were identified. If some disagreement occurred the group leader interfered and instructed farmers to carefully look at the disputed item again so that the group could reach a common opinion.

For general impression and dry matter content/eating quality, 1 represented very poor general impression or very low dry matter content, 2 poor or low, 3 fair or medium, 4 good or high and 5 excellent general evaluation or very high dry matter content. For pests, and defects, 1 represented for more than 75% of number of storage roots damaged, 2 between 51-75% damaged, 3 26-50%, 4 1-25%, and 5 0% damaged or with defects.

Farmers assessed root dry matter content/eating quality by hefting a storage root, scratching the skin, biting the root and tasting the flesh, and by observing the amount of latex produced after slicing the storage roots with a knife.

**Data processing**

Data collected by researchers and ratings done by farmers were analysed statistically with a focus on the variables yield, number of storage roots per plot, average storage root weight, harvest index (HI), dry matter content (DM), pest infestation, occurrence of defects, and general impression. Harvest index was calculated by dividing the fresh storage root weight by fresh foliar weight plus fresh storage root weight. The analysis of variance of these variables and the preparation of the graphics for the boxplots were done using Genstat (Genstat 5 Committee, 1997). For each trial, averages were calculated over replicates for yield, number of storage roots per plot, average storage root weight, HI, DM, while medians were calculated over replicates for the farmers' assessments. T-tests were performed to test the mean difference between selected varieties and non-selected ones for researcher-collected variables and to test the mean yield performance at the Serere and Arapai trials. For the farmers' general impression, dry matter content, pest and defects, the Mann-Whitney test was used. Correlations between ratings done by farmers and data taken by researchers were determined by Spearman rank correlations. Biplots (Gabriel, 1971) and scatterplots were used to visualize correlations among some of the variables mentioned above.

## RESULTS AND DISCUSSION

**Trial performance and climatic conditions**

Sweetpotato is particularly sensitive to drought at the storage root initiation stage, which occurs 50-60 days after planting. A suitable annual rainfall for sweetpotato crop is between 750-1000 mm with a minimum of 500 mm in the growing season (Ahn, 1993).

Establishment and growth of plants were good at both sites. No gap-filling was required. At Serere, rainfall was just enough to support the initial development of the crop. During the first two weeks of October in Arapai, the rainfall was adequate but not at the time of planting. Consequently, some irrigation had to be done during crop establishment: in November, December and January (Table 1). The amount of water was probably not enough to prevent drought stress during growth. The effect of irrigation did not affect the quality of data collected at harvest. This was inferred from the average of fresh storage root yield of Arapai which was still significantly lower than that of Serere trial (Table 2).

The monthly average of maximum and minimum air temperatures was relatively high: 31.3 °C and 18.4 °C, respectively. With inadequate rainfall at the time of the trials (Table 1) most storage roots did not develop to their full potential.

At Arapai the crop suffered more from poor soil conditions than at Serere (Table 2).

Table 1. Rainfall and air temperatures during trials at Serere and Arapai, in Uganda.

| Site/Meteorological Data | Oct. 1999 | Nov. 1999 | Dec. 1999 | Jan. 2000 | Feb. 2000 | Average over 8 years (1992-1999) |
|---|---|---|---|---|---|---|
| Serere | | | | | | |
| Max. Temperature (°C) | 29.2 | 31.1 | 30.1 | 33.1 | 32.2 | 30.7 |
| Min. Temperature (°C) | 18.0 | 18.0 | 18.4 | 18.2 | 18.2 | 17.9 |
| Rainfall (mm) | 155.3 | 118.0 | 79.0 | 1.2 | 7.7 | 1515 |
| Arapai | | | | | | |
| Max. Temperature (°C) | 30.1 | 28.8 | 31.4 | 33.1 | 33.8 | 30.6 |
| Min. Temperature (°C) | 16.2 | 15.8 | 15.6 | 16.0 | 16.1 | 17.6 |
| Rainfall (mm) | 194.5 | 16.3 | 64.8 | 3.9 | 14.7 | 1377 |

Sources: Meteorological Department of Serere Agricultural and Animal Research Institute (SAARI) and of Arapai Agricultural College (AAC) in Soroti District, Uganda. Before 1992 the agro-meteorological data were not available due to insurgency.

Table 2. Trial mean yields and frequency distribution of mean fresh storage root yields of sweetpotato genotypes evaluated in trials at Serere and Arapai, Uganda. Frequencies are presented by yield class for the overall trial, and initial and final selections by farmers.

| Fresh storage root yield ranges (t $ha^{-1}$) | # varieties | | | Average storage root yield (t $ha^{-1}$) |
|---|---|---|---|---|
| | Overall trial | Initial selections | Final selections | |
| Serere | | | | |
| <6.9 | 35 | 1 | 0 | |
| 6.9-10.5 | 37 | 4 | 0 | |
| 10.6-12.7 | 29 | 10 | 1 | 10.0 |
| 12.8-20.1 | 59 | 28 | 10 | |
| Total | 160 | 43 | 11 | |
| Arapai | | | | |
| <1.6 | 23 | 0 | 0 | |
| 1.6-3.0 | 54 | 8 | 3 | |
| 3.1-4.1 | 31 | 13 | 2 | 3.1 |
| 4.1-8.9 | 52 | 24 | 6 | |
| Total | 160 | 45 | 11 | |
| Serere minus Arapai | | | | 6.9** |

** Highly significant. The comparison for fresh storage root yield (t $ha^{-1}$) based on *t*-test.

Table 2 shows that the average yield of storage roots at Arapai was only 3 t $ha^{-1}$ but much higher at Serere. More than 50% of the varieties yielded below 4 t $ha^{-1}$ at Arapai while only 22% yielded below 6 t $ha^{-1}$ at Serere.

**Farmer participation in the varietal evaluation**

A group of 25 farmers came voluntarily to each station. The proportion of male farmers was higher at Arapai than at Serere. The findings of Bashaasha *et al.* (1995) indicate that women play a major role in cultivating the crop. In the districts where the germplasm varieties were collected, male and female farmers actively grow sweetpotato, except in the Pallisa District where female farmers are dominant, and in a few sub-counties of Kumi District where sweetpotato is becoming a commercial crop, male farmers predominantly work at harvest. Dissimilar gender issues during varietal evaluation did not bias the results because both genders used the same criteria for selecting the best varieties.

A group discussion in a varietal selection by farmers is not frequently practised (Sperling, 1993; Kitch, 1998; Soleri *et al.*, 2000) but we found it to be effective. Thiele *et al.* (1997) explained the weakness of group evaluations. If farmers had not been well managed they might have been susceptible to the leader's effect. The experience of Thiele *et al.* was not met in our case. Each observation was discussed by all farmers. Farmers who did not say much during the evaluation would learn from their expert colleagues and then expressed their agreement at the end of the group discussion. In addition, the researchers learned much about the farmers' opinions on the varieties.

It should be noted that only a limited number of parameters can be used for a varietal evaluation as described above (cf. Sperling *et al.*, 1993). In our experience, the general impression already covered a combined assessment of a number of attributes mentioned in the checklist.

**Selection criteria**

Farmers used several criteria, which we classified into three categories. The first category included numbers and size of the storage roots, taste, numbers of secondary stems, and shape of leaves. The second was skin and flesh colour and the third weevil damage and defects.

Farmers preferred varieties with many medium sized roots, which tend to yield well. Besides, as the medium sized roots are easily packed, this trait also contributes to the revenues when intended for sales. While collecting the sweetpotato germplasms farmers often expressed that they consider the number of medium-sized roots as an indication of a variety's yield potential.

In farmers' view, having few secondary stems meant that a variety potentially produced many roots. So this trait could be indicative for a variety's harvest index. Farmers did not like varieties with small leaves or deeply-lobed leaves, indicating that farmers preferred varieties with a high photosynthetic potential.

Apart from yield and/or yield potential the market situation demanding white skin and yellow flesh of storage roots also influenced the choice of farmers. Varieties identified by farmers to have good culinary quality were found to have high dry matter content. Farmers considered the following characteristics to be indicative of high dry matter content: 1) the storage root should be heavy; 2) the storage root is hard when bitten; 3) the skin is hard when peeled or scratched; 4) a relatively sweet taste; and 5) little latex produced in the flesh.

A number of selection criteria used by farmers like sweet taste, medium size of storage roots, few secondary stems, and the shape of leaves were noticed not to be generally alike to the formal breeders' selection criteria. Sweet taste is a common criterion for selecting sweetpotato by farmers in eastern and southern Africa. To favour a certain shape of leaves is not uncommon for Iteso farmers (Soroti, Katakwi and Kumi) and also for farmers in the West Nile region of Uganda (Očweda Morris, personal communication). These additional farmers' criteria deserve attention from breeders so as to understand consumer acceptance.

**Selected varieties**

Table 2 provides information on the ranges of fresh storage root yield (t $ha^{-1}$) related to the farmers' selected varieties at Serere and Arapai, Soroti District, Uganda.

Surprisingly, in the two sets of ten independently selected varieties nine were common to both trial sites (see Figure 1). Despite the striking differences in growing conditions between the two sites, as reflected by the large average yield difference between sites, farmers apparently were able to evaluate the varieties with fairly high precision, both in favourable and less favourable environments.

In contrast to Serere, farmers at Arapai had a difficult time to evaluate the varieties because of the harsh growing conditions. The storage root size was relatively small and the roots were poor, resulting in a low yielding performance. However, farmers observed that a number of varieties had a large potential number of roots. They made use of this trait to evaluate the varieties. Farmers expected the selected varieties to have a good yield if the soil moisture would be adequate. This demonstrates that farmers have a well-developed sense of a variety's yielding capacity, even when growing conditions are far from optimal.

**Comparison between selected and non-selected varieties**

Comparisons of mean yields, average weight of each storage root, number of storage

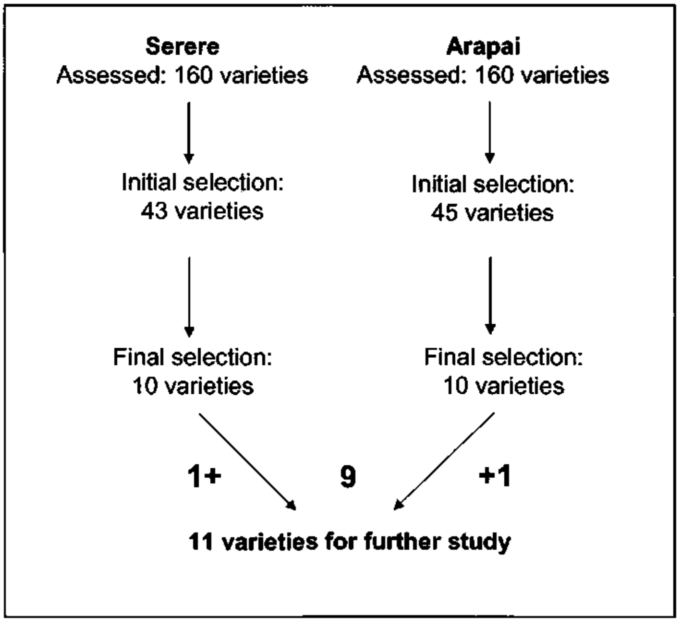



Figure 1. Independent selection of sweetpotato varieties by farmers at two trial sites in northeastern Uganda.

Table 3. Comparison of the means in yield (t $ha^{-1}$), weight of individual storage roots (Wt.st.rt in gram), number of roots per plots (# rts), harvest indices (HI in %), and dry matter content (DM in %) between non-selected varieties and 11 selected ones based on assessments by researchers in sweetpotato trials at Serere and Arapai, Uganda. P-values according to *t*-tests.

| | Serere site | | | | | Arapai site | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variety | Yield | Wt. st.rt | # rts | HI | DM | Yield | Wt. st.rt | # rts | HI | DM |
| Non Selected (n = 149) | 9.7 | 132 | 23.4 | 51 | 37.7 | 3.0 | 66 | 13.9 | 40 | 37.9 |
| Selected (n = 11) | 14.1 | 148 | 29.9 | 65 | 37.8 | 4.3 | 69 | 19.6 | 57 | 39.5 |
| P-value | <0.001 | 0.085 | 0.014 | <0.001 | 0.467 | 0.004 | 0.335 | 0.002 | <0.001 | <0.01 |

roots per plot, harvest index and dry matter content of selected and non-selected varieties at Serere and Arapai are shown in Table 3. The mean performance of selected varieties was significantly different from the non-selected ones with respect to yield and yield-related traits at both sites with the exception of mean storage root weight. Dry matter content of selected varieties was significantly higher at Arapai, but not at Serere.

Median values for variables rated by farmers in the trials at Serere and Arapai are presented in Table 4. There were highly significant differences between selected and non-selected varieties for general impression, while there were significant differences for dry matter assessment at both sites. No differences were detected for evaluations of pest damage and defects. The latter two traits were consistently found in both trials. Therefore, farmers could not assess these traits precisely. In the case of weevil (*Cylas* spp), little variability exists among sweetpotato germplasm for resistance to this pest. However, the majority of other studies show that resistance levels are low and sweetpotato reactions are inconsistent and unstable across environments (Collins *et al.*, 1999).

**Comparison between researchers' and farmers' assessment**

There was a high correlation between the general impression as observed by farmers and the yield as determined by researchers at both Serere and Arapai trials ($r = 0.83$ and $r = 0.75$ respectively; $n = 160$). Yield was one of the most important variables considered by farmers in the process of evaluation and selection. These high correlations indicate that farmers were capable of estimating yield differences. Figure 2 shows boxplots of farmers' general impression of varieties at Serere versus yield.

Table 4. Median scores of farmers' assessments of varieties in trials at Serere and Arapai, Uganda (scores: 1-5). Farmers (at each site, n = 25) rated varieties for the following variables: General impression (GenImp), dry matter content (DM), pests and defects. P-values according to Mann-Whitney test.

| | Serere | | | | Arapai | | | |
|---|---|---|---|---|---|---|---|---|
| Variety | GenImp | DM | Pests | Defects | GenImp | DM | Pests | Defects |
| Non-Selected (n=149) | 3.0 | 3.0 | 3.5 | 4.0 | 2.5 | 3.0 | 4.0 | 4.0 |
| Selected (n=11) | 4.5 | 4.0 | 3.5 | 3.5 | 4.5 | 4.0 | 4.0 | 4.0 |
| P-value | <0.001 | 0.011 | ns | ns | <0.001 | 0.059 | ns | ns |

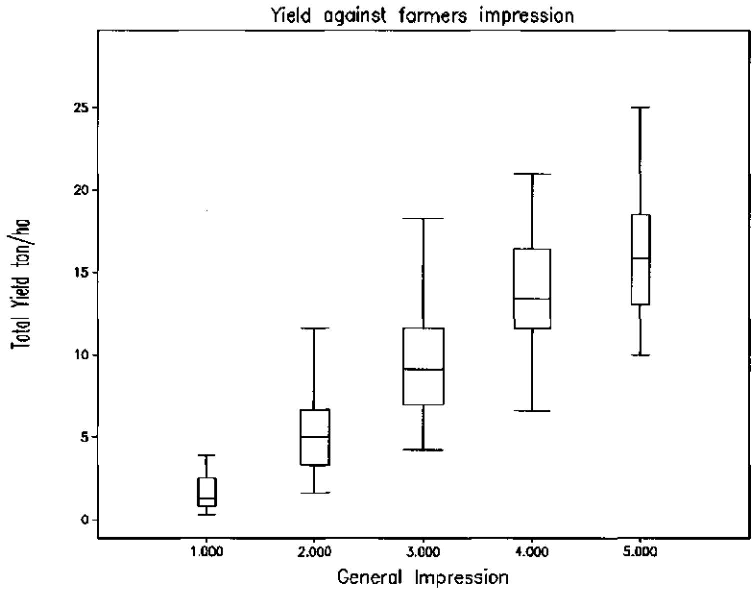
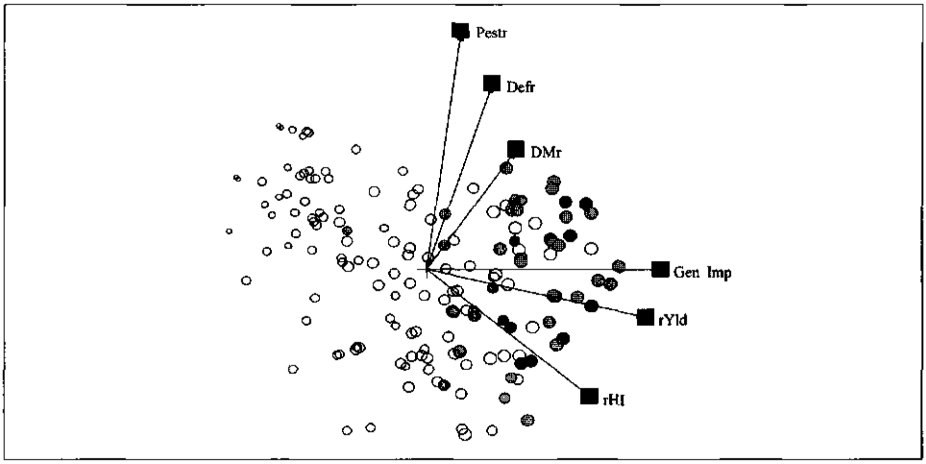



Figure 2. Boxplots of farmers' general impression versus yields for sweetpotato farmers' varieties assessed at Serere, Uganda. A central box spans the quartiles; a line in the box marks the median; and lines extend from the box out to the smallest and largest observations that are not suspected outliers.

Except for the lowest level of general impression, the spread of yield is similar and a clear linear relation exists between general impression and observed yield. The plot for Arapai (not shown) gave similar results.

A high correlation was also found between the general impression of the farmers and the harvest index determined by researchers, both at Serere (r = 0.64) and Arapai (r = 0.74). Farmers preferred varieties having less foliage weight to the favour of high yield. A high correlation also occurred between general impression and number of roots per plot at Serere (r = 0.66) but not at Arapai (r = 0.42). Figures 3a and 3b present biplots from Serere and Arapai of correlations among the ranked variables yield, HI, DM, pest infestation, and occurrence of defects based on the farmers' general impression. Rot was not shown in Figure 3a but shown in the centre of Figure 3b. There was only a weak correlation between the dry matter content determined by researchers (not shown) and the rating of dry matter content done by farmers (r = 0.21). However, dry matter content was among the important factors for farmers and the breeding programme in Uganda. The varieties tested mostly had high dry matter content, and there was relatively low variation for this variable among the varieties




Explained variance 67%

Figure 3a. Biplots of selected and non-selected varieties and the correlations among the variables yield, HI, DM, pest infestation and occurrence of defects based on the farmers' general impression at Serere, in Uganda. Size of symbols for varieties (circles) are proportional to yield. Open circles are non-selected varieties, grey filled circles are initially selected varieties and black circles are selected varieties for further in-depth study. Squares are the symbols for variables: Pestr = pest rated by farmers; Defr = defects rated by farmers; DMr = root dry matter rated by farmers; Gen Imp = general impression of farmers; rYld = yield ranked; rHI = harvest index ranked. The last two variables measured by researchers.

evaluated. In northeastern Uganda, there is a strong selection for high dry matter by farmers due to their traditional way of utilizing the sweetpotato for amukeke and inginyo. Table 5 provides correlations among variables either rated by farmers or measured by researchers. Not all variables rated by farmers were significantly correlated to the variables measured by researchers. Such different opinions are quite normally obtained in a farmer participatory approach (Solori *et al.*, 2000; Courtois *et al.*, 2001).

A scatter-plot of the Serere trial (Figure 4) shows the correlation between weight of storage roots and number of roots per plot. A negative correlation was found ($r = -0.96$; $n=160$). Essentially, no correlation was found between these variables at Arapai ($r = -0.03$; not shown). Conversely, a relatively high positive correlation was observed between number of roots and yield at Serere ($r = 0.79$) but not at Arapai ($r = 0.47$; not shown).

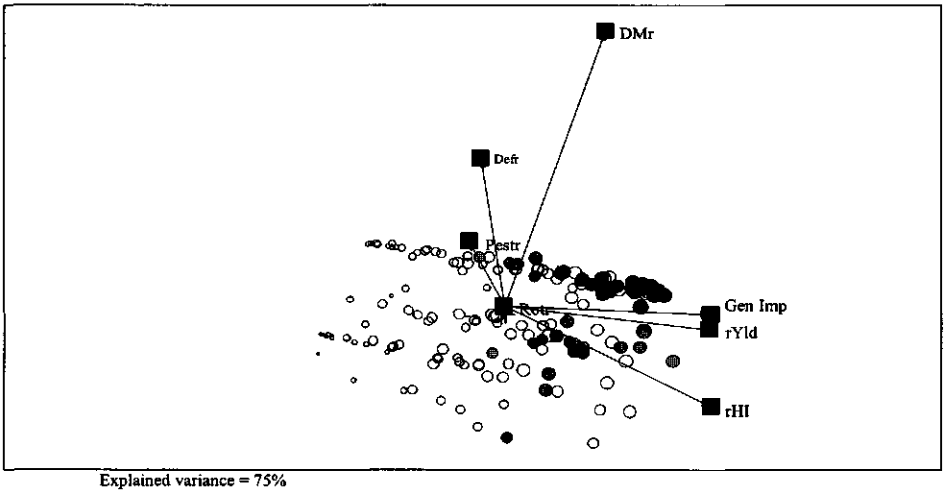



Figure 3b. Biplots of selected (black circles) and non-selected varieties and correlation among the variables yield, DM, HI, pest infestation and occurrence of defects based on the farmers' general impression at Arapai, in Uganda. The explanation of the symbols is provided in Figure 3a. Rotr = rots rated by farmers.

Table 5. Non-significant correlations between traits rated by farmers and by researchers.

| No. | Relationship explanation of variables | Correlation (r) Serere | Arapai |
|---|---|---|---|
| 1 | Between dry matter content and general impression rated by farmers | 0.14 | 0.44 |
| 2 | Between dry matter content rated by farmers and yield determined by researchers | 0.06 | 0.35 |
| 3 | Between dry matter content rated by farmers and harvest index determined by researchers | 0.02 | 0.33 |
| 4 | Between pests and defects rated by farmers | 0.30 | 0.45 |
| 5 | Between pests and dry matter content rated by farmers | 0.11 | –0.04 |
| 6 | Between pests and rots rated by farmers | 0.11 | 0.11 |

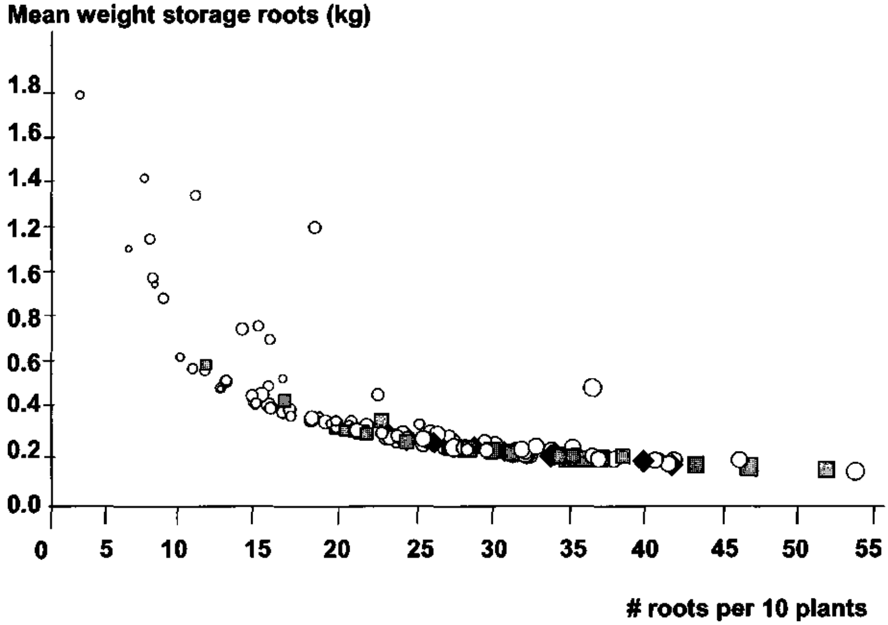



Figure 4. Scatterplot at Serere trial site showing the correlation between mean weight of storage roots (y-axis) and number of roots per 10 plants (x-axis). Circle = not selected; grey square = initially selected by farmers; black diamond = finally selected varieties. Size of symbol proportional to yield. Spearman rank correlation = –0.957.

In Figure 4, most of the 11 selected varieties are located in the area where their numbers of storage roots are greater than average, but their mean weights are below average. During the selection the farmers apparently gave more importance to the numbers of roots per plot than to the weight of each root. Moreover (see also Table 2), the significant difference between selected and non-selected varieties was in the number of storage roots per variety but not in the weight of storage roots.

From the comparison of the means and the observations on the correlations, it can be concluded that farmers are able to evaluate and to select the best varieties for both farmers' and researchers' preference. Farmers' rating of general impression of the varieties, in particular, was significantly and highly correlated with the yield, number of roots per variety, and harvest index assessed by researchers. In India, Courtois *et al.* (2001) also found a good agreement between farmers' and breeders' mean rankings, in about two-thirds of the trials.

Table 6. Selected passport data, including farmer assessment at the time of collection, and assessment by farmers and researchers (root yields) during field evaluation of 11 sweetpotato varieties selected by farmers in trials at Serere and Arapai, Uganda.

| | | | | | Performance of some traits recorded from | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Initial assessment | | | Farmers during the process of germplasm collection in 1999 | | | |
| | | General botanical characteristics | | | By farmers | | By researchers | | | | |
| Code and variety | Came from (district) | Leaf shape | Skin colour | Flesh colour | Taste of fresh str roots | # rts per plot each site | Mean fresh rt yld (t $ha^{-1}$) in two sites | Taste of str. roots | # root per plot | Weevil infestation | Drought tolerance |
| ERA016 (Osapat) | Soroti | Triangular | White | Dark yellow | Very sweet | Good (15-30 rts) | 8.7 | Very sweet | Very good | Little | Yes |
| ERA041 (Osapat) | Soroti | Triangular | Cream | Dark yellow | Sweet | Good | 9.2 | Not really sweet | Very good | Moderate | Yes |
| ERA066 (Etelepat) | Katakwi | Triangular | Cream | White | Sweet | Good | 10.2 | Sweet | Good | Moderate | Moderate |
| ERA080 (BaleAcol) | Lira | Lanceolate | Red pinkish | White | Sweet | Good | 8.7 | Sweet | Good | Moderate | Severe |
| ERA083 (Purple) | Lira | Lanceolate | Red purplish | Dark yellow | Sweet | Good | 8.4 | Very sweet | Fair (10-14 rts) | Moderate | Yes |
| ERA123 (Ejumula) | Katakwi | Lanceolate | Brownish orange (mutant) | Dark orange (mutant) | Very sweet (mutant) | Good (mutant) | 7.5 (mutant) | Not really sweet (original variety) | Good (original variety) | Moderate (original variety) | Severe (original variety) |
| ERA129 (ArakaRed) | Katakwi | Lanceolate | Red | White | Sweet | Good | 8.8 | Sweet | Good | Moderate | Severe |
| ERA139 (Opong Bur B) | Lira | Lanceolate | Cream | Dark yellow | Very sweet | Very good (>30 rts) | 9.9 | Sweet | Very good | Resistant | Yes |
| ERA167 (Muyambi) | Pallisa | Triangular | Reddish | White | Sweet | Very good | 11.0 | Not really sweet | Very good | Resistant | Yes |
| ERA185 (Osukut) | Kumi | Lanceolate | Cream | White | Sweet | Good | 10.3 | Sweet | Very good | Moderate | Severe |
| ERA196 (Ekampala) | Kumi | Lanceolate | Red pinkish | Dark yellow | Very sweet | Good | 8.9 | Sweet | Good | Resistant | Severe |

**Performance of the selected varieties alongside their verification from farmers during collecting the sweetpotato germplasms**

Table 6 and Figures 3a and 3b give information on the eleven selected varieties.

As can be seen from Figures 3a and 3b the finally selected varieties scored above average with respect to 'general impression' (assessed by farmers) and ranked yield (assessed by researchers), both at Serere and Arapai. It can also be seen that the highest yielding ones were not always selected. This results from (a) an imperfect correlation between measured yield and yield potential estimated by farmers, and (b) the fact that farmers also used selection criteria other than yield. The latter is clear from specific examples. Varieties ERA139 and ERA196 were selected because of their sweet taste, despite their poor rating on pest infestation and/or general impression. Similarly, ERA123 was selected because of its orange flesh colour and sweet taste.

While collecting the germplasm, local farmers at the collection sites over northern Uganda had provided information and their specific opinions on the varieties grown in their villages. We have noticed a number of similarities as well as differences between these opinions and the farmers' appreciations collected in the present study (see Table 6). For example, farmers' ratings of the number of storage roots per plot were not completely similar during germplasm collection and the on-station assessment. Although these differences should be taken with caution, because they apply to ratings rather than exact figures, it indicates that farmers' judgement of performance may depend on the local growing conditions.

Thus, the genotype-by-environment interaction factor may play a role and it should be considered when we make use of a farmer-participatory approach to find superior varieties for marginal environments (Courtois *et al.*, 2001). This consideration is important because sweetpotato is known to be sensitive to environmental variation (Manrique and Hermann, 2002).

**Implications for sweetpotato breeding**

Formal breeding programmes in which multi-environment testing is applied have been successful mainly in developing cultivars for high-input agricultural systems. They have been less successful in producing cultivars that are superior to indigenous landraces in marginal environments (e.g., Atlin *et al.*, 2001).

The farmer participatory approach in which the needs and preferences of resource-poor farmers are recognized can substantially contribute to breeding programmes with these target environments. The present study demonstrates that farmer participation may provide additional selection criteria which have been neglected by institutional breeding programmes. In addition, the approach we have taken by collecting local germplasm from a large area of sweetpotato cultivation has provided a valuable source of genetic variation that is potentially useful for the aforementioned breeding purposes.

The results of the farmers' selection described here are preliminary in the sense that multi-season, multi-location trials have to be carried out to assess the yield stability, broadness of adaptation or specific adaptation of the selected varieties. Nevertheless, the results obtained so far hold promise for future efficient identification of sweetpotato varieties that meet the needs of resource-poor farmers in marginal environments, which can be readily adopted by formal breeding programmes.

Adaptation may be influenced by viral disease incidence in the target areas, and the reaction of varieties from northeastern Uganda to sweetpotato virus disease (SPVD). So far, persistent viral disease problems have not been reported in northeastern Uganda (Smit, 1997; Aritua *et al.*, 1998), and it is probably safe to say that most of the varieties arising in northeastern Uganda are not particularly resistant to SPVD. SPVD pressure is high in the higher rainfall Tall Grassland AEZ areas of Lake Victoria Zone of Uganda. However, there are AEZs similar to northeastern Uganda, such as the Lake Victoria Zone of Tanzania, where selected varieties from northeastern Uganda can have a chance of performing well.

## CONCLUSION

The on-station farmer evaluation of local sweetpotato germplasm from northern Uganda has demonstrated that potentially useful genotypes are readily identified in this way. A high correlation was found between many characteristics judged by farmers and traits measured by researchers.

A number of farmers' selection criteria, such as sweet taste, medium size of storage roots, few secondary stems and size and shape of leaves, which are not considered by the Ugandan sweetpotato breeding programme should be given attention if the breeding programme aims at cultivars for low-input agriculture.

Farmer participation may contribute to efficiency improvement of varietal selection of sweetpotato in Uganda and elsewhere. The combined farmers' and breeders' efforts may lead to cultivars that would ultimately benefit farmers.

# CHAPTER 5

## Farmer-participatory selection of sweetpotato varieties in northeastern Uganda using an on-farm trial approach

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**Abstract**

On-farm trials were carried out, and managed by farmers, to assess acceptability and yield performance of sweetpotato cultivars at three locations in northeastern Uganda. In the first year, 144 farmers compared 11 farmer varieties selected by farmers in an on-station evaluation from a large regional germplasm collection, and 5 breeders' cultivars from the Ugandan national institution, with farmers' own varieties ("introductory trial"). In the second year, 45 farmers compared the 5 farmer varieties selected with the 3 breeders' cultivars preferred ("adaptive trial"). Group discussion and individual interviews played a role in evaluating the tested genotypes. Farmers selected five farmer varieties which were common in the three sub-counties but their ranking was different. In most cases, the 11 farmer varieties were preferred over local varieties, whereas local varieties were usually preferred over the breeders' cultivars. Farmers demonstrated very capable involvement in the varietal selection and had significant awareness on the genotype-by-environment interactions and biodiversity.

Key words: Agro-biodiversity, farmer-participatory research, farmer sweetpotato varieties, genotype-by-environment interactions, on-farm trial, sweetpotato variety selection.

## INTRODUCTION

Sweetpotato is an important co-staple crop in Uganda where it serves both for food security and, increasingly, as a cash crop for many resource-poor farmers throughout the country (Bashaasha *et al.*, 1995; Smit, 1997; Scott *et al.*, 1999). As elsewhere in eastern Africa, most sweetpotato varieties in Uganda are landraces which have been selected by farmers either from 'sports' of existing local varieties, volunteer seedlings, or from exotic introductions (Bashaasha *et al.*, 1995; Carey *et al.*, 1998). Recent germplasm collection and duplicate identification efforts in five districts of northeastern Uganda identified 188 distinct genotypes (out of 206 accessions collected) being grown by farmers there (Abidin and Carey, 2001). Distribution of diversity was not uniform across locations. Farmers at some commercially-oriented locations grew only one cultivar, while farmers at more remote locations grew up to 8 varieties (Abidin and Carey, 2001). The relative importance of sweetpotato varieties at a location tends to change with time, as farmers select better performing varieties or use less desired ones due to constraints on planting material availability (Ewell and Mutuura, 1994; Smit, 1997).

As is the case in many developing countries, formal sweetpotato breeding efforts were not established in Uganda until fairly recently (1982) (Hakiza *et al.*, 2000), and have functioned only sporadically since. Starting with local or introduced germplasm, or seed generated in crossing blocks, the Ugandan breeding programme, based at Namulonge, near Kampala, follows a multi-year selection programme involving multi-location and on-farm testing at the last stages prior to official varietal release (Mwanga *et al.*, 1995, 2001). Since 1995, 11 cultivars have been released in Uganda (Mwanga *et al.*, 2001; Mwanga *et al.*, 2003).

Modern plant breeding programmes for many crops have well-defined selection criteria and target environments for improved varieties that they release. These breeding approaches have been very successful, particularly for important commercial crops grown under 'high input' conditions, but often had less success in developing superior varieties for 'low input' conditions (Ceccarelli, 1996). Reasons postulated for lower success rates (Biggs and Farrington, 1991; Hardon and de Boef, 1993; Bänziger and Cooper, 2001) include (i) inadequate definition of selection criteria by breeders, who may not always be familiar with the requirements of resource-poor farmers, and (ii) the difficulty of developing superior, broadly adapted cultivars for diverse low-input production environments. Farmer participation at early stages of selection programmes is a useful tool to assist with the problem of fitting crops to a multitude of target environments and users' preferences (Sperling *et al.*, 1993; Kornegay *et al.*, 1996; Sthapit *et al.*, 1996; Weltzien *et al.*, 1998; Joshi and Witcombe, 1998).

Farmer participation in the advanced stages of sweetpotato variety selection has been reported to be successful in Ethiopia (Shamebo and Belehu, 2000), Kenya (Ndolo *et al.*, 2001) and in Tanzania (Chirimi *et al.*, 2000). In explaining sweetpotato variety performance under diverse growing conditions in farmers' fields in Tanzania, De Steenhuijsen Piters *et al.* (1996) reported that these performances are largely governed by genotype-by-environment interaction. In Ethiopia, the participation of farmers in the research process facilitates feedback for research and extension, paves the way for the consecutive dissemination and adoption of technologies and builds the confidence of farmers in research and in their innovation (Shamebo and Belehu, 2000). In Western Kenya, farmer participation succeeded to select a number of sweetpotato landraces in on-farm trials (Ndolo *et al.*, 2001), and in Tanzania, eight varieties were released officially after being accepted by farmers in the on-farm tests (Chirimi *et al.*, 2000).

The objective of this work was to assess acceptability and yield performance of sweetpotato varieties initially selected by farmers; trials were carried out on-farm over two years in three sub-counties in Soroti District in northeastern Uganda. An introductory trial was done in the first year. This trial attempted to introduce to farmers a number of 'new' genotypes and farmers were asked to compare these new genotypes with their own local varieties as they would usually do when trying new varieties. All the necessary agronomic observations including postharvest tests and taste tests were done. In the second year, an adaptive trial was conducted to compare the accepted new genotypes, now familiar to the farmers, among each other and with standards from the newly released varieties. This on-farm trial was set up based on farmer-designed and -managed research (cf. Witcombe *et al.*, 1998; Frazel and Coe, 2002).

## MATERIALS AND METHODS

In the first year, 144 farmers compared 11 farmer varieties (selected by farmers in an on-station evaluation (Abidin *et al.*, 2002) from a large regional germplasm collection) and five breeders' cultivars from the Ugandan national institution, with farmers' own varieties ('introductory trial'). In the second year, farmers compared the five farmer varieties selected with the three breeder cultivars preferred ('adaptive trial').

### Trial locations

Farmer groups were chosen to conduct on-farm trials in the following sub-counties of the Soroti District: Abalang-Arapai, Abilaep-Serere and Dokolo-Gweri. The members of these groups (both male and female) were innovative farmers, many of whom had been involved in sweetpotato variety trials before. The trial sites were situated in two different agro-ecological zones (AEZs): Abalang-Arapai and Dokolo-Gweri are in the North-central Farmbush Land with sandy soils while Abilaep-Serere is in the Northern

Moist Farmlands (Wortmann and Eledu, 1999). The Abilaep-Serere site has more rainfall than the Abalang-Arapai and Dokolo-Gweri sites (Bakema *et al.*, 1994) where long dry spells frequently occur.

**Planting and harvest dates**

The introductory on-farm trial was carried out in the second rainy season of the year 2000/2001. The crops were planted on $11^{th}$ (Dokolo-Gweri), $18^{th}$ (Abilaep-Serere), or $24^{th}$ (Abalang-Arapai) September 2000. Harvest was done 5 months after planting, on $11^{th}$ (Dokolo-Gweri), $18^{th}$ (Abilaep-Serere) or $24^{th}$ (Abalang-Arapai) February 2001.

The adaptive on-farm trial was carried out in the first rainy season of the year 2001. The crops were planted on $24^{th}$ (Abalang-Arapai), $25^{th}$ (Dokolo-Gweri), or $27^{th}$ (Abilaep-Serere) March 2001. Harvest was conducted 5 months after planting, on $15^{th}$ (Dokolo-Gweri), $16^{th}$ (Abalang-Arapai), or $17^{th}$ (Abilaep-Serere) August 2001.

**Genotypes included in the experiments**

In the introductory trial, farmer varieties were Araka red (ERA129), Bale Acol (ERA080), Ekampala (ERA196), Ejumula (ERA123), Etelepat (ERA066), Muyambi (ERA167), Opong Bur B (ERA139), Osapat (ERA016), Osapat (ERA041), Osukut (ERA185), and Purple (ERA083). The breeder cultivars were the newly released Ugandan cultivars: NASPOT 1 (No. 52), NASPOT 2 (No. 178), NASPOT 5 (No. 316), NASPOT 6 (No. 324) (Mwanga *et al.*, 2003), and No. 93/29 (a promising clone). Some farmers in Abilaep-Serere and Dokolo-Gweri were already familiar with the nationally released cultivars, and selected those considered to be most promising at their locations. For farmers in Abalang-Arapai the Ugandan cultivars were completely new so the use of the Ugandan cultivars in their trials was based on the knowledge of farmers at the other two sites. In the adaptive trial, the farmer-selected varieties were Ejumula (ERA123), Ekampala (ERA196), Etelepat (ERA066), Opong Bur B (ERA139) and Osapat (ERA016). The breeder cultivars were NASPOT 1 (No. 52), NASPOT 5 (No. 316) and NASPOT 6 (No. 324).

**Replication and randomization**

In the introductory trial, each participating farmer was randomly assigned a single genotype, with three farmers evaluating each genotype. In each sub-county 48 farmers were involved in the assessment (144 farmers in total). Cuttings of one genotype were supplied to each farmer and farmers compared the genotype with a specific local variety. The two entries were planted at the same time and grown in adjacent plots.

In the adaptive trial, each participating farmer was randomly allocated a single genotype plus one nationally released cultivar. Local varieties were not included in the adaptive trial. In every location, each farmer variety was allocated to three farmers whereas a particular breeder cultivar was allocated to all participating farmers. The cultivar NASPOT 1 was selected by farmers at Abilaep-Serere, NASPOT 5 at Dokolo-Gweri and NASPOT 6 at Abalang-Arapai. In every sub-county, 15 farmers were involved (45 farmers in total).

Data were analysed according to a randomized complete block design. Sub-counties were considered as replicates within the overall assessment; within these replicates genotypes investigated were replicated thrice.

**Trial management**

Prior to planting, farmer group leaders and some individual farms in each sub-county were visited by the researcher, to agree on trial sites, the layout of the plots, and the breeder cultivars to be included in the assessment. Farmers were asked to plant trials in their normal sweetpotato production fields and to use regular cultural practices, including no fertilizers or pesticides.

Planting materials for the introductory trial were from nurseries at the Arapai Agricultural College (AAC) or the Serere Agricultural and Animal Production Research Institute (SAARI) in Soroti District. Planting materials of farmer varieties for this trial came from farmers' own fields. Planting materials for the adaptive trial were from nurseries at the AAC (in Soroti District) or the Namulonge Agricultural and Animal Production Research Institute (NAARI) in Mpigi District. Clean planting materials (free of pest damage and symptoms of diseases) were selected from the nurseries.

Farmers planted three apical vine cuttings per mound. Mound spacing was recorded at time of harvest. The diameter of each mound was about 30-60 cm and the distance between mounds also differed per farmer resulting in plant arrangements of circa 60 × 60 cm to 80 × 80 cm. Each plot consisted of 20 mounds (60 cuttings).

During the introductory trial, at Abalang-Arapai and Dokolo-Gweri, drought at the time of planting led to some failure of establishment. Gaps were promptly filled to ensure a uniform stand. Gap-filling was not necessary at Abilaep-Serere. In the adaptive trial, some gap-filling was needed in all sub-counties due to incidence of sweetpotato virus diseases and drought (Abilaep-Serere) and millipedes (order: Diplopoda) (Abalang-Arapai and Dokolo-Gweri).

Evaluations by researchers and farmers were done (i) 2 weeks after planting for gap-fillings, (ii) 6 weeks after planting, and (iii) at harvest. In addition to the varietal evaluation, individual interviews and group discussions were conducted in each sub-county for both sets of on-farm trials.

During farm walks, farmers visited each other's plots, either accompanied by the researchers, or on their own. In the introductory trial, six weeks after planting, visits to some farmers' fields at each site were organized by the senior author. Sixteen farmers in each sub-county visited neighbours' farms to observe the performance of the varieties. Formal farm walks were not organized in the adaptive trial, but farmers were requested to visit their neighbours to assess varietal performance.

**Data collection**

On the agreed date, farmers harvested their crop and brought the produce to a meeting area at each location. For the introductory trial, evaluations took two working days but evaluation in the adaptive trial could be finished in one day. For the introductory trial yields of fresh storage roots, total number of roots, number of marketable roots, and occurrence of diseases and pests were assessed by researchers and farmers. Yield data were collected only for the experimental genotypes, not for the local check cultivars, which were used by farmers for their own on-farm comparisons. Individual interviews based on a standard checklist, and peeling and slicing tests of storage roots were also conducted. Farmers tested the taste, and a group discussion was done to select the best tested varieties.

For the adaptive trial, weight of fresh storage roots, total number of roots, and number of marketable roots were determined by researchers and farmers for each farm, and individual interviews and group discussions based on a standard checklist were accomplished.

During the individual interviews, for both introductory and adaptive trials, each farmer was questioned on agronomic details and market orientation. In the introductory trial, the questions were specifically related to (i) comparison of the performance of tested genotypes and local varieties during crop growth, (ii) his/her opinion on yield performance of the tested genotype, (iii) plans to multiply the tested genotype and future use. For the adaptive trial, farmers were questioned about (i) familiarity with the Ugandan bred cultivars, and (ii) differences between farmer variety and Ugandan cultivar, i.e., crop growth and performance of root yield, total numbers of roots and numbers of marketable roots.

In group discussions, at each location, 15 to 16 farmers representing each tested genotype in the introductory trials (16 tested genotypes in total) and all replicates of tested genotypes in the adaptive trial, enlightened their observations on the performance of their variety from planting till harvesting. Other farmers listened to the discussion (introductory trial), contributing if they felt inclined to. The results from group discussion were altogether recorded by researchers.

Ease of peeling and slicing was evaluated using a 5-point ordinal scale 1 = very hard, 2 = hard, 3 = fair, 4 = easy, 5 = very easy. Male and female farmers peeled and sliced a few storage roots of each tested variety selected.

For the taste tests, a few female farmers at each location steamed some storage roots of each variety. The names of varieties were not revealed to farmers in order to avoid bias. The steamed storage roots were cut into small pieces. Water was provided to each participant to rinse the mouth between tasting varieties. Male and female adult farmers as well as children participated in taste tests of the experimental varieties. Adult participants scored the storage roots for sweetness, blandness, water content after boiling (high or low), fibrousness (had fibres or no fibres), smell (good or bad), and general remarks for the taste (good, fair, bad). Children only assessed a good or bad taste of storage roots. The children's evaluations were conducted separately from, and after the adults' assessment. Thirty children and 56 adults participated in the taste assessment.

Predominant flesh and skin colour of fresh storage roots were rated using sweetpotato descriptors (CIP, AVRDC, IBPGR, 1991), and steamed flesh colour was rated using the scale for raw flesh colour.

**Data processing**

For the introductory trial, the genotype-by-environment interaction analysis was done by ANOVA for fresh storage root yield (t $ha^{-1}$), total number of storage roots per farmer's plot, and number of marketable roots per farmer's plot. Subsequently, a *t*-test was done to compare the means of the variables fresh storage root yield, number of marketable and total number of storage roots for the selected and non-selected varieties across and within the trial sites. A Chi-square test of the Friedman non-parametric ANOVA was done for variables generated from the post harvest activities (ease of peeling and slicing; scoring the skin and flesh colour of storage roots, and flesh colour after steaming) and for the taste assessment.

For the adaptive trial, firstly, the mean values for fresh storage roots, total number of roots and number of marketable roots for each selected variety and released cultivar were calculated. Secondly, significance of the mean deviation within and across locations was tested. All statistical analyses mentioned above were done using Genstat (Genstat 5 Committee, 1997).

The information from individual interviews including numbers of farmers giving their perceptions (worse, same, or better) on the genotypes investigated during the introductory and adaptive trials were compiled across locations.

## RESULTS AND DISCUSSION

### Group discussion

In the introductory trial, 108 farmers showed up at the harvest and discussed the general performance of the 16 genotypes derived from the field observations, postharvest assessment, and taste tests. The same five farmer varieties Ejumula (ERA123), Ekampala (ERA196), Etelepat (ERA066), Opong Bur B (ERA167), and Osapat (ERA016) were selected by farmers at each site but the ranking was different (Table 1).

Farmers in every location selected one preference breeder cultivar which resulted in different cultivars in the three locations. Two out of three selected cultivars were ranked among the top 5 at two sites (Table 1).

The selection by farmers of the five farmer varieties and three national cultivars was based on the general observation of growth vigour, yielding capacity on the basis of numbers of storage roots, number of marketable roots, susceptibility to pests, perishability, taste assessment, possibility for making amukeke (dried, sliced product), and root characteristics preferred by markets.

In the adaptive trial, farmers in each sub-county also ranked varieties differently (Table 2) and their ranking of the same variety had markedly changed over years (Tables 1 and 2). In this assessment, the preference of farmers was clearly revealed. In

Table 1. Five farmer varieties and three Ugandan cultivars selected by farmers during the introductory trial for further on-farm investigation and their ranking at Abalang-Arapai, Abilaep-Serere and Dokolo-Gweri, Soroti District, Uganda.

| Genotypes for further investigation on farm | Abalang-Arapai (n = 43) Ranking | Abilaep-Serere (n = 33) Ranking | Dokolo-Gweri (n = 32) Ranking |
|---|---|---|---|
| *Farmer varieties* | | | |
| Osapat (ERA016) | 1 | 1 | 3 |
| Opong Bur B (ERA139) | 2 | 2 | 4 |
| Ekampala (ERA196) | 3 | 5 | 5 |
| Etelepat (ERA066) | 4 | 6 | 6 |
| Ejumula (ERA123) | 5 | 4 | 1 |
| *Ugandan breeder cultivars* | | | |
| NASPOT 1 (No. 52) | - | 3 | - |
| NASPOT 5 (No. 316) | - | - | 2 |
| NASPOT 6 (No. 324) | 6 | - | - |

Table 2. Five farmer varieties and three Ugandan cultivars ranked by farmers during the adaptive trial at Abalang-Arapai, Abilaep-Serere and Dokolo-Gweri, Soroti District, Uganda (Number of farmers at each group discussion in each sub-county = 15; total = 45).

| Genotypes for further investigation on farm | Abalang-Arapai Ranking | Abilaep-Serere Ranking | Dokolo-Gweri Ranking |
|---|---|---|---|
| *Farmer varieties* | | | |
| Osapat (ERA016) | 2 | 5 | 2 |
| Opong Bur B (ERA139) | 1 | 2 | 3 |
| Ekampala (ERA196) | 4 | 1 | 5 |
| Etelepat (ERA066) | 5 | 6 | 4 |
| Ejumula (ERA123) | 3 | 3 | 1 |
| *Ugandan breeder cultivars* | | | |
| NASPOT 1 (No. 52) | - | 4 | - |
| NASPOT 5 (No. 316) | - | - | 6 |
| NASPOT 6 (No. 324) | 6 | - | - |

Abalang-Arapai farmers were familiar with the marginally growing conditions, so they selected the best variety suitable for poor soils and less damaged by soil pests. In Abilaep-Serere, where subsistence farmers were living, the best variety was the one with a high yield and a sweet taste, whereas in Dokolo-Gweri, farmers were strongly oriented to the market so their preference was much affected by the up-to-date market force.

During the group discussions, farmers stated that they would not discard any varieties either from the two sets of trials or from their own local varieties even though some of them did not perform well during the assessments.

**Individual interviews**

Summarized results from the individual interviews comparing the 11 farmer varieties, 5 breeder cultivars and the local varieties (introductory trial) or comparing the five farmer varieties and breeder cultivars (adaptive trial) are presented in Tables 3 and 4. In some cases, some local varieties had the same name as a few tested genotypes, but farmers were able to consistently discriminate them.

During the introductory trial, farmers indicated that the farmer varieties showed an above-ground growth pattern similar to the local varieties. The majority perceived that the yield performance of the 11 selected varieties was better than that of the local ones but the yield of the breeder cultivars was rather poor compared to local varieties. In most cases, the 11 farmer varieties were preferred over local varieties, but local varieties were usually preferred over the breeder cultivars (Table 3).

In the adaptive trial, farmers judged that the yield performance of selected varieties was higher than the breeder cultivars. This was not associated with differences in damage by pests or diseases (Table 4). For pest incidence, farmers found in general that the selected varieties and the breeder cultivars suffered equally from pests. As for diseases, three out of five selected varieties, had, according to farmers, less disease incidence than the breeder cultivars; and the other two scored similar to the breeder cultivars.

Table 3. Farmers' perceptions of the 16 experimental varieties versus the local farmer varieties. Information was recorded from the individual interviews of the introductory trial carried out in Abalang-Arapai, Abilaep-Serere, and Dokolo-Gweri sub-counties in Soroti District, Uganda (number of farmers interviewed = 108; number of farmers per genotype: between brackets following each genotype).

| Genotype | Experimental varieties versus local farmer varieties | | | | | | Preferred genotype | |
|---|---|---|---|---|---|---|---|---|
| | Growth performance | | | Yield performance | | | | |
| | Worse | Same | Better | Worse | Same | Better | Local | Tested |
| *Farmer varieties* | | | | | | | | |
| Araka Red (ERA129)(9) | 0 | 9 | 0 | 3 | 0 | 6 | 3 | 6 |
| Bale Acol (ERA080)(9) | 0 | 9 | 0 | 3 | 0 | 6 | 3 | 6 |
| Ejumula (ERA123)(5) | 1 | 3 | 1 | 1 | 1 | 3 | 2 | 3 |
| Ekampala (ERA196)(9) | 0 | 6 | 3 | 0 | 0 | 9 | 0 | 9 |
| Etelepat (ERA066)(4) | 0 | 2 | 2 | 0 | 0 | 4 | 0 | 4 |
| Muyambi (ERA167)(4) | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 2 |
| Opong Bur B (ERA139)(9) | 3 | 5 | 1 | 3 | 1 | 5 | 3 | 6 |
| Osapat (ERA016)(6) | 0 | 3 | 3 | 2 | 0 | 4 | 2 | 4 |
| Osapat (ERA041)(7) | 2 | 3 | 2 | 2 | 0 | 5 | 2 | 5 |
| Osukut (ERA185)(8) | 6 | 2 | 0 | 5 | 0 | 3 | 5 | 3 |
| Purple (ERA083)(6) | 0 | 4 | 2 | 1 | 3 | 2 | 2 | 4 |
| *Ugandan breeder cultivars* | | | | | | | | |
| No. 93/29(7) | 5 | 2 | 0 | 2 | 0 | 5 | 3 | 4 |
| NASPOT 1 (No. 52)(7) | 2 | 5 | 0 | 4 | 1 | 2 | 4 | 3 |
| NASPOT 2 (No. 178)(7) | 2 | 5 | 0 | 5 | 0 | 2 | 4 | 3 |
| NASPOT 5 (No. 316)(4) | 1 | 1 | 2 | 3 | 0 | 1 | 3 | 1 |
| NASPOT 6 (No. 324)(7) | 2 | 5 | 0 | 4 | 0 | 3 | 4 | 3 |

Table 4. Individual perception on the differences between the five selected genotypes and three Ugandan cultivars as recorded for the adaptive trial. The information was summarized from the three sub-counties of Abalang-Arapai, Abilaep-Serere and Dokolo-Gweri in Soroti District, Uganda (number of farmers interviewed = 45; number of farmers per genotype, n = 9).

| Selected genotype | Selected genotype versus breeder cultivars | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yield performance (including yield-related traits) | | | Pest damage | | | | Disease incidence | | | |
| | Worse | Same | Better | Worse | Same | Less | No damage | Worse | Same | Less | No disease |
| Ejumula (ERA123) | 0 | 3 | 6 | 1 | 3 | 0 | 5 | 2 | 2 | 0 | 5 |
| Ekampala (ERA196) | 0 | 0 | 9 | 0 | 3 | 0 | 6 | 0 | 0 | 3 | 6 |
| Etelepat (ERA066) | 3 | 1 | 5 | 2 | 2 | 1 | 4 | 0 | 0 | 3 | 6 |
| Opong Bur B (ERA139) | 2 | 2 | 5 | 1 | 4 | 1 | 3 | 0 | 0 | 3 | 6 |
| Osapat (ERA016) | 0 | 3 | 6 | 0 | 6 | 0 | 3 | 1 | 3 | 0 | 5 |

**Post harvest assessment**

No significant differences were recorded for ease of peeling and slicing, taste, water content (wet textured) and fibres in the flesh of storage roots. However, the overall scores of good taste and aroma showed significant differences among varieties, primarily due to the presence of orange-coloured varieties (data not shown). The orange (beta-carotene content) flesh colour of Ejumula (ERA123) (score = 8; CIP, AVRDC, IBPGR, 1991) was quite stable across the sites and was still present after cooking.

Children first ate all sweetpotato with bright orange-flesh colour such as Ejumula (ERA123) and NASPOT 5, then they turned to the yellow and finally to the white-fleshed varieties. This could be an indication that most children were attracted by the bright colour of storage root flesh. Adults rated the orange-flesh varieties differently from the children. For example, only 64 % of farmers said that Ejumula (ERA123) had a good smell and only 51% scored this variety to have good overall taste.

**Comparisons of selected versus non-selected experimental genotypes based on fresh yields and root numbers: results of introductory trial**

Table 5 presents mean fresh storage root yields, and storage root numbers, across locations, for each cultivar in the introductory trials. A highly significant difference between selected and non-selected genotypes was found for number of marketable roots but not for fresh storage root yield and total number of storage roots. The difference between the two groups was strongly influenced by the inclusion of the poorly performing NASPOT 5.

Table 6 presents detailed results of genotype performance within locations. In the Abalang-Arapai sub-county, no significant differences were observed between selected and non-selected genotypes for fresh storage root yield, number of marketable roots, or total number of storage roots. In the Abilaep-Serere sub-county, there were significant differences between selected and non-selected genotypes in number of marketable roots and total number of roots but not in fresh storage root yield. In the Dokolo-Gweri sub-county, the number of marketable roots differed significantly but the other two traits did not.

**Root yields of farmer varieties and breeder cultivars in adaptive trial**

Figure 1 provides information on the fresh storage root yield (t $ha^{-1}$) in each sub-county, Abalang-Arapai, Abilaep-Serere and Dokolo-Gweri.

In Abalang-Arapai sub-county, the mean of root yields was relative high (10 t $ha^{-1}$). This yielding situation may have been supported by the optimum growing conditions with adequate rainfall (155 mm per month) during the trial. In Abilaep-Serere sub-county, the trial had many failed plots due to drought and diseases (mainly sweetpotato virus disease and *Alternaria* stem blight) reported by farmers. The mean of root yields was 4 t $ha^{-1}$ or below. In Dokolo-Gweri sub-county, the performance of individual genotypes in the farmers' plots was inconsistent. Dokolo-Gweri received rainfalls but it was less than for Abalang-Arapai. Based on the observations across locations, the average fresh storage root yields of the five selected farmer varieties were lower than those recorded in the previous rain season (introductory trial).

From the investigation of the genotype-by-environment interactions, in the across location analysis, the mean deviation of selected farmer varieties and Ugandan cultivars showed that differences among the selected varieties were not significant for fresh storage root yields and total number of storage roots. Significant differences were observed for the number of marketable storage roots. In the within-location analysis, this mean deviation for fresh storage root yields and total number of storage roots was also not significantly different, but for number of marketable storage roots it was.

Table 5. Across location comparisons of selected versus non-selected genotypes (Abalang-Arapai, Abilaep-Serere and Dokolo-Gweri sub-counties in Soroti District, Uganda). Data were collected from 108 farms.

| Genotype | Fresh storage root yield (t $ha^{-1}$) | Number of marketable storage roots | Total number of storage roots |
|---|---|---|---|
| *Selected genotypes* | | | |
| Ejumula (ERA123) | 15.3 | 49 | 115 |
| Ekampala (ERA196) | 17.8 | 33 | 117 |
| Etelepat (ERA066) | 18.8 | 47 | 112 |
| Opong Bur B (ERA139) | 19.7 | 56 | 102 |
| Osapat (ERA016) | 12.7 | 36 | 81 |
| NASPOT 1 (No. 52) | 9.4 | 45 | 110 |
| NASPOT 5 (No. 316) | 1.1 | 6 | 22 |
| NASPOT 6 (No. 324) | 13.5 | 44 | 95 |
| Mean of selected | 13.5 | 40 | 94 |
| *Non-selected genotypes* | | | |
| Araka Red (ERA129) | 11.9 | 23 | 100 |
| Bale Acol (ERA080) | 19.9 | 41 | 115 |
| Muyambi (ERA167) | 15.4 | 41 | 157 |
| Osapat (ERA041) | 21.7 | 38 | 88 |
| Osukut (ERA185) | 10.5 | 31 | 81 |
| Purple (ERA083) | 19.9 | 30 | 78 |
| NASPOT 2 (No. 178) | 11.9 | 20 | 117 |
| No. 93/29 | 5.0 | 20 | 88 |
| Mean of non-selected | 14.5 | 31 | 103 |
| Mean of selected minus non-selected genotypes | $-1.0^{ns}$ | $9.0^{*}$ | $-9.0^{ns}$ |

T-test: $^{*}$ $P < 0.05$; $^{ns}$ non significant.

## Participatory trial methodology

The one farmer-one variety method developed by Witcombe *et al.* (1998) was demonstrated to be useful for our set of on-farm trials. Each farmer intensely assessed each experimental genotype and harvested the crop with no trouble.

A large number of farmers involved in our 'introductory' on-farm trials (n = 144) could also correspond to a large plot size as well as recommended by Mutsaers *et al.*

Table 6. Within location comparisons of selected versus non-selected genotypes (Abalang-Arapai, Abilaep-Serere and Dokolo-Gweri sub-counties in Soroti District, Uganda).

| | Abalang-Arapai sub-county (# farms = 43) | Abilaep-Serere sub-county (# farms = 33) | Dokolo-Gweri sub-county (# farms = 32) |
|---|---|---|---|
| *Fresh storage root yield (t ha$^{-1}$)* | | | |
| Mean selected genotypes | 10.0 | 24.4 | 13.4 |
| Mean non-selected genotypes | 8.6 | 20.0 | 10.1 |
| Mean of selected minus non-selected genotypes | $1.4^{ns}$ | $4.4^{ns}$ | $3.3^{ns}$ |
| *Number of marketable roots* | | | |
| Selected genotypes | 23.0 | 63.0 | 51.0 |
| Non-selected genotypes | 14.0 | 41.0 | 30.0 |
| Mean of selected minus non-selected genotypes | $9.0^{ns}$ | $22.0^{**}$ | $21.0^{**}$ |
| *Total number of roots* | | | |
| Selected genotypes | 76.0 | 131.0 | 98.0 |
| Non-selected genotypes | 78.0 | 100.0 | 112.0 |
| Mean of selected minus non-selected genotypes | $-2.0^{ns}$ | $31.0^{*}$ | $-14^{ns}$ |

T-test: $^{*}$ $P < 0.05$; $^{**}$ $P < 0.01$; $^{ns}$ non significant.

(1997). This large number might have induced a large farm variation. Not all farmers turned up at the end of the introductory trial (only 108 farmers participated instead of 144) but 'no show' did not happen in the adaptive trial. This enthusiasm declined due to having some inconvenient experiences with the previous on-farm research. Sthapit *et al.* (1996) described the same decline in enthusiasm of farmers early in the on-farm research programme, but this reluctance declined as the farmers gained some benefits from the programme. In the adaptive trial, farmers acknowledged some reimbursement

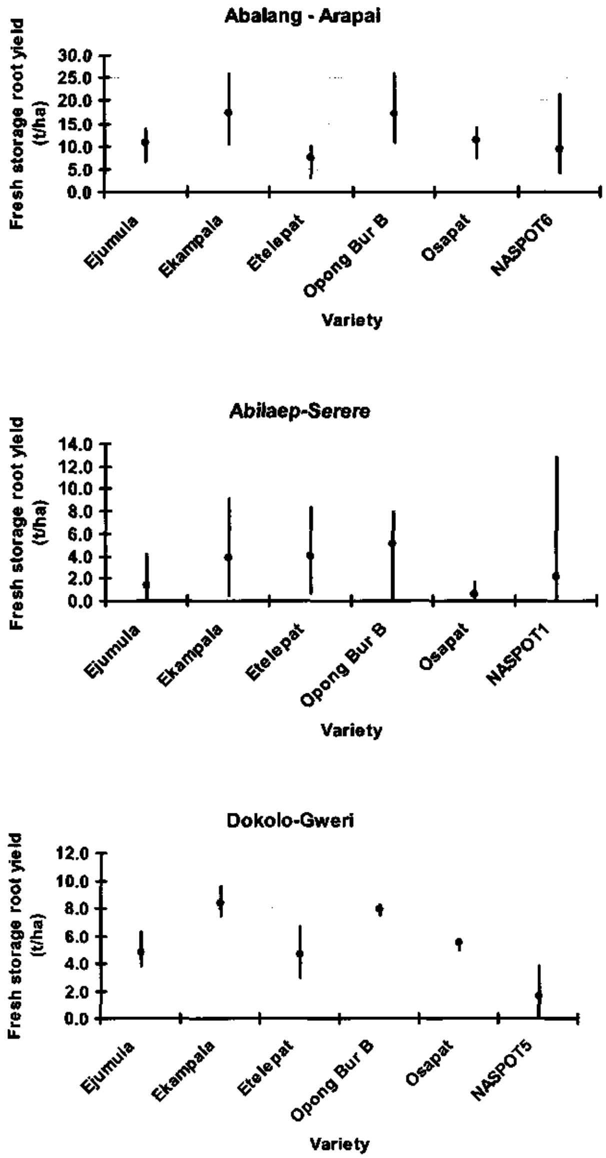


Figure 1. Bar-graphs of fresh storage root yields (t $ha^{-1}$) from the adaptive trial conducted in Abalang-Arapai, Abilaep-Serere, and Dokolo-Gweri sub-counties in Soroti District, northeastern Uganda. Each bar indicates the range between the maximum and minimum values for root yields of each genotype. The dot found in each bar gives the mean root yield of each genotype (n-farmer variety per sub-county = 3; n-Ugandan cultivar per sub-county = 15).

for their labour costs as this had allowed them to increase planting materials of desired varieties. This opportunity in obtaining the planting materials through the trial programme might have solved their serious problem on the availability of planting materials at the beginning of planting season (Ewell and Mutuura, 1994; Smit 1997).

In the introductory trial, farmers found it difficult to select the best farmer varieties because they performed so similarly over the area, despite differences in soils. In hindsight, this is reflected by the minor differences between selected and non-selected genotypes except for number of marketable roots (Table 5). Nevertheless, group discussion decided to select five farmer varieties and one Ugandan cultivar for further evaluation in the consecutive on-farm adaptive trial. According to farmers, five farmer varieties were a number that made trials manageable and fitted to the real number of members in every group of farmers in each location (average between 10 and 15 farmers).

In the introductory trial, both across and within locations, the precision of farmers in evaluating the genotypes for the traits fresh storage root yield and total number of roots was low but not so for the number of marketable roots (Tables 5 and 6). The inaccurate selection by farmers may have been due to (i) the inclusion of the national Ugandan cultivars among the selected genotypes; (ii) the eleven selected varieties by farmers in the initial on-station trials (Abidin *et al.*, 2002) continued to show their superior performance in on-farm trials; (iii) the agro-ecological range of the three sites was relatively narrow (fitting to the description made by the Uganda Working Group 9A, Agricultural Policy Committee 1991) so the genotype-by-environment interaction for fresh storage root yield did not occur (Table 5).

Yield and quality were important criteria for farmers (Abidin *et al.*, 2002). However, the predominance of market forces (Osukut type) was really crucial, as was a growing awareness by farmers of potential nutritional advantages of orange-fleshed types (i.e., NASPOT 5 and Ejumula (ERA123)). There is a considerable current interest in using orange-fleshed sweetpotato varieties as a means of combating vitamin A deficiency (http://www.cipotato.org/VITA.htm; Hagenimana *et al.*, 2001). Furthermore, at the time of these trials, farmers were excited by reported high market demand in Kenya for amukeke prepared from orange-flesh sweetpotato by local newspapers and radio programmes. So, farmers were eager to have the two orange-fleshed cultivars in their collection.

## CONCLUDING REMARKS

During the farmer participatory research trials farmers demonstrated very capable involvement in the work of varietal selection. This type of on-farm trials, combined with an attitude towards learning and understanding from farmers and researchers provided new information for assessing the overall usefulness of new genotypes. It could be worthwhile to identify locally well-adapted varieties from the often wide range of already released varieties or from breeders' initial varietal trials. Such participatory evaluation and selection of existing or released varieties has great potential for identifying locally acceptable varieties quickly. This may be useful at an early stage in the variety dissemination process or may contribute valuable information during the variety release process.

The implications of our on-farm trials for the structuring of a testing programme are probably worth noting. We probably over-did the on-farm testing component, and we could have just done preliminary selection, with farmer participation on station, after which a multiplication effort (by NGOs or the District Agricultural Offices) could have distributed planting materials to farmers.

Our work also provides a low-cost model for speeding up the rate of identification and distribution of new varieties, whether landraces, or newly-bred varieties. This may give some valuable contribution to the local NGOs, farmer associations, farmers' field school (FFS), and seed multiplication agencies in order to develop their programmes especially when the farmers are highly knowledgeable, willing to do some research and having capability in the variety selection in the region.

# CHAPTER 6

## Adaptation and stability analysis of sweetpotato varieties for low input systems in Uganda

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**Abstract**

Sixteen sweetpotato varieties were evaluated for fresh storage root yield in 20 trials during 2000-2001 for three seasons in four locations in Uganda. Of the sixteen varieties, 11 were developed by farmers and five by a central breeding programme. The behaviour of the varieties was quantified in terms of wide adaptation (genotypic mean across trials), specific adaptation (genotypic predictions for specific locations) and stability (Shukla stability variance). With respect to all three aspects of yield behaviour, farmer varieties performed on average better than the official varieties. Our results illustrate the potential that farmer varieties can have in the improvement of sweetpotato in Uganda and other regions where high diversity of sweetpotato landraces exists.

Key words: Farmer varieties, genotype-by-environment interaction, *Ipomoea batatas*, specific adaptation, stability, sweetpotato, wide adaptation.

## INTRODUCTION

Sweetpotato is an important low-input crop for many places in Sub-Saharan Africa (Ewell and Mutuura, 1994; Bashaasha *et al.*, 1995; Kapinga *et al.*, 1995; Tayo, 2000). Throughout the region, production of this crop is mainly based on large numbers of landraces (Carey *et al.*, 1998). Many of these varieties have been reported to be relatively low yielding, narrowly adapted, and susceptible to diseases and pests (Bashaasha *et al.*, 1995). For much of Sub-Saharan Africa, successful variety selection efforts have relied on the selection of elite varieties from existing farmers' sweetpotato varieties. Examples include the varieties Mugande in Rwanda, SPN/O in Tanzania, Kenya and Uganda, and New Kawogo in Uganda (Ndamage *et al.*, 1992; Mwanga *et al.*, 2001a).

The Ugandan national sweetpotato breeding programme develops improved cultivars, and has released selected farmer varieties and bred cultivars following a programme of multi-locational and on-farm testing (Mwanga *et al.*, 2001a; Mwanga *et al.*, 2003). Eleven cultivars have been released by the Ugandan National Agricultural Research Organization to date (Mwanga *et al.*, 2001a, 2003). However, there is continued demand for new varieties to satisfy the needs of farmers for superior varieties with wide adaptation to Ugandan conditions or specific adaptation to certain production regions.

Assessment of wide and specific adaptation and stability play a central role in many breeding programmes. Also for sweetpotato these concepts seem essential for describing the performance of varieties across environments, as sweetpotato has been shown to be very sensitive to environmental changes (Bacusmo *et al.*, 1988; Carpena *et al.*, 1982; Janssens, 1984). Wide adaptation is generally ascribed to varieties that do well over large areas. Widely adapted varieties have a high mean across environments. A variety is said to have specific adaptation if it ranks among the highest yielders at some locations, but not at others. In the definition of Shukla (1972), a stable variety is a variety of which yield varies relatively little around the average yield for that variety, after correction for the average differences that will always exist between environments. Bacusmo *et al.* (1988) and Manrique and Hermann (2002) employed stability measures in the selection of superior sweetpotato varieties for traits like root yield, total number of roots, beta-carotene content, and root dry and fresh matter. Manrique and Hermann (2002) reported that none of their high-yielding cultivars had satisfactory stability for total root yield and suggested the need for further study to elucidate the nature of sweetpotato root-yield performance in response to varying agro-ecological conditions.

Recent germplasm collection in five districts of northeastern Uganda identified 188 distinct genotypes (out of 206 accessions collected) that were grown by farmers

(Abidin and Carey, 2001). Out of 160 morphologically distinct genotypes which were investigated in initial on-station trials in 1999/2000, 84 genotypes yielded at least 10.6 t $ha^{-1}$ (Abidin *et al.*, 2002). Eleven farmer-preferred varieties, out of the 84 genotypes with superior yields, were used for further on-farm and multi-location on-station trials. This study was conducted to identify superior cultivars as possible candidates for release and/or parents for hybridization, one of the main sweetpotato breeding activities in Uganda (Hakiza *et al.*, 2000; Mwanga *et al.*, 2001b).

The main objective of the present research was to identify the genotypes, which could have wide or specific adaptations in low-input agricultural systems in Uganda. In addition, yield stability was investigated. Since yield is the most important trait we confined our analyses to fresh storage root yield of the genotypes in the study.

## MATERIALS AND METHODS

### Genotypes used in the study

Eleven varieties selected by farmers from the germplasm landraces in northeastern Uganda in 2000 (Abidin *et al.*, 2002) plus four established Ugandan cultivars (Mwanga *et al.*, 2003) and one promising clone were investigated at four stations with a total of 20 environments. Table 1 lists the genotypes used in this study. All released cultivars (NASPOT series) were selected from bulked seed generated from an open-pollinated polycross nursery of 24 parents planted in 1991 at Namulonge Agricultural and Animal Production Research Institute (NAARI), Uganda (Mwanga *et al.*, 2003).

### Description of trial sites

Trials were conducted at the Arapai Agricultural College (Arapai), at the Serere Agricultural and Animal Production Research Institute (Serere) in Soroti District of northeastern Uganda, at NAARI (Namulonge) in Mpigi District of central Uganda, and at the Kyera Farm Institute (upland) and a nearby farmer field (swamp), which was under the management of the Kyera Farm Institute (Mbarara) in the Mbarara District of southwestern Uganda. Trials were conducted on both upland and swampy soils at each station. A soil-map of each research station was used to distinguish between upland and swamp.

The four locations experience a bimodal rainfall pattern (Musiitwa and Komutunga, 2001). Mbarara District has an average annual rainfall of 1200 mm, Mpigi District 1500 mm, Soroti District between 1000 to 1500 mm (Rwabwoogo, 1997). Within the district of Soroti, based on the rain distribution pattern described by Bakema *et al.* (1994), Serere has more rainfall than Arapai. In Arapai, long dry spells frequently occur. The daily air temperatures at the trial locations varied from 25 to 30 °C

Table 1. Sweetpotato genotypes evaluated in 20 environments at four locations and three seasons in Uganda in 2000 and 2001.

| Name of cultivar | Code | Type of genotype |
|---|---|---|
| Araka red | ERA129 | Farmer variety |
| Bale Acol | ERA080 | Farmer variety |
| Ekampala | ERA196 | Farmer variety |
| Ejumula | ERA123 | Farmer variety |
| Etelepat | ERA066 | Farmer variety |
| Muyambi | ERA167 | Farmer variety |
| Opong Bur B | ERA139 | Farmer variety |
| Osapat | ERA016 | Farmer variety |
| Osapat | ERA066 | Farmer variety |
| Osukut | ERA185 | Farmer variety |
| Purple | ERA083 | Farmer variety |
| NASPOT1 | No. 52 | Released variety |
| NASPOT2 | No. 178 | Released variety |
| NASPOT5 | No. 316 | Released variety |
| NASPOT6 | No. 324 | Released variety |
| - | No. 93/29 | Promising clone |

(Rwabwoogo, 1997). Meteorological data were also collected from each location. The data on rainfall, maximum and minimum air temperatures were recorded daily at each trial location in every planting season (Table 2). Soils were analysed, and latitude, longitude and altitude were also determined.

**Environmental setup**

A total of 20 environmental conditions were used. These test environments were derived from (i) 4 locations, (ii) two types of soil reclamation (i.e., swamp and upland), and (iii) different planting seasons in the two or three consecutive rain seasons in years 2000 and 2001.

Tables 2 and 3 provide detailed information on the meteorological conditions, crop rotation practices, soil textures and fertility of each trial location.

**Crop cultivation**

In Arapai and Serere, trials were repeated in three consecutive rainy seasons: first and second rain seasons of 2000 and first rain season of 2001. In Namulonge and Mbarara, trials were repeated in two consecutive rainy seasons: second rain season of 2000 and

Table 2. Meteorological data across locations and planting seasons (rainfall, and average maximum and minimum air temperatures recorded from trial locations Arapai Agricultural College, Serere Research Institute, Namulonge Research Institute and Kyera Farm Institute, Mbarara, Uganda).

| Location | First rain season 2000 | | | Second rain season 2000 | | | First rain season 2001 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Rain-fall (mm) | Min. temp. (°C) | Max. temp. (°C) | Rain-fall (mm) | Min. temp. (°C) | Max. temp. (°C) | Rain-fall (mm) | Min. temp. (°C) | Max. temp. (°C) |
| Arapai | 131.7 | 16.1 | 30.5 | 105.7 | 19.0 | 28.1 | 196.9 | 16.4 | 29.8 |
| Serere | 143.9 | 18.3 | 29.9 | 119.2 | 18.2 | 30.7 | 152.9 | 18.1 | 29.1 |
| Namulonge | - | - | - | 76.5 | 15.8 | 27.9 | 113.9 | 15.8 | 27.5 |
| Mbarara | - | - | - | 299.8 | 24.0 | 26.8 | 54.8 | 25.2 | 29.2 |

first rain season of 2001. Detailed information on the planting and harvesting dates is given in Table 4.

No fertilizers, pesticides or irrigations were applied. Cropping rotations and fallows prior to the trials were recorded at the four locations (Table 3).

Sixty cuttings of each variety were planted on 20 mounds arranged in two-row plots. Each mound had three vine cuttings. Each plot was made by marking an area of 8.4 m × 1.2 m, and two rows of 10 mounds were heaped within the plot using a hoe according to the traditional farmers' practice in northeastern Uganda. Mounds were roughly 30 cm high and 30 cm in diameter. All outside rows of the experimental plots had boarder plants. A randomized complete block design with three replicates was used. Gaps were promptly filled to ensure a uniform stand in each trial. Harvest was done 4 months after planting.

### Data collecting

At harvest, data on fresh storage root yield, the incidence of diseases (sweetpotato virus disease and *Alternaria* stem blight) and pests, i.e., sweetpotato weevils (*Cylas* spp.) and millipedes (order Diplopoda) were collected at each trial in every season. The number of diseased plants per plot was counted. The results from both diseases and pests were not statistically analysed because their variations were too low across the test environments.

### Statistical analyses

To comply with the assumption underlying analysis of variance, the square root of root

Table 3. Previous crop, soil type and soil fertility measured before planting the trials in the Arapai College, Serere Research Institute, Namulonge Research Institute, and Kyera Farm Institute of Mbarara in Uganda.

| Items | Arapai | | Serere | | Namulonge | | Mbarara | |
|---|---|---|---|---|---|---|---|---|
| | Swampy | Upland | Swampy | Upland | Swampy | Upland | Swampy | Upland |
| *First rain season of year 2000* | | | | | | | | |
| Previous crop | Fallow 5 yrs | Fallow 3 yrs | Fallow 4 yrs | Millet | - | - | - | - |
| Soil type | Sandy-clay loam | Sandy loam | Sandy-clay loam | Sandy loam | | - | - | - |
| pH | 4.4 | 4.7 | 5.2 | 6.0 | - | - | - | - |
| Organic matter (%) | 2.30 | 2.40 | 2.40 | 3.50 | - | - | - | - |
| N (%) | 0.07 | 0.05 | 0.17 | 0.16 | - | - | - | - |
| P (ppm) | 10.40 | 1.50 | 2.26 | 8.15 | - | - | - | - |
| K (mg/100g soil) | 11.10 | 5.33 | 10.00 | 14.80 | - | - | - | - |
| Ca (mg/100g soil) | 25.70 | 12.90 | 24.60 | 36.80 | - | - | - | - |
| *Second rain season of year 2000* | | | | | | | | |
| Previous crop | Fallow 5 yrs | Fallow 3 yrs | Fallow 4 yrs | Millet | Fallow 5 yrs | Fallow 5 yrs | Irish potato | Maize |
| Soil type | Sandy-clay loam | Sandy loam | Sandy-clay loam | Sandy loam | Sandy-clay loam | Sandy loam | Sandy loam | Sandy loam |
| pH | 5.2 | 5.3 | 5.2 | 6.1 | 6.0 | 5.9 | 5.8 | 5.5 |
| Organic matter (%) | 1.80 | 1.50 | 1.80 | 3.40 | 5.01 | 6.62 | 2.80 | 2.00 |
| N (%) | 0.08 | 0.09 | 0.12 | 0.09 | 0.10 | 0.14 | 0.05 | 0.04 |
| P (ppm) | 1.53 | 4.36 | 2.98 | 28.70 | 2.93 | 4.80 | 17.57 | 10.80 |
| K (mg/100g soil) | 9.26 | 9.63 | 11.00 | 28.00 | 0.66 | 0.20 | 27.50 | 17.00 |
| Ca (mg/100g soil) | 23.70 | 24.60 | 28.70 | 73.70 | 11.20 | 9.10 | 62.50 | 41.20 |
| *First rain season of year 2001* | | | | | | | | |
| Previous crop | Fallow 5 yrs | Maize | Beans | Millet | Fallow 5 yrs | Yam | Fallow 1 year | Maize |
| Soil type | Sandy loam | Sandy loam | Sandy loam | Sandy-clay loam | Sandy-clay loam | Sandy loam | Sandy loam | Sandy-clay loam |
| pH | 5.0 | 5.0 | 5.9 | 5.8 | 4.9 | 5.0 | 5.4 | 5.6 |
| Organic matter (%) | 1.60 | 1.40 | 4.70 | 4.20 | 3.70 | 2.50 | 2.40 | 2.50 |
| N (%) | No data | No data | No data | No data | No data | No data | No data | No data |
| P (ppm) | 3.40 | 2.20 | 29.90 | 27.60 | 3.70 | 3.00 | 55.20 | 62.70 |
| K (mg/100g soil) | 4.80 | 6.20 | 15.10 | 12.00 | 7.30 | 4.40 | 5.00 | 12.90 |
| Ca (mg/100g soil) | 6.30 | 4.90 | 22.70 | 22.00 | 11.20 | 8.50 | 11.70 | 17.60 |

Note: Soil analysis was done at Kawanda Research Institute, Uganda. The standard critical value (pH: 5.2, Organic matter: 3.0%, N: 0.2%, P: 5.0 ppm, K: 15 mg/100 g soil, Ca: 35.0 mg/100 g soil) can be used to indicate the fertility of the soils in the 20 trial sites. If the values are lower than the critical values as mentioned above, the fertility is considered to be poor.

Table 4: Planting and harvesting dates of each environment including its latitude, longitude, altitude and abbreviation of multi-environmental trials done in Uganda in the three consecutive rain seasons of years 2000 and 2001 (total number of environments = 20).

| | First rain season 2000 | Second rain season 2000 | First rain season 2001 |
|---|---|---|---|
| | | **Northeastern Uganda – Arapai** | |
| Swamp | 1°47′N; 33°38′E; 1093 m<br>planted on 27 May '00<br>harvested on 27 Sept. '00 | 1°47′N; 33°38′E; 1093 m<br>planted on 19 Sept. '00<br>harvested on 20 Jan. '01 | 1°48′N; 33°38′E; 1093 m<br>planted on 3 April '01<br>harvested on 27 July '01 |
| Upland | 1°48′N; 33°38′E; 1134 m<br>planted on 19 May '00<br>harvested on 19 Sept. '00 | 1°47′N; 33°37′E; 1134 m<br>planted on 19 Sept. '00<br>harvested on 20 Jan. '01 | 1°47′N; 33°37′E; 1134 m<br>planted on 25 March '01<br>harvested on 28 July '01 |
| | | **Northeastern Uganda – Serere** | |
| Swamp | 1°32′N; 33°27′E; 1100 m<br>planted on 25 May '00<br>harvested on 25 Sept. '00 | 1°32′N; 33°27′E; 1100 m<br>planted on 25 Sept. '00<br>harvested on 26th Jan. '01 | 1°32′N; 33°27′E; 1100 m<br>planted on 24 April '01<br>harvested on 14 Aug. '01 |
| Upland | 1°32′N; 33°27′E; 1100 m<br>planted on 26 May '00<br>harvested on 26 Sept. '00 | 1°32′N; 33°27′E; 1100 m<br>planted on 26 Sept. '00<br>harvested on 27 Jan. '01 | 1°32′N; 33°27′E; 1100 m<br>planted on 2 April '01<br>harvested on 30 July '01 |
| | | **Central and southern Uganda – Namulonge** | |
| Swamp | Nil | 0°31′N; 32°7′E; 1120 m<br>planted on 8 Dec. '00<br>harvested on 7 April '01 | 0°31′N; 32°37′E; 1120 m<br>planted on 7 April '01<br>harvested on 3 August '01 |
| Upland | Nil | 0°30′N; 32°39′E; 1125 m<br>planted on 8 Dec. '00<br>harvested on 6 April '01 | 0°31′N; 32°37′E; 1120 m<br>planted on 7 April '01<br>harvested on 4 August '01 |
| | | **Central and southern Uganda – Mbarara** | |
| Swamp | Nil | 0°39′S; 30°36′E; 1379 m<br>planted on 30 Sept. '00<br>harvested on 4 Feb. '01 | 0°39′S; 30°36′E; 1379 m<br>planted on 30 March '01<br>harvested on 9 August '01 |
| Upland | Nil | 0°39′ S; 30°40′E; 1459 m<br>planted on 30 Sept. '00<br>harvested on 3 Feb. '01 | 0°39′ S; 30°40′E; 1459 m<br>planted on 30 March '01<br>harvested on 8 August '01 |

yield was analysed instead of root yield itself. Phenotypic variation was partitioned into components due to genetic, environmental, and genotype-by-environment interaction variation. The variance components were estimated by restricted maximum likelihood (REML) using Genstat (2002). Since the relative magnitude of the variance components was important, variance components were not back-transformed. To investigate wide and specific adaptation, genotypic means across locations were calculated. Means were calculated on the square root scale, using models for which all terms were random. For ease of interpretation, the genotypic means were back-transformed.

To help in the assessment of wide and specific adaptations, a multivariate scatter plot, or biplot, of the genotype-by-location means was used. Such plots allow the simultaneous display of genotypic responses for a number of environments. Similar to a bivariate scatter plot, genotypic yields in specific environments can be obtained by projecting genotypic points on environmental axes. The difference between bivariate scatter plots and biplots, is mainly that the environmental axes in a biplot do not necessarily intersect each other at a right angle, but more likely at an acute angle when the correlation between the environments is positive and at an obtuse angle when the correlation is negative. Detailed description of biplots for plant breeding data can be found in Yan and Kang (2003).

Finally, for stability assessments, we followed Shukla (1972), giving each genotype its own genotype-by-environment interaction variance. We estimated the Shukla stability variances by REML from a mixed model with genotypes and environments random, and interaction variance depending on genotype. The stability variances were back-transformed for ease of interpretation.

## RESULTS AND DISCUSSION

### Optimal versus worst conditions from the target population of environments

Three types of target environments were defined, consistent with the Ugandan sweetpotato breeding strategy described by Hakiza *et al.* (2000). Our target population of environments was

- Warm and sub-humid where weevils (*Cylas* spp.) and drought are important. Arapai and Serere locations represented this type of environments,
- Warm and moist where viruses are most severe. This environment was represented by Namulonge location; and
- Cool and moist southwestern highlands where *Alternaria* stem blight and low soil fertility are major constraints. Mbarara location was selected for this type of environment.

While conducting the trials, we observed that our experimental environments deviated from the expected behaviour of our defined target environments in some respects. First, the Serere and Arapai trials had sufficient rainfall without the usual dry period whereas the Mbarara and Namulonge trials experienced drought. Second, problems with weevils in Serere and Arapai, and *Alternaria* stem blight in Mbarara did not occur

Table 5. Mean of fresh storage root yields (t ha$^{-1}$) of the sweetpotato genotypes at four locations (Arapai, Mbarara, Namulonge and Serere) in Uganda, averaged over two soil types (swampy and upland) and two or three rain seasons in years 2000 and 2001.

| Genotype | Arapai | Mbarara | Namulonge | Serere |
|---|---|---|---|---|
| *Farmer varieties* | | | | |
| ERA016 (Osapat) | 7.4 | 10.6 | 12.9 | 18.7 |
| ERA041 (Osapat) | 6.5 | 9.2 | 13.3 | 18.2 |
| ERA066 (Etelepat) | 7.8 | 9.1 | 11.6 | 21.7 |
| ERA080 (Bale Acol) | 7.3 | 10.1 | 12.9 | 20.6 |
| ERA083 (Purple) | 8.3 | 7.9 | 13.0 | 20.3 |
| ERA123 (Ejumula) | 6.7 | 8.7 | 11.0 | 15.5 |
| ERA129 (Araka Red) | 7.7 | 9.7 | 11.9 | 22.6 |
| ERA139 (Opong Bur B) | 7.7 | 9.6 | 8.8 | 14.2 |
| ERA167 (Muyambi) | 9.0 | 10.2 | 11.1 | 16.3 |
| ERA185 (Osukut)* | 6.3 | 7.8 | 10.8 | 18.7 |
| ERA196 (Ekampala) | 7.7 | 8.6 | 9.6 | 19.7 |
| *Ugandan cultivars* | | | | |
| No. 178 (NASPOT 2) | 6.3 | 8.2 | 8.3 | 16.7 |
| No. 316 (NASPOT 5) | 1.4 | 3.8 | 4.0 | 2.3 |
| No. 324 (NASPOT 6) | 5.1 | 9.0 | 11.9 | 15.3 |
| No. 52 (NASPOT 1) | 4.2 | 10.9 | 11.3 | 14.2 |
| No. 93/29 | 4.1 | 8.3 | 9.2 | 12.1 |

* The morphological characteristics of this genotype are distinct from the commercial Osukut (Abidin, 2001).

but were recorded in Namulonge. Third, soil fertility in Mbarara was not poor compared to Arapai. Fourth, we could only reach the altitude of 1500 m above sea level (asl), i.e., Mbarara location. This altitude was not typical of the highland environment of Uganda (2000 m asl).

Tables 2 and 3 summarize the trial conditions. Soil analysis showed that Namulonge and Serere had higher organic matter and nitrogen than Mbarara and Arapai. The trials in Arapai could be indicated to have the poorest soil conditions. Three out of four trials of Namulonge had some incidence of the sweetpotato virus disease (SPVD) and occurred in one trial at Mbarara. Serere probably had the most favourable conditions for growing sweetpotatoes. As seen in Table 5, the highest average root yield was found here (16.7 t ha$^{-1}$). In contrast, the lowest mean yields occurred in Arapai (6.5 t ha$^{-1}$). Apparently, severe stress occurred at this location.

**Estimated variance components and genotype-by-environment (G×E) interaction investigation**

Table 6 provides information on the estimated variance components. The genotypic main effect was important and was larger than the interaction terms containing the genotypes (all kinds of G×E). This means that the G×E was relatively unimportant. However, it should be noted that the sum of the G×E components is equal to the G component, so G does not clearly dominate. Thus, there seems to be room for breeding for wide adaptation, which may be good news for sweetpotato breeders in Uganda. To understand the relative importance of wide adaptation in comparison to specific adaptation, we also inspected the size of the genotype-by-location (G×L) interaction variance. The G×L variance was about a third of the G component, so local adaptation seems to be relatively unimportant. The magnitude of the G×L term was about the same as that of the three-way interaction genotype-by-location-by-season and the four-way interaction genotype-by-location-by-season-by-soil. However, these last two interactions are not very manipulable from a breeder's point of view, whereas G×L interactions may be exploited by choosing those varieties that do best at a particular location.

Soil analysis showed that the soil properties of swamp versus upland in our trials were not consistent (Table 3). Variance components including soil were small, except for the four-way interaction genotype-by-location-by-season-by-soil component. The latter may well represent trial error rather than variation directly related to soil type. Therefore, we did not account for the swamp versus upland contrast in our G×E analysis.

Table 6. Estimated variance components for the full random models (genotypes, locations, soil types, and seasons) of fresh storage root yields from multi-environment trials conducted in Uganda during in two or three consecutive rain seasons in years 2000 and 2001.

| Random term | Component | Standard error |
|---|---|---|
| Genotype | 0.1784 | 0.0769 |
| Genotype × location | 0.0662 | 0.0273 |
| Genotype × season × location | 0.0502 | 0.0216 |
| Genotype × season × soil | 0.0087 | 0.0111 |
| Genotype × location × soil | 0.0065 | 0.0147 |
| Genotype × season × location × soil | 0.0733 | 0.0238 |
| Error | 0.2043 | 0.0118 |

The estimated error variance component was quite large, a not uncommon observation for low-input systems. Possible reasons include irregular rainfall, drought, poor soil conditions, pests and disease incidences, i.e., *Alternaria* stem blight, sweetpotato virus diseases (SPVD), sweetpotato weevils and millipedes. Precautionary measures were taken such as adjusting planting dates, gap-filling (once), and weeding/field sanitation (twice). However, to reduce error variance, more trials would be required.

**Adaptability and stability of experimental genotypes**

In order to identify stability and wide versus narrow adaptation of the experimental genotypes we jointly inspect Table 5 and Figures 1 and 2.

First of all we observe from Table 5 that almost all genotypes increased their yield under better environmental conditions. Remarkably, the farmer varieties as a group outyielded the group of national varieties (NASPOTs) at all locations. At the poorest of locations, Arapai, all farmer varieties are above, while all NASPOTs are below the average of that location. For the other locations this ranking is less outspoken, but here also the majority of varieties with above average (local) yield were farmer varieties.

Figure 1 shows a scatter plot of stability, measured by the Shukla stability variance, versus average fresh storage root yields. The scatter plot is divided into four quadrants (I-IV) by the lines of average stability and yield. The centre of quadrant I represents genotypes of high yield and low stability. Similarly, the quadrants II, III and IV represent genotypes of low yield and low stability, low yield and high stability, and high yield and high stability, respectively. NASPOTs are in quadrant II, indicating both a lower than average stability and lower than average yield. Two of them are either extremely low in yield (No. 316) or in stability (No. 52). The poor stability of No. 52 is due to its very low yield at Arapai (Table 5). The remainder of the NASPOTs are located towards the centre of the scatter plot, but all three of them yield less than or at most equal to the farmer varieties.

Figure 1 also shows that among the farmer varieties we find the highest yielding and most stable varieties (located in quadrant IV). For example, ERA016 and ERA080 have the highest average yield and are very stable at the same time. These varieties perform better than average at each individual location and can be regarded as widely adapted. This is also confirmed by the biplot of Figure 2 (see below).

Next we ask ourselves to what extent we find specific adaptation among the tested genotypes. To this end we inspect Figure 2, showing a genotype-by-location biplot of fresh storage root yield. In this biplot the (approximate) yield of a particular genotype in a given location can be found by perpendicularly projecting the genotype's point on the line (arrow) of that location (the environmental axis).

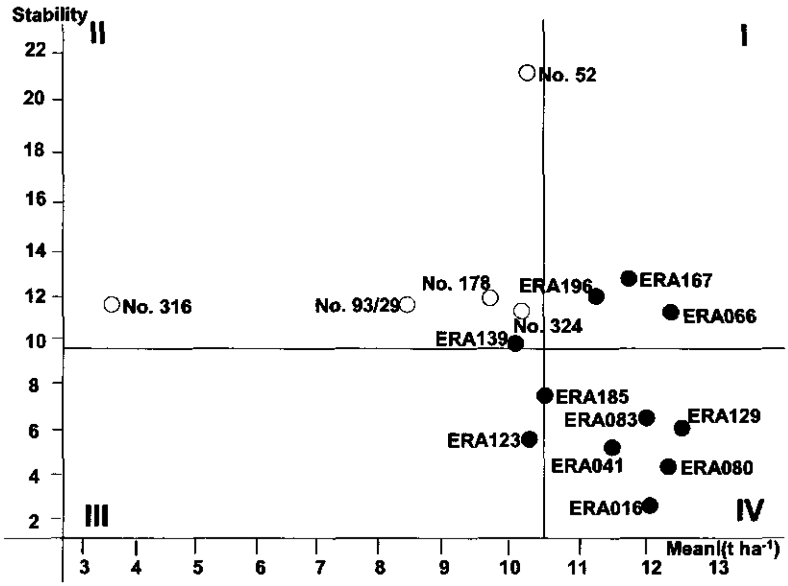


Figure 1. Scatter-plot of Shukla stability variance (y-axis) versus genotypic main effect (x-axis; root yields (t $ha^{-1}$)). Filled circles are the farmer varieties and open circles are the breeder cultivars. The four quadrants (I-IV) were separated by the lines of average stability and yield.

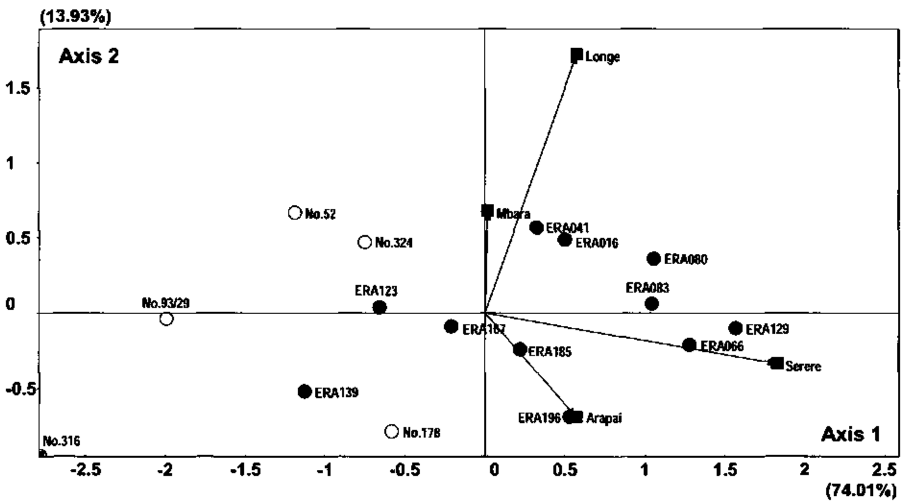


Figure 2. Biplot of genotype by location means for fresh storage root yield. Squares are the four trial locations (Arapai, Serere, Namulonge (abbreviated as Longe) and Mbarara (abbreviated as Mbara)). Filled circles are the farmer varieties and open circles are the breeder cultivars.

From Figure 2 we see that farmer varieties ERA080 and ERA016, which we identified as high yielding and stable, have indeed above average yield at all locations. Examples of specific adaptation are farmer varieties ERA066 and ERA129 which perform well at Serere and Arapai, but poor at Mbarara. Similarly, farmer variety ERA041 and national cultivar No. 52 yielded relatively well at Mbarara (a poor environment – cf. Aniku, 2001), but not so at the other locations.

Our analysis has revealed substantial differences among the genotypes investigated with respect to yield stability and wide versus specific adaptation. We have identified at least two farmer varieties (ERA080 and ERA016) that are both stable and high yielding. At least two farmer varieties (ERA066 and ERA129) were identified to be specifically adapted to two environmental conditions. Remarkably, these growing conditions represent the poorest (Arapai) and the richest (Serere) of conditions in our trials.

Another remarkable observation is that none of the varieties released by the national Ugandan breeding programme matches the most promising farmer varieties either with respect to yield stability or with respect to yield averaged over the test environments.

In our trials we made observations on the incidence of sweetpotato virus disease (SPVD), but this provided no clear indication that disease incidence affected yield seriously. However, it is known that SPVD causes severe yield reduction in susceptible cultivars (Hahn, 1979; Gibson *et al.*, 1998). When targeting areas where a high disease pressure is likely to be met, breeders should continue paying attention to screen germplasm and potential new cultivars under this condition. It should be noted that the farmer varieties tested in our study had been selected from areas of low disease pressure. Therefore, their level of SPVD resistance may be limited, and, despite the findings in our trials, their performance in high disease pressure areas may eventually be disappointing.

**Implication of findings for sweetpotato breeding**

The farmer varieties that we evaluated in this study had been selected from a large germplasm collection by means of farmer participation in the initial evaluation of the germplasm at Serere and Arapai (Abidin *et al.*, 2002). Our results indicate that in this way potentially useful cultivars may rapidly be identified: several of the farmer varieties showed good average yield and stability, while others displayed specific adaptation. The wide adaptation we found may specify that farmer varieties originating from northern Uganda could also perform well in southern Uganda. As long as potentially new cultivars have a required level of resistance to sweetpotato virus disease and meet the quality demands, it may be possible to select for wide adaptation, targeting northern and southern Uganda at the same time.

A remarkable degree of coincidence between the farmers' selections at Arapai and Serere (Abidin *et al.*, 2002) could be an additional indicator of the stability of selected varieties. This result is very good news for predicting the future success of sweetpotato breeding efforts both in the near term and long term in Sub-Saharan Africa. There has been some concern that G×E interactions might make sweetpotato improvement overly difficult. However, our results reveal that it is possible to identify superior broadly adapted genotypes capable of performing well over broad areas. Hence, the Ugandan breeding programme, and partners throughout the region, if they correctly target selection sites, should be able to efficiently breed for large areas of Sub-Saharan Africa. This hypothesis needs to be further tested by international multi-locational testing of the selected superior varieties from this work. The work conducted here did not cover the highland environment, and there may be other important environments that would be distinct from the environments used here. However, previous sweetpotato breeding work elsewhere, such as in China shows that single broadly adapted cultivars can give rise to prominence over large geographic areas (Ma *et al.*, 1998). The current broad importance of cultivar 'Tanzania' (known as 'Osukut' in northeastern Uganda) through much of Sub-Saharan Africa also bodes well for the selection of broadly adapted sweetpotato cultivars by the Ugandan sweetpotato breeding programme. The precise role of farmers in this process requires further consideration, as do the prospects for continued selection of superior varieties from the local germplasm.

Apart from fresh storage root yield, other traits are to be considered when nominating a farmer variety as potentially useful. For example, orange-fleshed varieties are considered to be important in children's diets because of their high beta-carotene content. For that reason the orange-fleshed variety ERA123 could be considered as useful despite its slightly below average yield, which is compensated for by its fairly good stability (see Figure 1).

Another example is the farmer variety ERA139 which had below average yield and around average stability (Figure 1). In on-farm evaluation farmers in Abalang sub-county (Soroti District) ranked it first because this variety grew well in poor soils and was not much affected by sweetpotato weevils and millipedes. In addition to this farmers' observation, we noted that ERA139 was not destroyed by a heavy hail storm that occurred at the Serere nursery in April 2000, while the other 15 genotypes in the study were severely damaged. So, these additional observations could be a reason to retain ERA139 in a further evaluation programme.

## CONCLUSION

Among the eleven farmer varieties that had been selected with a farmer-participatory approach we identified two varieties with broad adaptation to various agro-ecological zones of northern and southern Uganda, whereas two others showed specific adaptation to some of the growing conditions of our evaluation trials. This demonstrates that taking advantage of farmers' knowledge and experience by means of the participatory approach in a preliminary on-farm and on-station evaluation enables a quick identification of promising genotypes in a germplasm collection, thus contributing to an improvement of sweetpotato breeding in Uganda.

# CHAPTER 7

# Variance component estimates and allocation of resources for breeding sweetpotato (*Ipomoea batatas* (L.) Lam.) under east African conditions

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**Abstract**

In Africa average sweetpotato storage root yields are low and breeding is considered to be an important factor in increasing production. The objectives of this study were to obtain further variance component estimates for sweetpotato in this region of the world and then use these to determine the efficiency of variety trials and breeding systems. From an incomplete series of variety trials in Kenya and Uganda (comprising 15 genotypes, 5 locations and 3 seasons), variance components were estimated – using the REML method – for the following traits: storage root yield, biomass production, harvest index, storage root dry matter as well as the Elston index (which was used to aggregate all previous four traits). The variance components were significant for all traits, except the genotype × season interactions for storage root dry matter. The efficiency of selection systems was determined for total test capacities of 450 and 900 plots, selection of 5 genotypes and using not more than 5 locations. Two-stage selection is 15% to 80% more efficient than one-stage selection after two seasons of testing. Two-stage selection was optimized under the restriction of using at least two locations at Step 1. For storage root yield, the optimum was associated with two locations and one replication at Step 1 and five locations and one replication at Step 2. For index selection the optimum was associated with two locations and one replication at Step 1 and five locations and two replications at Step 2. In the case of storage root yield, two replications at Step 2 resulted in a decline in the response to selection of only 0.8% to 3.2%. In conclusion, for a test capacity of 450 to 900 plots, trials with two locations and one replication at Step 1 and five locations and two replications at Step 2 may be an appropriate system both for selecting for storage root yield and for simultaneously selecting for storage root yield, biomass production, harvest index and storage root dry matter content by using the Elston index. There are indications that such an allocation of resources for breeding sweetpotato is also appropriate for other regions in Sub-Saharan Africa.

Key words: Sweetpotato (*Ipomoea batatas*), variance component estimates, East Africa, G×E interactions, index selection, allocation of test capacity.

## INTRODUCTION

Sweetpotato is the second most important African root crop after cassava, and is grown on approximately $0.5 \times 10^6$ ha in East Africa. However, the storage root yields of sweetpotato in this area are (with an average of about 5.6 t $ha^{-1}$) the lowest of any region of the world. The identification and development of new varieties are considered to be an important way of increasing sweetpotato production and food supply in East Africa, because farmers there have very limited opportunities with regard to the use of agro-chemicals.

To improve the efficiency of variety testing and breeding systems, estimates of variance components are required. Focus is usually placed upon yield, but estimates concerning nutritional characteristics are informative, while those made for indices in which several traits are combined, allow us to optimize variety testing and breeding systems for the most important traits simultaneously. There are few reports of variance component estimates being made for sweetpotato cultivation in Africa. Furthermore, estimates are often based on data for a single year or growing season.

One exception is the study made by Ngeve (1993), who reported the mean squares due to genotypes ($MS_G$), genotype × location interactions ($MS_{GxL}$), genotype × year interactions ($MS_{GxY}$) and genotype × location × year interactions ($MS_{GxLxY}$) for two series of sweetpotato trials in Cameroon (Central Africa). The corresponding ratios of variance components calculated from these MS values for $\sigma^2_G : \sigma^2_{G\times L} : \sigma^2_{G\times Y} : \sigma^2_{G\times L\times Y} : \sigma^2_E$ were 1 : 0.32 : 0.06 : 0.50 : 1.33 in the first series of trials and 1 : 0 : 0 : 1.97 : 3.34 in the second series of trials. The component $\sigma^2_{G\times Y}$ was not significant in the first series of trials while $\sigma^2_{G\times L}$ and $\sigma^2_{G\times Y}$ were not significant in the second series of trials. However, all remaining variance component estimates were significant. This indicates that spatial variation can substitute for temporal variation in series of variety trials for sweetpotato in this region of the world. However, in other crops and regions the $\sigma^2_{G\times Y}$ component is often found to be significant across several series of variety trials (Hill *et al.*, 1998). The variance component $\sigma^2_{G\times Y}$ is a critical term, because the effect this component has on test efficiency can only be changed if tests are conducted across years (Talbot, 1997). A large $\sigma^2_{G\times Y}$ may require two years of testing to obtain both sufficient test precision and response to selection. Nevertheless, negative as well as non-significant variance components of $\sigma^2_{G\times Y}$ must be expected in single-series of variety trials, due to the larger error associated with variance component estimates.

Here we report variance component estimates from an international sweetpotato trial in Sub-Saharan Africa. Data were restricted to only those locations which were used across seasons (Kenya and Uganda in East Africa). No variance component estimates had previously been reported for sweetpotato in East Africa. The variance component estimates and corresponding lower bound confidence limits were used to determine the efficiency of sweetpotato trials when the breeder is aiming to improve the trait storage root yield or the traits storage root yield, biomass production, harvest index and storage root dry matter content simultaneously using the Elston index (Elston, 1963).

## MATERIALS AND METHODS

An international sweetpotato trial was conducted from 1999-2001 in several countries of Sub-Saharan Africa. However, only the trials in Kenya and Uganda could be used for this study, as trials in all other locations were conducted over only one growing season. It should be noted that sweetpotato (like many other crops grown in the tropics) is often grown twice within a 12-month period and that the beginning and end of a growing season can be in different years. Therefore, we propose to use the term season (S) instead of the term year when considering sweetpotato variety trials. Moreover, sweetpotato growth is indeterminate and crop duration within a season can vary depending on the farmer's needs and preferences.

In total 15 genotypes were grown at 3 locations: (1) Kabete (Kenya, 01°15' S, 36°15 E, 1820 m a.s.l., 2 growing seasons: December 1999 - June 2000 and April 1999 - November 2000), (2) Kakamega (Kenya, 00°16' N, 34°45' E, 1585 m a.s.l., 3 growing seasons: December 1999 - June 2000, May 2000 - November 2000 and November 2000 - May 2001) and (3) Serere (Uganda, 01°32' N, 33°27' E, 1100 m a.s.l., 2 growing seasons: August 2000 - January 2001 and April 2001 - August 2001). At Kabete and Kakamega both a short-duration crop (harvested 4 months after planting) and a long-duration crop (harvested 6 months after planting) were planted. The treatments (short-duration and long-duration crop) were applied to spatially separate experiments and therefore considered as different environments. At Serere, harvests were conducted 147 days after planting in the first season and 115 days after planting in the second season.

A randomized block design, comprising three replications, was used at each experiment. Plot size was 14.4 $m^2$ at Kabete and 18 $m^2$ at Kakamega and Serere. Total storage root yield (TYLD), total storage root dry matter yield (TDYLD) and biomass production (BIOM) were recorded in t $ha^{-1}$, while harvest index (HI = TYLD / BIOM) and storage root dry matter content (DM = TDYLD / TYLD) were recorded as percentages. For four traits, namely TYLD, BIOM, HI and DM, the observed values $x_j$ ($j = 1,\ldots,4$) were standardized using

$$x_j^* = \frac{x_j - \bar{x}_j}{s_j}$$

(where $\bar{x}_j$ is the mean and $s_j$ the standard deviation across genotypes for each experimental block) in order to calculate the Elston index (Elston, 1963). The index was calculated using the formula

$$I = \prod_{j=1}^{4} (x_j^{*} - k_j)$$

(where $k_j$ is the lowest observed value in each block for trait $j$). The data from each location (L) were classified into three growing seasons (S): Kabete 1 and Kabete 2 (S1 and S2), Kakamega 1 and Kakamega 2 (S1, S2 and S3) and Serere (S2 and S3). The analysis of variance was carried out using SAS6.12 (SAS Institute Inc., 1988, SAS Institute Inc., 1997), more specifically using the procedure PROC MIXED, the REML method (Patterson, 1997) and the Model statement

$$X = BL(L,S) + G + L + S + L \times S + G \times L + G \times S + G \times L \times S.$$

The estimated variance components and a total test capacity of 450 and 900 plots were used to determine and improve allocation of resources on the basis of the formula for the response to selection for clones and homozygous lines (Wricke and Weber, 1986).

The basic equation for the expected selection response is the well known equation

$$R = h^2 S,$$

where, $R$ is the expected response, $h^2$ is the heritability of the trait, and $S$ is the selection differential.

For the experimental setup used in our trials the heritability reads

$$h^2 = \frac{\sigma_G^2}{\sigma_P^2} = \frac{\sigma_G^2}{\sigma_G^2 + \frac{\sigma_{G\times S}^2}{s} + \frac{\sigma_{G\times L}^2}{l} + \frac{\sigma_{G\times L\times S}^2}{l \cdot s} + \frac{\sigma_E^2}{l \cdot s \cdot r}},$$

in which $s$, $l$ and $r$ are the number of seasons, locations and replicates, respectively.

The selection differential, $S$, can be expressed in the proportion of the population that is selected and can be obtained from the Gaussian probability density function (see, e.g., Wricke and Weber, 1986). We expressed $R$ in units genotypic standard deviation ($\sigma_G$).

Thus, for a given total test capacity of $l \times s \times r$ plots, a given allocation (actual values of $l$, $s$ and $r$), and a given selection intensity, the expected selection response was calculated using the estimates of the different variance components.

In two-stage selection a certain proportion of the population is selected after the first evaluation (season), which then is tested in a second season, after which again a certain proportion is selected. Calculation of the total expected response after two stages runs along the same lines as for one-stage selection, now using the appropriate variance components for the two successive seasons. For calculation of the optimal scenario (with or without restrictions on the number of locations or replicates) in the two-stage selection we used a self-written computer programme.

We calculated expected responses for the selection of the top five genotypes, either in one or two steps, from an initial population of variable size.

The following restrictions were applied to all resource allocation scenarios: a maximum of five locations, a maximum of three replications per location, and the use of common locations at Step 1 and 2 in the two-stage selection system. Using the variance component estimates made for storage root yield, as well as the Elston index, the efficiency of one-stage selection after two seasons of testing was compared with that of an optimized two-stage selection. Emphasis was placed upon the use of an optimized two-stage selection system involving at least two locations at the first selection Step, because we strongly oppose trials which are conducted at only one location. Moreover, the efficiency of practical interesting alternatives to the obtained optimal allocation was considered, in order to allow practical recommendations to be made.

## RESULTS AND DISCUSSION

The estimated variance components were found to be significant for all traits, except for the component $\sigma^2_{G\times S}$ for storage root dry matter content (Table 1). The lower bound confidence limit was usually considerably greater than zero. Owing to the magnitude of $\sigma^2_G$ an improvement can be made in all sweetpotato traits considered. Of the variance components $\sigma^2_E$ is most often the largest one; however, as indicated above in the equation for heritability, with regard to test precision this term is reduced by a factor obtained by multiplying the number of locations, test seasons and replications (Talbot, 1997).

With regard to storage root yield, biomass production and the index the genotype × environment interactions ($\sigma^2_{G\times L}$ + $\sigma^2_{G\times S}$ + $\sigma^2_{G\times L\times S}$) were considerably larger than $\sigma^2_G$, whereas for harvest index and storage root dry matter content the genotype × environment interactions were considerably smaller than $\sigma^2_G$. For all traits $\sigma^2_{G\times L\times S}$ was the largest component of genotype × environment interactions. This observation is consistent with the variance component estimates reported for many other crops and regions (Hill *et al.*, 1998).

In the case of storage root yield, storage root dry matter and the index, $\sigma^2_{G\times S}$ was smaller than $\sigma^2_{G\times L}$ so that, for these traits, spatial variation of test environments can be substituted for temporal variation of test environments. Only for biomass production

Table 1. Variance component estimates for sweetpotato, for storage root yield, biomass, harvest index, storage root dry matter and the Elston index (aggregating all previous four traits) from trials conducted in Kenya and Uganda (1999 to 2001); Rel. = relative magnitudes (in brackets); $CL_{lb}$ = lower bound 95% confidence limits of variance components.

| Trait | | $\sigma^2_G$ | $\sigma^2_{GxL}$ | $\sigma^2_{GxS}$ | $\sigma^2_{GxLxS}$ | $\sigma^2_E$ |
|---|---|---|---|---|---|---|
| Storage root | Estimate | 13.19* | 19.24* | 12.63* | 24.16* | 34.57* |
| yield | Rel. | (1) | (1.46) | (0.96) | (1.83) | (2.62) |
| ($t^2$ $ha^{-2}$) | $CL_{lb}$ | 4.61 | 10.33 | 5.86 | 15.54 | 29.87 |
| | Rel. $CL_{lb}$ | (1) | (2.24) | (1.27) | (3.37) | (6.48) |
| Biomass | Estimate | 82.88* | 11.01* | 60.40* | 82.84* | 131.56* |
| production | Rel. | (1) | (0.13) | (0.73) | (0.99) | (1.59) |
| ($t^2$ $ha^{-2}$) | $CL_{lb}$ | 35.92 | 2.05 | 30.25 | 51.87 | 113.67 |
| | Rel. $CL_{lb}$ | (1) | (0.06) | (0.84) | (1.44) | (3.17) |
| Harvest | Estimate | 113.84* | 6.14* | 10.31* | 24.34* | 86.82* |
| index | Rel. | (1) | (0.05) | (0.09) | (0.21) | (0.76) |
| ($\%^2$) | $CL_{lb}$ | 58.35 | 1.49 | 3.68 | 13.03 | 74.99 |
| | Rel. $CL_{lb}$ | (1) | (0.03) | (0.06) | (0.22) | (1.29) |
| Root dry | Estimate | 9.34* | 0.39* | 0.00 | 1.39* | 5.92* |
| matter | Rel. | (1) | (0.04) | (0.00) | (0.15) | (0.63) |
| ($\%^2$) | $CL_{lb}$ | 4.90 | 0.10 | 0.00 | 0.75 | 5.12 |
| | Rel. $CL_{lb}$ | (1) | (0.02) | (0.00) | (0.16) | (1.04) |
| Elston | Estimate | 30.46* | 11.37* | 2.86* | 42.53* | 117.47* |
| index | Rel. | (1) | (0.37) | (0.09) | (1.40) | (3.87) |
| | $CL_{lb}$ | 13.42 | 3.17 | 0.34 | 23.65 | 100.56 |
| | Rel. $CL_{lb}$ | (1) | (0.24) | (0.03) | (1.76) | (7.49) |

* Significant at 5% level.

was $\sigma^2_{G\times S}$ clearly larger than $\sigma^2_{G\times L}$, though the genotype × environment interactions $\sigma^2_{G\times L}$ + $\sigma^2_{G\times L\times S}$ were still larger than $\sigma^2_{G\times S}$. Nevertheless, owing to the magnitude of $\sigma^2_G$ and $\sigma^2_{G\times S}$, the heritability for biomass in one season of testing cannot be much greater than 0.5, even when the experiment is very large. However, the ratios of variance components obtained here indicate that a two-stage selection system should be superior to one-stage selection after two seasons of testing.

Model calculations made using the ratio of variance component estimates (Table 1), as well as the ratio of the lower bound confidence limits of these estimates (results not presented), show that a two-stage selection system is between 15% and 80% more efficient than a one-stage selection system after two seasons of testing (Table 2). Furthermore, it was observed to be true for the storage root yield trait and for the index (aggregating storage root yield, biomass, harvest index and storage root dry matter content), for a test capacity of both 450 and 900 plots, as well as if the variance component ratios ($\sigma_G^2 : \sigma_{G\times L}^2 : \sigma_{G\times S}^2 : \sigma_{G\times L\times S}^2 : \sigma_E^2$) of 1 : 1.46 : 0.96 : 1.83 : 2.62 (category 'A' (storage root yield) in Table 2), 1 : 0.37 : 0.09 : 1.40 : 3.87 (category 'B' (Elston index) in Table 2) or if the corresponding ratios of lower bound confidence limits (results not presented) were used. Hence, a two-stage selection system may be generally more efficient than a one-stage selection system after two seasons of testing in sweetpotato trials.

The highest response in the two-stage selection system without using two locations at Step 1 ("No" in Table 2) – theoretically the optimal test capacity allocation –was always associated with one location and one replication at selection Step 1. However, the value of conducting tests at one location without replication may be disputable – though we do not dispute the value of unreplicated field trials, since efficient methods for controlling soil variation in unreplicated trials are available (Kempton and Gleeson, 1997). We feel that recommending the use of one location is not acceptable from a practical perspective because of the risk that the plant material at one location is lost (e.g., due to bad weather conditions). For this reason, optimization was conducted under the restriction that a minimum of two locations were used at each selection stage ("Loc = 2" in Table 2). Under this restriction the highest response to selection and optimal allocation was associated with two locations and one replication for storage root yield and index selection at selection Step 1 and with five locations and one replication for yield at selection Step 2. By contrast, the optimal allocation for index selection was associated with five locations and two replications at selection Step 2. This optimum should be considered to be an operational optimum as (in contrast with the theoretical optimum which is associated with one location at selection Step 1) it avoids the need to conduct risky field experiments.

At the operational optimum the differences between the number of tested genotypes at each selection step with regard to yield and index selection are smaller than the differences between the number of tested genotypes at each selection step obtained at the theoretical optimum, However, these differences were still considerable. It is not possible to conduct optimized field trials for different traits within the same experiment and breeders need guidelines how they should allocate resources. For this reason (as well as to avoid the psychological barrier which discourages breeders from conducting unreplicated trials) it was decided to test the smaller subset of genotypes at selection Step 2 in two replications, which is the operational optimum for selection based on the index. This resulted in a decline in the expected response to selection for

Table 2. Response to selection for storage root yield in sweetpotato, and response to selection based on the Elston index (which aggregates storage root yield, biomass production, harvest index and root dry matter content); TCAP = total test capacity in plots; V. Ratio = Variance component ratios of $\sigma_G^2 : \sigma_{G\times L}^2 : \sigma_{G\times S}^2 : \sigma_{G\times L\times S}^2 : \sigma_E^2$ A) 1 : 1.46 : 0.96 : 1.83 : 2.62 for yield and B) 1 : 0.37 : 0.09 : 1.40 : 3.87 for the Elston index, $TG_i$: number of genotypes tested in season *i*; $LOC_i$: number of locations in season *i*; $REP_i$ : number of replications in season *i*; R: response to selection; Standard: one stage selection after two seasons of testing; No: no restriction on number of replicates in two-stage selection; Loc = 2: two locations at first step in two-stage selection; Suggested: suggested allocation with two locations at first step in two-stage selection.

| Trait | TCAP | V. Ratio | Restriction | $TG_1$ | $TG_2$ | $LOC_1$ | $LOC_2$ | $REP_1$ | $REP_2$ | R |
|---|---|---|---|---|---|---|---|---|---|---|
| Yield | 450 | A | Standard 1 | 15 | 15 | 5 | 5 | 3 | 3 | 0.763 |
| | | | Standard 2* | 22 | 22 | 5 | 5 | 2 | 2 | 0.919 |
| | | | Standard 3 | 45 | 45 | 5 | 5 | 1 | 1 | 1.145 |
| | | | No | 290 | 32 | 1 | 5 | 1 | 1 | 1.381 |
| | | | Loc = 2 | 170 | 22 | 2 | 5 | 1 | 1 | 1.354 |
| | | | Suggested | 150 | 15 | 2 | 5 | 1 | 2 | 1.322 |
| Index | | B | Standard 1 | 15 | 15 | 5 | 5 | 3 | 3 | 0.926 |
| | | | Standard 2* | 22 | 22 | 5 | 5 | 2 | 2 | 1.101 |
| | | | Standard 3 | 45 | 45 | 5 | 5 | 1 | 1 | 1.329 |
| | | | No | 270 | 36 | 1 | 5 | 1 | 1 | 1.588 |
| | | | Loc = 2 | 140 | 17 | 2 | 5 | 1 | 2 | 1.563 |
| | | | Suggested | 150 | 15 | 2 | 5 | 1 | 2 | 1.558 |
| Yield | 900 | A | Standard 1 | 30 | 30 | 5 | 5 | 3 | 3 | 1.049 |
| | | | Standard 2 | 45 | 45 | 5 | 5 | 2 | 2 | 1.180 |
| | | | Standard 3 | 90 | 90 | 5 | 5 | 1 | 1 | 1.356 |
| | | | No | 610 | 58 | 1 | 5 | 1 | 1 | 1.553 |
| | | | Loc = 2 | 370 | 32 | 2 | 5 | 1 | 1 | 1.534 |
| | | | Suggested | 320 | 26 | 2 | 5 | 1 | 2 | 1.526 |
| Index | | B | Standard 1 | 30 | 30 | 5 | 5 | 3 | 3 | 1.272 |
| | | | Standard 2 | 45 | 45 | 5 | 5 | 2 | 2 | 1.414 |
| | | | Standard 3 | 90 | 90 | 5 | 5 | 1 | 1 | 1.573 |
| | | | No | 470 | 43 | 1 | 5 | 1 | 2 | 1.819 |
| | | | Loc = 2 | 300 | 30 | 2 | 5 | 1 | 2 | 1.812 |
| | | | Suggested | 320 | 26 | 2 | 5 | 1 | 2 | 1.810 |

* Total test capacity 440 plots.

storage root yield of 3.3% and 0.8% at a test capacity of 450 and 900 plots, respectively. This decline in the response to selection is small, and under the restriction that the trial should be conducted with two replications at selection Step 2, the differences in the number of tested genotypes between storage root yield and index selection are negligible at each selection step (Suggested in Table 2). The same result was observed using for $\sigma^2_G : \sigma^2_{G\times L} : \sigma^2_{G\times S} : \sigma^2_{G\times L\times S} : \sigma^2_E$ the ratios 1 : 2.24 : 127 : 3.37 : 6.48 for storage root yield and 1 : 0.24 : 0.03 : 1.76 : 7.49 for index selection (results not presented). These ratios correspond to the ratios of the lower bound confidence limits of estimated variance components (Table 1). These results reinforce our conclusion that within a test capacity of 450 to 900 plots and using a maximum of five locations, an appropriate allocation for sweetpotato testing is the use of two locations and one replication at selection Step 1 and five locations and two replications at selection Step 2. Such an allocation allows efficient single-trait improvement of storage root yield as well as efficient simultaneous improvement of storage root yield, biomass, harvest index and storage root dry matter using the Elston index. This recommended allocation is associated with the use of about 1/3 of the total test capacity for the number of genotypes at selection Step 1 and testing about 10% of the total number of genotypes at selection Step 2. It should be noted that the variance component ratio of 1 : 0.37 : 0.09 : 1.40 : 3.87 (for category 'B' (Elston index) in Table 2) is not considerably different (except for the error term) from the ratio 1 : 0.32 : 0.06 : 0.50 : 1.33 obtained by Ngeve (1993) in this author's first series of trials. Hence, the allocation recommended here for sweetpotato trials in East Africa may be also appropriate for sweetpotato trials in Central Africa.

We want to emphasize that index selection is considered to be the more efficient, when compared with the selection of single traits at different selection steps (Baker, 1986), although this has not been shown after several generations of selection. The practical advantage of the index used here is that the Elston index requires no estimates of the genetic variances and co-variances for the traits considered. Therefore this index might enable breeders to increase multi-trait selection efficiency without information of the genetic co-variances in the breeding material, which are often not available in practice.

A major limitation of this study is that only a single series of variety trials were used. Variance component estimates not only have large errors associated with them, they also depend on the genotypes and environments used. However, very different ratios of variance components were used in this study. Moreover, the differences between our results and those obtained by Ngeve (1993) are not too large. Hence, we expect that more precise estimates of variance components will not be out of the range considered in this study. It is expected that the following two conclusions will be consistent over time: (i) in sweetpotato a two-stage selection system is superior to a one-stage selection system after two seasons of testing (ii) an appropriate allocation of resources in sweetpotato testing entails the use of two locations with one replication at selection Step 1 and five locations with two replications at selection Step 2. Nevertheless, if the total number of plots is considerably smaller than 450 or considerably greater than 900, and especially if the maximum number of locations is increased, the allocation recommended here might not be appropriate. For example, it has to be expected that with a larger maximum number of locations and without an increase in the total test capacity, the optimum will clearly change (becoming one replication at selection Step 2). At the same time, if two replications are used at selection Step 2, it is clear that there will be a larger decline in the response to selection based on storage root yield.

In conclusion, a significant genotype × season interactions has to be expected in sweetpotato trials in Sub-Saharan Africa. These interactions are not large enough so that two-stage selection trials are recommended instead of one-stage selection trials after two seasons of testing. If the total test capacity is neither considerably smaller than 450 plots nor considerable larger than 950 plots, an appropriate allocation is the use of two locations and one replication at selection Step 1 and five locations and two replications at selection Step 2. This is true both for selection based on storage root yield and for a simultaneous selection based on storage root yield, biomass production, harvest index and storage root dry matter using the Elston index.

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# CHAPTER 8

# General discussion

**Summary of results**

This thesis describes some observations that are highly relevant to the development of farmer-participatory sweetpotato breeding for northeastern Uganda. These highlights are

- Farmers have demonstrated valuable knowledge on their varieties.
- Farmer varieties grown in northeastern Uganda represent a highly diverse germplasm.
- Farmers are able to select superior varieties for cultivation under their local conditions, i.e., a low input agricultural system with erratic seasonal variation in growing conditions.
- Farmers are, in a qualitative sense, aware of genotype-by-environment interaction.
- The majority of the tested varieties, selected by farmers from a germplasm collection, showed stable performance and yielded well, averaged over locations, soil types and seasons.

The approach that was taken in this research included the following steps:

- Collection of germplasm.
- Assessment of morphological variation in the germplasm collection (landraces).
- Drawing up an inventory of farmers' knowledge on the varieties they grow (both landraces and cultivars released by the Ugandan sweetpotato breeding programme).
- Preliminary selection by farmers of superior varieties from a large collection of landraces.
- Evaluation of the farmer-selected varieties in multi-location on-farm and on-station trials in several seasons.
- In addition, variance components in variety trials were quantified based on a separate data set.

In the initial on-station and on-farm assessment a number of agronomic traits, including tuber yield, were recorded by researchers, so that we were able to compare yield capacity of landraces with the farmers' ranking based on their criteria and preferences.

By following this approach we aimed at answering the question to what extent and in which way farmers' knowledge could become a valuable ingredient to sweetpotato improvement in northeastern Uganda.

**Methodological issues**

While carrying out the research a number of potential weaknesses concerning the methodology were faced. These have been underlined and discussed in the previous chapters under the relevant research activity. Since they are of a general nature and as such apply to farmer-participatory plant breeding in a broad sense, we briefly summarize them.

***Germplasm collection***

Germplasm can be collected in several ways. Brown *et al.* (1995), Pain *et al.* (1995) and Huamán *et al.* (1995) used a collection strategy based on a single visit to every farmer's field in the target area. We have used an alternative method of communally collecting germplasm by means of participatory rural appraisal (PRA, Chapter 2). With this method the collection activities are concentrated in several central collection points. Comparing the single-visit strategy with PRA it is to be expected that the first will result in a better coverage of the available gene pool. The necessity of gene pool coverage, however, depends on the objectives of the collection. If the goal is to establish a collection for conservation of genetic resources to be used for future breeding by crossing, a good coverage of the total genetic diversity is preferred. Such a collection may contain genotypes that are of little interest to the majority of farmers. In our case, however, the goal was to obtain a collection to be used in a farmers' selection programme. For that purpose a PRA-based collection is preferable since it makes little sense to include genotypes that are not recognized by most farmers as being potentially useful.

***Farmers' knowledge and farmer participation***

In northeastern Uganda, sweetpotato is an important staple crop and is gaining importance as a cash crop (Bakema *et al.*, 1994; SDPP, 1994; Scott *et al.*, 1999). In view of the status of the crop it is in the farmers' interest to gain and maintain knowledge on all aspects of cultivating and selecting newly introduced varieties, paying attention to their preferences and local conditions (Chapter 2). Thus, over the course of time, farmers have extensively examined their varieties. This tradition could obviously strengthen the knowledge of farmers about their sweetpotato varieties. Therefore, in this region, the level of farmers' knowledge is such that farmer participation can easily be applied in collecting landraces, in preliminary variety selection and in carrying out on-farm trials. A high level of farmers' knowledge is a prerequisite for successful farmer participation. If this condition is not met, farmer participation should be applied with extreme caution. This is the case in southwestern Uganda, as well as a number of districts in central and northwestern Uganda, where farmers have lost interest in sweetpotato because other crops have become preferred in recent years (Low, 1997; Bashaasha *et al.*, 1995). Farmers' knowledge about crops and their cultivars varies with the intensity of cultivation, which should be recognized when planning farmer participatory breeding and/or selection.

***Assessment of genetic diversity***

We have used morphological descriptors to assess diversity in our germplasm collection of sweetpotato. The morphology-derived measure of similarity revealed a high degree of diversity in the germplasm from northeastern Uganda. In order to verify whether the diversity measured by morphology reflects the total genetic diversity in the collection, a technique such as DNA fingerprinting should be used. In cultivated crop species morphology-based similarities are not always fully confirmed by similarities based on DNA markers, but on the other hand clusters of genotypes that represent different morphological groups are usually well separated on the basis of DNA similarity. Thus, although DNA fingerprinting would have resulted in a more complete picture, the morphological variation alone in our collection indicates a high genetic diversity.

***Selection of varieties for further testing***

The aim of selection of varieties from a large collection of landraces, described in Chapter 4, was to arrive at a manageable number of varieties for their evaluation in multi-location trials. This selection of potentially superior varieties was done based on data collected only in one year and two locations. This may have been a too limited set up since seasonal variation in growing conditions may alter the rank order of genotypes (genotype-by-environment interaction). However (results from Chapter 7), using estimated variance components to optimize resource allocation in sweetpotato breeding indicated that observations in a single season at two locations would be sufficient for East African conditions. Thus, the size of our initial assessment trials complies with this recommendation.

In this selection farmers participated by means of group discussions to arrive at a final decision. For the purpose of this study the limited number of finally selected varieties (11) turned out to be satisfactory. However, for the purpose of a sweetpotato breeding programme we recommend that more varieties be included in the initially selected set, thus avoiding a too stringent selection in the early phase of the multi-year, multi-location testing and selection cycles.

***Group discussion and individual opinions***

In our research a group discussion was often used to make a decision. We have observed that, based on their experience, farmers are able to identify superior varieties and that individual opinions did not widely vary. Consequently, an 'average' opinion of individual farmers will not be at variance with the outcome of a consensus group discussion. Yet, the common opinion obtained in a group discussion might be more valuable than an average of individual opinions, because a group discussion, whether or not observed by the researcher, is likely to be dominated by those farmers who are most experienced in cultivating the crop and are most familiar with its varietal differences.

***On-farm trials after preliminary selection***

As stated in the concluding remarks of Chapter 5, we probably over-did the on-farm testing component, and we could have just done preliminary selection with farmer participation on-station, after which a multiplication effort (by NGOs or the district agricultural offices) could have generated planting material for future testing in multi-location, multi-season trials. On the other hand, an advantage of on-farm trials in this phase is that it enables a focus on farmer acceptance of varieties, alongside with multiplication efforts.

***Multi-location trials***

This set of trials revealed the performance of farmers' selected varieties and thus the farmers' ability to recognize superior varieties during the initial assessment. Stability of varieties was measured as well as their yield, averaged over the four locations with two soil types and two or three rain seasons. Since the highland agro-ecological zone was not included in these trials, they did not cover the whole target environment of the national Ugandan sweetpotato breeding programme. So the best performing varieties identified in our research would require additional testing in the highland zone, if they are to be adopted by the national breeding programme.

***Performance of newly released Ugandan cultivars and farmer varieties***

Four recently released Ugandan cultivars (the NASPOTs) were used for standardizing the varietal performance in on-farm and on-station trials. In contrast to Mwanga *et al.* (2003), who reported high yield and excellent yield stability of these NASPOTs, they performed poorly in our trials (Chapter 6). Whatever the reason of this discrepancy may be, our observation indicates that including landraces from northeastern Uganda in the national breeding programme may well contribute to its success.

***Specific versus wide adaptation of new cultivars and release strategy***

In our analysis of genotype-by-environment interactions we found clear indications that some of the tested varieties showed specific adaptation, whereas others displayed a broader adaptation. For example, the NASPOT varieties turned out to be specifically well performing under Namulonge and Mbarara conditions. In order to avoid future disappointments, the release of these varieties should be restricted to areas of similar growing conditions. An example of wide adaptation is the farmer variety ERA139, showing stable, though less than average, performance over locations and seasons. Thus, depending on the target area of cultivation, the release and dissemination of new cultivars can be tuned according to the results obtained in multi-location, multi-season trials.

***Awareness of farmers on genotype-by-environment interaction and on biodiversity***

A notable observation during the initial assessment (Chapter 4) was that the sets of varieties selected by farmers from two districts largely overlapped, although the actual ranking by farmers was slightly different in every location. Most likely this reflects a wide adaptation of the farmer-selected varieties.

During the group discussion on the adaptive on-farm trials farmers stated that they would not discard any of the preliminarily selected varieties, although some of them did not perform well in their fields. Farmers were willing to retain these and observe their performance in the future. This clearly indicates consciousness of farmers about genotype-by-environment interaction, i.e., the perception, based on previous experience, that two seasons may be too short a time to definitely judge the long-run performance of varieties. It may also reflect the awareness of farmers that, in relatively risky rain fed conditions, potential advantages are to be gained from maintaining a diversity of landraces and bred cultivars, as a risk spreading strategy. This practice could also imply that farmers continuously preserve specifically adapted varieties. Thus, in this farmers' tradition a network could be set up for *in situ* conservation of locally adapted germplasm.

## Challenges and opportunities for sweetpotato breeding in East Africa

In the routine Ugandan sweetpotato breeding programme, briefly described in Chapter 1, the development of a new variety takes between 8 and 16 years (Mwanga, pers. comm.). Next to such a steady breeding programme there is another opportunity for crop improvement, i.e., by quickly and efficiently selecting superior landraces. Based on the results presented in this thesis we propose a model for a three-year programme to identify a number of superior farmers' varieties for low-input agriculture and suitable for resource-poor farmers. The proposed procedure may enhance the efficiency of sweetpotato breeding in Uganda as well as in other regions of east Sub-Saharan Africa, where farming systems and growing conditions are similar to those encountered in northeastern Uganda.

In addition to identifying promising landraces that may promptly serve the needs of farmers, such landraces can be used as progenitors (crossing parents) in the steady institutional breeding programme. Although the description below specifically refers to northeastern Ugandan conditions, the general principle may be applicable to east Sub-Saharan Africa.

**A model procedure for farmer participatory variety selection**

Year 1

- The sources of the material are the sweetpotato landraces grown in northeastern Uganda. Using a participatory rural appraisal, a number of potentially superior landraces are quickly identified and selected.
- The first cycle of selection is achieved using on-station trials in one season at two locations. Competent farmers should select varieties according to their preference. It is advised to choose the two locations in the region where the landraces were collected, thus avoiding problems with transporting the bulky vine cuttings. Since Uganda has a bimodal rainfall distribution, these two selection activities (collecting germplasm by PRA and the first selection cycle) can be carried out in one year.

Year 2

- The second year comprises two-seasonal on-farm trials with the main purpose to confirm consumer acceptance and to set up an early multiplication programme. Unlike in the on-farm trials described in Chapter 5, farmers should not select among genotypes, unless it was because of an exceptional discovery of a desired trait. Farmers are requested to observe the experimental genotypes in detail and to rank them according to performance and farmers' preference. In the second season a large number of farmers' fields are prepared for multiplication of the material for testing in the third year.

Year 3

- In the third year the second (and final) cycle of selection is done, based on the evaluation in multi-location on-station trials in two seasons. Five locations with a test capacity of 500-900 plots of 15 $m^2$ should be sufficient for this final evaluation (Chapter 7).

During the set up of a programme as described above, nursery management requires ample attention, as the programme's success critically depends on the availability of adequate planting material. A rapid multiplication technique must be applied immediately after the first selection cycle in year 1, to fill the needs of the on-farm trials. The nursery activities should continue in order to adequately supply the multi-location trials of the third year with planting material.

Concerning the size of the proposed programme in successive cycles of selection we envisage that from approximately 200 initial genotypes 40 to 50 be selected in the first cycle, which are then reduced to 5 to 10 in the second cycle, i.e., after year 3. Theoretical considerations on the efficiency of multicyclic clonal selection indicate that the total area to be allocated to testing should be approximately equal in each cycle (Finney, 1958). In other words: few genotypes to be selected from require more reliable information per genotype than many genotypes from which a selection is to be made. An exact optimization of resource allocation in multicyclic selection demands *a priori* knowledge of the variance components due to environmental and genotypic differences, as well as their interaction. Thus, although the test capacity in successive cycles should be in balance with the number of genotypes to be selected, the selection intensities proposed must be considered as rough guidelines.

**Summarizing conclusions**

The research activities presented in this thesis have led to two recommendations for improving sweetpotato breeding, serving the needs of resource-poor farmers in low-input agricultural systems of east Sub-Saharan Africa:

- Setting up a targeted release and maintenance strategy for new cultivars, accounting for either specific or wide adaptation of these cultivars, and
- Application of a quick procedure for farmer participatory variety selection.

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# Summary

Sweetpotato is a staple food in Uganda as well as in other parts of East and Sub-Saharan Africa. At present farmers are largely dependent on local landraces since superior bred cultivars for low input agricultural systems are hardly available. Most of the landraces are low yielding, narrowly adapted and susceptible to pests and diseases.

This thesis describes an attempt to invoke a farmer participatory approach towards sweetpotato breeding in Uganda by exploiting the genetic diversity that is available in local landraces. In this approach, farmers' knowledge about the local germplasm and their needs and preferences are taken into account.

The general idea of this research was to quickly identify, from a large germplasm collection, a number of local varieties that would meet farmers' needs and requirements. Such varieties could, after proper evaluation, either be used for direct dissemination in the target area or could enter an institutional sweetpotato breeding programme as progenitors of future bred cultivars.

In our research we have included farmer participatory germplasm collection, on-farm and on-station evaluation by farmers as well as multi-environment evaluation of farmer-selected varieties. This approach enabled a comparison of farmers' selection criteria with agronomic criteria used by institutional breeders. In addition, the multi-season, multi-location trials contribute to understanding yield stability and specific adaptation of the varieties and, above all, these trials allowed a verification of the effectiveness of selection based on a quick farmers' evaluation. A separate study estimated variance components from multi-locational trials and calculated optimized resource allocation in sweetpotato breeding for East African conditions. Our combined results allowed us to recommend an approach for the rapid and efficient selection of superior genotypes from local germplasm East Africa.

**Germplasm collection**

We collected 206 sweetpotato accessions from five districts (Lira, Soroti, Katakwi, Kumi and Pallisa) in northeastern Uganda. We used a participatory rural appraisal (PRA) and group discussions as evaluation and collection method; so the information on the collected accessions reflects a farmers 'group opinion at the collection site rather than individual farmers' opinions.

After morphological characterization, 188 genotypes were identified to be distinct. This large number of dissimilar genotypes is indicative for the high level of genetic diversity in the region. We speculate that the low pressure of sweetpotato virus disease as well as the spontaneous outcrossing in farmers' fields, producing botanical seeds,

may have contributed to the enrichment of sweetpotato genetic diversity in northeastern Uganda.

**On-station selection by farmers**

In a large-scale evaluation, carried out at two research stations (Arapai and Serere) in a single season (1999), farmers selected a limited number of genotypes from a total of 160 accessions (landraces). Farmers at each of the two sites chose eleven varieties, using their own selection criteria. Selection was done at harvest and group discussions were organized to reach a common opinion on the varieties. Selection criteria used by farmers were recorded and the farmers' evaluation was compared with the agronomical data, collected on the same varieties by researchers. The 'general impression index' assigned by farmers correlated well with fresh storage root yield and number of roots, which were reflected by a significant yield difference between selected and non-selected varieties. These preliminary results indicate that a farmers' assessment at two locations in a single season can efficiently be applied as the first cycle in a multi-cyclic clonal selection process.

**On-farm evaluation**

The eleven farmer-selected varieties and five national Ugandan bred cultivars were evaluated for their performance and were compared in-depth to local farmer varieties in a series of on-farm trials. The individual knowledge of farmers about sweetpotato varieties and the capability of farmers of conducting the research were also examined. Group discussions and individual interviews were applied to assess the farmers' competence and to identify farmers' varietal preferences. The eleven farmer-selected varieties continued to perform well and proved to be superior under the farmer's conditions. This could be indicative of a fairly high precision with which farmers selected varieties in the preliminary on-station evaluation. In every sub-county, farmers ranked varieties in a different way, which was a reflection of the degree of their market orientation. Farmers in Dokolo-Gweri and Abalang-Arapai emphasized the importance of market forces, whereas in Abilaep-Serere the emphasis was more on criteria related to home-consumption. During the germplasm collection the Abalang-Arapai and Abilaep-Serere sub-counties were recognized to have different types of farmers, the commercial and the subsistence farmers, respectively. Farmers at the three research locations were aware of genotype-by-environment interaction and of the relatively risky rainfed conditions when growing the crop under their marginal conditions. Thus, farmers said they would not discard any of the experimental varieties, although some of them did not do well during the evaluation. They were willing to maintain these and observe their performance in the future. This clearly indicates a potential advantage to be gained by maintaining a diversity of landraces and bred cultivars, as a risk avoidance strategy. Consequently, a network could be established for *in situ* conservation of locally adapted germplasm based on this farmers' tradition.

**Multi-environment trials**

On-station, multi-environment trials were set up to evaluate the eleven farmer varieties and five Ugandan bred cultivars, four of which were released in 1999. In this assessment we were able to verify that the farmers' involvement in the initial varietal selection had been successful. We used an analysis of genotype-by-environment interaction to assess yield stability as well as wide and specific adaptation of the experimental genotypes.

Taken as a group, the farmer-selected varieties outperformed the national bred cultivars with respect to both average yield and yield stability. This observation alone indicates the ability of farmers to reliably identify superior genotypes. Individual farmer-selected varieties scored variably with respect to average yield (averaged over environments) and yield stability. We identified two farmer varieties as high yielding and stable at the same time, indicating their wide adaptation. At least two farmer varieties appeared to be specifically adapted to environmental conditions, i.e., high yielding at a specific location but not at the others.

From these observations we conclude that the initial farmers' selection was quite successful, revealing the farmers' ability to identify genotypes that are highly promising for cultivation under their marginal and resource-poor conditions. Furthermore, the fact that we observed specific adaptation of some of the varieties indicates that a strategy of cultivar release that is adjusted to a well-defined target area may be rewarding.

**Estimation of variance components**

Variance component estimates were obtained from an international sweetpotato yield trial conducted between 1999 and 2001 in several East African countries. No variance component estimates had previously been described for sweetpotato in East Africa. The variance component estimates were used to determine the efficiency of yield trials. The goal is to arrive at an optimal allocation of a given total test capacity over test locations and replicates per location. We also investigated whether clonal selection should be done in a single step, after two seasons of testing of all clones, or in a two-step procedure. In a two-step procedure a first selection is made after one season of testing; the selected clones are then re-tested on a larger scale in a second season.

The analysis was done for storage root yield and the Elston index, which accommodates storage root yield, biomass production, harvest index and root dry matter content.

It turned out that, given the estimates of variance components we obtained, a two-step selection procedure is more efficient than a single-step procedure.

For a total test capacity of between 450 and 950 plots of 15 $m^2$, an appropriate allocation is the use of two locations and one replication at selection step 1 and five locations and two replications at selection step 2. This could be applied both for selection on storage root yield and for the Elston index.

**Relevance for sweetpotato breeding in East and Sub Saharan Africa**

From the results presented in this thesis we propose a model for a three-year programme to identify a number of superior farmer varieties for low-input agriculture and suitable for resource-poor farmers. The proposed procedure may be applicable to sweetpotato varietal selection in Uganda as well as in other regions of East and Sub-Saharan Africa, where farming systems and growing conditions are similar to those encountered in northeastern Uganda. We recognize that local circumstances, including previous breeding efforts, abundance of sweetpotato landraces and other germplasm sources, and farmer knowledge of sweetpotato, will need to be taken into consideration when applying our methods elsewhere in Sub-Saharan Africa. Nevertheless, it is clear from our experiences that increased farmer participation in sweetpotato breeding efforts can contribute significantly to increasing the efficiency of selecting superior genotypes for target environments. In the proposed procedure there will be two activities in the first year i.e. (i) collecting of sweetpotato germplasm using the PRA approach, and (ii) the first cycle of selection using on-station trials in one season at two locations. Competent farmers should select varieties according to their preference. In the second year the activity comprises two-seasonal on-farm trials with the main purpose to confirm consumer acceptance and to set up an early multiplication programme. In the third year the second (and final) cycle of selection is done, based on the evaluation in multi-location on-station trials in two seasons. Five locations with a test capacity of 500-900 plots over the two selection cycles should be sufficient for this final evaluation. Nursery management requires full attention, as the programme's success critically depends on the availability of adequate planting material.

In addition to identifying promising landraces that may rapidly serve the needs of farmers, such landraces can be used as progenitors (crossing parents) in the steady institutional breeding programme.

The research activities presented in this thesis have led to two recommendations for improving sweetpotato breeding aimed at the needs of resource-poor farmers in low-input agricultural systems of East and Sub-Saharan Africa. Firstly, we recommend setting up a targeted release and maintenance strategy for new cultivars, accounting for either specific or wide adaptation of these cultivars, and secondly, we propose to apply a quick procedure for farmer participatory variety selection. These measures may prevent serious disappointments of newly released varieties in regions where they have not been tested properly or, despite a good yield potential, they fail to be adopted because of specific preferences of local farmers.

# Samenvatting

De zoete aardappel of bataat (*Ipomoea batatas* (L.) Lam.) is een belangrijk voedselgewas in Oeganda en andere delen van oostelijk Afrika ten zuiden van de Sahara. Heden ten dage zijn boeren in deze gebieden voornamelijk afhankelijk van lokale landrassen, aangezien gekweekte rassen die geschikt zijn voor de lage-input landbouwsystemen aldaar, nauwelijks beschikbaar zijn. Het merendeel van deze landrassen geeft een lage opbrengst, is niet geschikt voor teelt onder uiteenlopende, wisselende omstandigheden en is vatbaar voor ziekten en plagen.

Dit proefschrift beschrijft hoe de veredeling van zoete aardappel een impuls kan krijgen door, met behulp van boerenparticipatie, de genetische diversiteit die aanwezig is in lokale landrassen, te benutten. Bij boerenparticipatie wordt niet alleen gebruik gemaakt van de kennis die boeren hebben over het lokaal beschikbare genetische materiaal, maar wordt ook rekening gehouden met hun specifieke eisen en voorkeuren aangaande de rassen die zij wensen te verbouwen.

Het onderzoek had tot doel om in korte tijd uit een grote verzameling genotypen een aantal ervan te selecteren die voldoen aan de eisen die boeren aan rassen stellen. Zulke rassen zijn in principe geschikt voor directe uitgifte in het teeltgebied of kunnen worden gebruikt als geniteur in een veredelingsprogramma.

In het onderzoek waren allereerst boeren betrokken bij het verzamelen van landrassen. Daarnaast gaven boeren een beoordeling van de landrassen in proeven uitgevoerd op proefstations en op boerenbedrijven. Tenslotte werden de door boeren als goed beoordeelde landrassen in rassenproeven op meerdere locaties en in meerdere seizoenen onderzocht. Door deze benadering was het mogelijk om de selectiecriteria die boeren hanteren te vergelijken met de criteria die professionele veredelaars gebruiken in hun veredelingsprogramma's. De uitkomsten van de meerjarige rassenproeven op meerder lokaties verschaften niet alleen inzicht in de opbrengststabiliteit en specifieke adaptatie van de door boeren geselecteerde rassen, maar, als allerbelangrijkste, lieten deze proeven bovendien zien in hoeverre de snelle procedure van boerenselectie geslaagd was.

### Verzamelen van landrassen

In vijf districten (Lira, Soroti, Katakwi, Kuma en Palllisa) in noordoost Oeganda werden in totaal 206 zoete aardappel accessies verzameld bij lokale boeren. Hierbij gebruikten we een zogenaamde 'participatieve plattelandswaardering' (participatory rural appraisal (PRA)) en groepsdiscussies. Dit betekent dat de informatie over de verzamelde accessies de neerslag is van de opinie van de gezamenlijke plaatselijke boeren en niet de mening van individuele boeren weergeeft.

Uit een morfologische karakterisering van de 206 accessies bleek dat 188 hiervan onderscheidbaar waren. Dit grote aantal morfologisch onderscheidbare genotypen duidt op een grote genetische diversiteit in de regio. Een mogelijke verklaring voor deze grote genetische diversiteit in noordoost Oeganda is enerzijds de lage ziektedruk van het zoete aardappel virus in het gebied en anderzijds de spontane kruisbestuiving die leidt tot genetisch heterogeen zaad dat op de akkers achterblijft.

**Selectie door boeren op proefstations**

Op twee proefstations (Arapai en Serere) selecteerden boeren, in één groeiseizoen, uit een totaal van 160 landrassen (accessies) een beperkt aantal (11) genotypen. Deze selectie, op het moment van oogst, vond in twee stappen plaats, waarbij boeren hun eigen beoordelingscriteria konden hanteren. In groepsdiscussies kwamen de deelnemende boeren over elk van de landrassen tot een gemeenschappelijk oordeel. De beoordelingscriteria van de boeren werden genoteerd en vergeleken met de landbouwkundige gegevens die door de proefstationmedewerkers waren verzameld over dezelfde landrassen. De beoordeling door boeren werd samengevat in een index, de 'algemene indruk'; deze vertoonde een goede correlatie met de versopbrengst van wortelknollen en het aantal knollen per plant. Deze correlatie kwam goed tot uiting in het verschil in opbrengst tussen de geselecteerde en niet-geselecteerde rassen. Deze voorlopige resultaten wijzen er op dat een beoordeling door boeren, verricht op twee locaties, in één groeiseizoen als eerste doeltreffende selectieronde kan fungeren bij klonale selectie over meerdere cycli.

**Evaluatie op boerenbedrijven**

Tesamen met vijf gekweekte nationale Oegandese rassen zijn de elf door boeren uitgekozen landrassen beoordeeld en vergeleken met lokale landrassen in een reeks vergelijkende proeven, uitgevoerd op boerenbedrijven. Hierbij werden zowel de kennis die individuele boeren hebben over de geteelde rassen als hun vermogen om deze vergelijkingsproeven adequaat uit te voeren, beoordeeld. Op grond van groepsdiscussies en uit individuele interviews werd een indruk verkregen over de competentie van de deelnemende boeren en hun rassenvoorkeur.

De elf eerder door boeren geselecteerde landrassen presteerden goed in deze proeven en bleken over het algemeen superieur te zijn onder deze teeltomstandigheden. Dit is een aanwijzing dat de eerdere selectie van landrassen op proefstations tamelijk nauwkeurig is geweest.

De rangorde die boeren toekenden aan de op hun bedrijf geteelde rassen, varieerde tussen de diverse sub-districten, hetgeen samenhing met de mate waarin het gewas geteeld werd voor de markt dan wel voor de eigen voedselvoorziening. De boeren in Dokolo-Gweri en Abalang-Arapai, bijvoorbeeld, benadrukten het belang van de marktwaarde van de oogst, terwijl voor de boeren in Abilap-Serere de waarde voor eigen consumptie van groter belang was. Reeds tijdens het verzamelen van de landrassen was duidelijk geworden dat in de sub-districten Abalang-Arapai en Abilap-Serere de teelt van zoete aardappel voor twee doeleinden plaats vindt, namelijk voor eigen consumptie én voor verhandeling op de markt.

De boeren waren zich bewust van genotype-milieu interactie en van het risico van misoogsten in hun niet-geïrrigeerde gebied. Dit bleek uit het feit dat zij geen van de experimentele rassen, die ze zonder naamsaanduiding op het veld hadden, wilden afdanken, ook wanneer de opbrengst er van te wensen over liet. Zij wilden deze, voor hen onbekende, rassen aanhouden en hun prestatie in volgende seizoenen opnieuw beoordelen. Deze strategie van risicospreiding die boeren hiermee aan de dag leggen pleit er voor om een zekere diversiteit aan landrassen en gekweekte rassen te handhaven. Dezelfde boerentraditie zou de basis kunnen vormen van een netwerk voor *in situ* conservering van lokaal aangepast genetisch materiaal.

**Beproevingen in meerdere milieus**

Ten einde de elf door boeren geselecteerde landrassen tesamen met vijf gekweekte Oegandese cultivars op grotere schaal te beproeven werden deze op drie proefstations in noordoost Oeganda in meerdere groeiseizoenen in rassenproeven gelegd. Zowel de opbrengststabiliteit als de mate van brede dan wel specifieke aanpassing van de beproefde rassen werden bepaald. Bij deze evaluatie kon worden vastgesteld dat de boerenparticipatie bij de eerste selectie succes heeft gehad.

Als groep presteerden de door boeren geselecteerde landrassen beter dan de gekweekte cultivars, zowel wat betreft gemiddelde opbrengst als opbrengststabiliteit. Dit feit is op zichzelf een duidelijke aanwijzing dat boeren heel wel in staat zijn om met hun eenvoudige beoordelingscriteria goede rassen te herkennen.

Uiteraard scoorden niet alle boeren-selecties even hoog ten aanzien van gemiddelde opbrengst en opbrengststabiliteit. Twee van de landrassen sprongen er uit vanwege hun hoge gemiddelde opbrengst én hun grote opbrengststabiliteit, hetgeen wijst op hun breed aanpassingsvermogen. Tenminste twee landrassen vertoonden duidelijk specifieke adaptatie, d.w.z. dat zij een hoge opbrengst gaven op één proeflocatie, maar niet op de andere lokaties. Hieruit kunnen we concluderen dat de selectie door boeren succes heeft gehad en dat boeren in staat zijn rassen te kiezen die veelbelovend zijn voor de teelt op marginale gronden met een bedrijfsvoering die zich kenmerkt door een minimaal gebruik van hulpbronnen (kunstmest en gewasbeschermingsmiddelen). Het feit dat enkele rassen specifieke adaptatie te zien gaven, pleit voor een uitgiftebeleid van rassen dat rekening houdt met de in de beproevingen gebleken geschiktheid voor specifieke milieus en teeltomstandigheden.

**Schatting van variantiecomponenten**

In een serie internationaal opgezette rassenproeven, uitgevoerd tussen 1999 en 2001 in Oost Afrika werden variantiecomponenten m.b.t. diverse eigenschappen geschat. Dit is het eerste onderzoek in zijn soort voor zoete aardappel in Oost Afrika. De schattingen van de variantiecomponenten werden gebruikt om de efficiëntie van vergelijkende opbrengstproeven met (potentiële) rassen vast te stellen. Hierbij gaat het erom bij een gegeven totale testcapaciteit deze optimaal te verdelen over testlocaties en herhalingen per locatie. Tevens werd onderzocht of selectie van klonen het best kan worden gedaan op grond van een beoordeling van alle klonen in twee opeenvolgende seizoenen dan wel in een twee-traps procedure waarbij in het eerste seizoen een eerste selectie wordt gemaakt die in een volgend seizoen op grotere schaal wordt beproefd, gevolgd door een tweede selectiestap.

De analyse werd uitgevoerd voor de eigenschap wortelknolopbrengst en voor de zogeheten Elston index waarin de eigenschappen knolopbrengst, biomassaproductie, oogstindex en drogestofgehalte van wortelknollen zijn vervat.

De analyse leerde dat bij de gevonden onderlinge verhouding van variantiecomponenten een twee-traps procedure efficiënter is dan selectie in één stap, ook al is de laatste gebaseerd op waarnemingen in twee seizoenen.

Bij een totale testcapaciteit van 450 à 900 veldjes van 15 $m^2$ is het gebruik van twee locaties met slechts één herhaling in de eerste selectieronde en vijf locaties met twee herhalingen voor de tweede selectieronde optimaal. Deze optimale allocatie van middelen geldt zowel voor selectie op wortelknolopbrengst als selectie op de Elston index.

**Belang voor de veredeling van zoete aardappel in oostelijk sub-Sahara Afrika**

Gebaseerd op de resultaten beschreven in dit proefschrift stel ik voor een drie jaar durende werkwijze in te voeren voor de selectie van landrassen die geschikt zijn voor arme boeren op marginale gronden. Deze werkwijze kan de doeltreffendheid van rassenselectie vergroten, niet alleen in Oeganda, maar ook in andere delen van oostelijk Afrika ten zuiden van de Sahara, waar bedrijfsvoering en teeltomstandigheden vergelijkbaar zijn met die in noordoost Oeganda. Als de hier voorgestelde werkwijze wordt toegepast in de genoemde gebieden buiten Oeganda dient men wel rekening te houden met eventuele andere lokale omstandigheden. Deze omstandigheden kunnen betrekking hebben op de beschikbaarheid van uit eerdere kweekarbeid verkregen cultivars, de beschikbare rijkdom aan genetische variatie in landrassen of andere genetische bronnen en het niveau van kennis dat deelnemende boeren hebben over zoete aardappel. Hoe deze specifieke lokale omstandigheden ook mogen zijn, uit onze ervaring blijkt dat een grotere boerenparticipatie bij de veredeling van zoete aardappel kan leiden tot een meer doeltreffende selectie van genotypen die geschikt zijn voor teelt in gespecificeerde doelmilieus.

Bij de voorgestelde werkwijze vinden er in het eerste jaar twee activiteiten plaats, te weten: (1) het verzamelen van genetisch materiaal met gebruikmaking van de eerder genoemde 'participatieve plattelandswaardering' methode en (2) de eerste selectieronde op basis van een beproeving op proefstations gedurende één groeiseizoen, op twee locaties. Vakkundige boeren voeren deze selectie uit op basis van hun eigen criteria en voorkeuren.

Het tweede jaar wordt gebruikt voor beproeving van de eerste selecties op boerenbedrijven, gedurende twee groeiseizoenen, met als hoofddoel de consumentenacceptatie van de selecties te verifiëren en een eerste vermeerderingscyclus te realiseren.

In het derde jaar vindt de tweede en laatste selectieronde plaats op basis van rassenproeven, uitgevoerd op proefstations op meerdere locaties en in twee groeiseizoenen. Vijf locaties met een testcapaciteit van 500 à 900 veldjes zijn voldoende voor deze uiteindelijke evaluatie.

Voor het welslagen van dit programma, dat afhankelijk is van de beschikbaarheid van voldoende plantmateriaal, is een optimaal beheer van de vermeerderingspercelen essentieel.

Behalve dat de op boven beschreven wijze verkregen veelbelovende landrassen geschikt zijn voor uitgifte onder boeren, kunnen zij tevens dienen als geniteur in een lopend institutioneel veredelingsprogramma.

**Aanbevelingen**

Het in dit proefschrift beschreven onderzoek heeft geleid tot een tweetal aanbevelingen ter verbetering van de zoete aardappelveredeling die gericht is op de behoefte van arme, kleine boeren in oostelijk sub-Sahara Afrika die over weinig hulpmiddelen beschikken. De eerste aanbeveling is het uitzetten van een doelgericht uitgifte- en vermeerderingsbeleid voor nieuwe rassen. Dit beleid dient rekening te houden met de brede dan wel specifieke geschiktheid van deze rassen. Ten tweede stellen wij voor boeren actief te betrekken bij het selecteren van rassen en/of kweekmateriaal.

Deze maatregelen kunnen voorkomen dat nieuw uitgegeven rassen ernstig teleurstellen in regio's waarin zij onvoldoende zijn beproefd of, vanwege specifieke voorkeuren van de plaatselijke bevolking, ondanks een goed opbrengstpotentieel, niet in gebruik worden genomen.

# Ringkasan

Ubi jalar merupakan komoditi tanaman pokok di Uganda dan bagi sebagian besar negara-negara di Afrika Timur dan Sub-Sahara Afrika. Pada saat ini para petani di Uganda sangat bergantung pada plasma nuftah local, dikarenakan varitas unggul untuk daerah dengan pengelolaan sumber daya yang minimum, ketersediaannya dapat dikatakan hampir tidak ada. Sebagian besar dari plasma nuftah tersebut berproduksi rendah, kurang beradaptasi luas dengan lingkungan, dan tidak mempunyai daya tahan terhadap serangan hama dan penyakit tanaman.

Disertasi ini menggambarkan suatu pendekatan yang menggunakan partisipasi petani dalam pemuliaan ubi jalar di Uganda dengan mengeksplotasi keanekaragaman sumber daya ubi jalar yang tersedia sebagai plasma nuftah lokal. Di dalam pendekatan ini, pengetahuan petani terhadap varitas lokal serta kebutuhan berikut pilihan mereka terhadap varitas-varitas yang diingini diletakkan sebagai prioritas utama.

Secara umum, penelitian ini bertujuan untuk menyeleksi secara cepat sejumlah varitas dari suatu koleksi plasma nuftah yang cukup besar untuk memenuhi kebutuhan petani secara tepat. Idealnya, setelah beberapa varitas dipilih dengan seksama kiranya dapat langsung disebarluaskan pada petani dengan daerah yang sudah ditentukan, di samping itu juga akan dapat dipergunakan sebagai tetua oleh balai penelitian dalam pemuliaan ubi jalar di masa mendatang.

Garis besar dari penelitian ini meliputi partisipasi petani selama pengoleksian plasma nuftah, evaluasi varitas-varitas oleh petani di kebun percobaan milik balai penelitian (evaluasi awal) maupun milik petani sendiri (evaluasi lanjutan), dan evaluasi varitas yang sudah dipilih oleh petani pada multi-lingkungan percobaan. Pendekatan ini menghasilkan perbandingan yang cukup tinggi antara kriteria penyeleksian yang digunakan oleh petani dan kriteria agronomi yang biasanya digunakan oleh pemulia di balai penelitian. Ternyata hasil dari percobaan di multi-lingkungan menyumbang suatu pengertian yang mendalam akan stabilitas produksi dan daya adaptasi varitas-varitas dari petani tersebut terhadap lingkungan tertentu, dan terutama sekali adalah bahwa percobaan di multi-lingkungan ini memberikan suatu bukti yang cukup jelas tentang keefektifan penyeleksian berdasarkan evaluasi petani. Suatu penelitian tambahan yang dilakukan terpisah bertujuan untuk mengetahui perbedaan komponen (*variance components*) dari multi-lokasi percobaan serta memperhitungkan alokasi sumber yang terbaik pada pemuliaan ubi jalar yang sesuai dengan kondisi Afrika Timur. Dari hasil kombinasi penelitian ini kami menganjurkan suatu pendekatan penyeleksian beberapa genotipe superior dari plasma nuftah lokal yang terdapat di Afrika Timur secara tepat guna.

**Pengoleksian plasma nuftah**

Sebanyak 206 tanaman sampel (*accession*) dari ubi jalar dikoleksi dari lima kabupaten (Lira, Soroti, Katakwi, Kumi dan Pallisa) yang berada di Timur-Laut Uganda. Kami menggunakan partisipasi rakyat pedesaan (*participatory rural appraisal*) dan kelompok diskusi sebagai metoda pengoleksian, karena itu informasi tanaman sampel adalah merupakan suatu refleksi dari rata-rata opini yang didapat dari kelompok diskusi yang berlangsung di pusat-pusat pengoleksian (*collection sites*), jadi bukanlah merupakan hasil dari opini yang diperoleh melalui tanya jawab yang dilakukan pada setiap individu petani. Setelah dilakukan karakterisasi secara morfologi terhadap tanaman-tanaman sampel, sebanyak 188 genotipe dapat diidentifikasi yang masing-masingnya mempunyai perbedaan yang nyata. Besarnya perbedaan ini menunjukkan bahwa variasi yang tercatat pada sumber daya alami tanaman ubi jalar di daerah tersebut cukup tinggi. Kami berpraduga bahwa hal ini dapat terjadi karena rendahnya serangan virus tanaman ubi jalar (SPVD) di daerah-daerah itu, di samping kemungkinan adanya proses persilangan alami di kebun-kebun petani sehingga dapat menghasilkan suatu benih 'benar' (*botanical seed*). Proses ini memberikan suatu kontribusi yang dapat memperkaya rekayasa alami bagi tanaman ubi jalar di Timur-Laut Uganda.

**Penyeleksian oleh petani di kebun percobaan balai penelitian**

Penelitian berskala besar yang dilakukan di dua kebun percobaan milik balai penelitian (Arapai dan Serere) pada satu musim tanam (1999), melibatkan sejumlah petani untuk menyeleksi genotipe-genotipe yang jumlahnya dibatasi, dari 160 tanaman sampel keseluruhan. Para petani di kedua lokasi tersebut memilih sebelas varitas dengan menggunakan kriteria penyeleksian menurut kebiasaan yang mereka lakukan sehari-hari. Penyeleksian dilaksanakan pada waktu panen dan kelompok diskusi diadakan untuk mencari kesepakatan umum terhadap varitas-varitas yang akan dipilih. Kriteria penyeleksian yang digunakan oleh para petani itu dicatat, dan hasil evaluasi dari petani dibandingkan dengan data agronomi dari varitas yang sama yang dikumpulkan oleh kelompok peneliti. Indeks dari kesan umum yang dikemukakan oleh para petani berkorelasi cukup baik dengan produksi umbi segar dan jumlah umbi (data yang diolah oleh peneliti), hal ini terlihat pada kesignifikanan perbedaan produksi antara varitas yang diseleksi dan yang tidak diseleksi. Hasil penelitian ini menunjukkan bahwa keterlibatan petani di dalam penelitian yang dilakukan pada dua lokasi dalam satu musim tanam dapat diterapkan secara efisien sebagai sirkulasi awal dari rangkaian multi sirkulasi pada suatu proses penyeleksian klon.

**Evaluasi di kebun percobaan petani**

Sebelas varitas hasil seleksi para petani dan lima varitas dari hasil persilangan yang dilakukan oleh balai penelitian nasional ubi jalar Uganda dievaluasi penampilannya, dan dibandingkan secara seksama dengan varitas lokal milik petani setempat di dalam suatu rangkaian penelitian di kebun-kebun petani. Tingkat pengetahuan perorangan petani mengenai varitas ubi jalar, dan kemampuan mereka di dalam mengelola penelitian juga dipelajari. Diskusi kelompok dan tanya jawab pada petani secara perorangan juga dilakukan yang bertujuan untuk mengetahui tingkat kemampuan mereka di samping untuk mengidentifikasi varitas yang paling disenangi. Kesebelas varitas lokal tersebut selanjutnya menunjukkan keunggulan pada kondisi petani. Hal ini menjadi suatu indikasi bahwa ketelitian petani di dalam menyeleksi varitas ubi jalar yang juga telah dilakukan sebelumnya pada kebun percobaan balai penelitian cukup tinggi.

Di setiap kecamatan, petani menggolongkan varitas-varitas tersebut secara berbeda-beda, yang tercermin dari tingkat kecenderungan mereka akan pasar. Petani Dokolo-Gweri dan Abalang-Arapai lebih mementingkan permintaan pasar, sementara itu petani di Abilaep-Serere lebih mengutamakan kebutuhan rumah tangga. Sewaktu pengumpulan sampel di Abalang-Arapai dan Abilaep-Serere, ternyata mereka mempunyai kelompok tani yang berbeda yaitu petani komersial terdapat di Abalang-Arapai dan petani subsisten di Abilaep-Serere. Petani di ketiga kecamatan tersebut sangat sadar akan adanya interaksi antara genotipe dengan lingkungannya (G×E), dan juga resiko akibat ketergantungan mereka kepada musim penghujan bila pembudidayaan tanaman dilakukan pada kondisi tanah mereka yang marginal. Karena itu para petani bertekat bahwa mereka tidak akan membuang semua genotipe yang tengah diteliti meskipun beberapa genotipe tidak tumbuh dengan baik. Mereka bersedia memelihara dan meneliti penampilannya kembali dikemudian hari. Ini jelas menunjukkan suatu potensi yang dapat dimanfaatkan untuk mempertahankan tingkat keragaman plasma nuftah dan tanaman hasil pemuliaan, sebagai suatu strategi penghindaran resiko. Sebagai tindak lanjutnya, suatu rangkaian kerja (*network*) sehubungan dengan upaya konservasi *in situ* bagi plasma nuftah yang beradaptasi secara lokal ini dapat diupayakan berdasarkan pada kebiasaan petani.

**Percobaan di multi-lingkungan**

Percobaan multi-lingkungan di kebun balai penelitian dibuat untuk mengevaluasi kesebelas varitas dari petani dan lima kultivar hasil pemuliaan di Uganda, di mana empat kultivar telah dilepas pada tahun 1999. Pada percobaan ini kami dapat membuktikan bahwa keterlibatan petani pada seleksi awal beberapa varitas ubi jalar tersebut cukup berhasil. Kami menganalisis suatu interaksi antara genotipe dari setiap varitas yang diteliti dengan lingkungannya untuk mengukur stabilitas produksi umbi dan juga daya adaptasinya secara luas dan spesifik.

Dilihat secara kelompok, varitas yang diseleksi oleh petani berpenampilan lebih unggul dibandingkan dengan kultivar nasional baik dari segi rata-rata produksi maupun kestabilannya. Pengamatan ini sendiri menunjukkan tingginya kemampuan petani di dalam mengidentifikasi varitas unggul. Setiap varitas yang diseleksi petani mempunyai perbedaan rata-rata produksi (rata-rata atas seluruh lingkungan) dan kestabilan produksi. Kami mengidentifikasi dua varitas petani yang berproduksi tinggi dan juga bersifat stabil, sementara itu juga disimpulkan keduanya beradaptasi luas. Jadi sekurang-kurangnya ada dua varitas petani beradaptasi pada lingkungan tertentu, yaitu berproduksi tinggi pada suatu lokasi tertentu namun potensi ini tidak terlihat pada tempat lainnya.

Dari beberapa pengamatan ini kami menyimpulkan bahwa seleksi awal oleh petani cukup berhasil, mengungkap kemampuan petani dalam mengidentifikasi beberapa genotipe yang mempunyai harapan tinggi untuk dapat ditanam di daerah-daerah marginal dengan sumber daya yang rendah. Lebih lanjut ditemui kenyataan mengenai adaptasi spesifik bagi beberapa varitas, yang menunjukkan bahwa suatu strategi dapat diterapkan dalam melepas kultivar yang hendaknya disesuaikan dengan keadaan daerah yang dituju.

**Estimasi perbedaan beberapa komponen**

Estimasi perbedaan komponen diperoleh dari suatu penganalisaan produksi ubi jalar yang penelitiannya dilakukan di beberapa negara Afrika Timur pada tahun 1999 sampai 2001. Belum pernah tercatat adanya penulisan ilimiah mengenai estimasi perbedaan komponen pada tanaman ubi jalar untuk kawasan Afrika Timur. Estimasi perbedaan komponen ini dapat digunakan untuk menetapkan efisiensi penelitian dalam memproduksi tanaman per kapita.

Tujuan analisis ini adalah untuk mendapatkan suatu gambaran yang jelas mengenai pengoptimalan alokasi dari total kapasitas uji yang direncanakan yang meliputi jumlah lokasi uji dan ulangan per lokasi. Kami juga menyelidiki apakah penyeleksian klon ini sebaiknya dilakukan hanya satu tahap dengan dua musim tanam untuk seluruh klon yang diteliti, atau melalui prosedur yang menggunakan dua tahap penyeleksian. Pada prosedur yang menggunakan dua tahap penyeleksian, seleksi pertama dilakukan dalam satu musim tanam, kemudian klon yang sudah terseleksi tersebut diuji coba lagi dengan skala yang lebih besar pada musim tanam berikutnya.

Analisis dilakukan untuk produksi umbi dan Elston indeks, yang mana memuat mengenai produksi umbi, biomassa, indeks panen dan umbi kering. Dari gambaran analisis yang diperoleh terlihat bahwa estimasi perbedaan komponen menggunakan dua tahap prosedur penyeleksian, lebih efisien dibandingkan dengan prosedur yang hanya menggunakan satu tahap penyeleksian. Untuk total kapasitas uji antara 450 sampai 950 plot yang berukuran 15 $m^2$, alokasi yang cocok adalah menggunakan dua lokasi dan satu ulangan pada tahap pertama penyeleksian, dan lima lokasi dengan dua ulangan pada tahap kedua. Ini dapat diaplikasikan baik pada penyeleksian produksi umbi maupun pada Elston indeks.

**Hubungan perlunya pemuliaan tanaman ubi jalar di Afrika Timur dan Sub-Sahara Afrika**

Dari beberapa hasil yang disajikan pada disertasi ini, kami mengusulkan sebuah model berdasarkan program tiga tahunan untuk mengidentifikasi sejumlah varitas dari petani yang unggul untuk sumber daya pertanian yang rendah dan juga sesuai dengan tingkat kemampuan petani miskin. Prosedur yang disarankan ini mungkin dapat diterapkan pada penyeleksian varitas ubi jalar di Uganda dan diharapkan pula dapat diterapkan pada daerah lainnya di Afrika Timur dan Sub-Sahara Afrika, dimana sistem pertanian (*farming system*) dan kondisi bercocoktanamnya hampir sama dengan keadaan yang tercatat pada daerah di Timur-Laut Uganda. Kami mengetahui bahwa keadaan lokal yang meliputi upaya-upaya pemuliaan sebelumnya, keberlimpahan plasma nuftah ubi jalar dan sumber daya plasma nuftah lainnya, dan pengetahuan petani tentang ubi jalar perlu diperhitungkan bila mengaplikasikan metoda ini pada daerah lainnya di Sub-Sahara Afrika. Setidaknya sangatlah jelas dari beberapa pengalaman kami bahwa dengan meningkatnya partisipasi petani di dalam upaya pemuliaan ubi jalar dapat menyumbang suatu yang berarti untuk meningkatkan efisiensi dalam menyeleksi genotipe-genotipe unggul pada lingkungan yang ditargetkan. Di dalam prosedur yang diusulkan ada dua aktivitas yang dapat dilakukan pada tahun pertama yaitu (i) pengoleksian plasma nuftah ubi jalar melalui pendekatan partisipasi rakyat pedesaan (*Participatory Rural Appraisal*), dan (ii) sirkulasi pertama penyeleksian yang dilakukan di kebun percobaan milik balai penelitian pada satu musim di dua lokasi berbeda. Petani yang kompeten sebaiknya dibebaskan menyeleksi varitas-varitas berdasarkan pilihan mereka. Pada tahun kedua aktivitas ini terdiri atas dua musim tanam percobaan yang dilakukan di ladang petani (*on-farm*) dengan tujuan utamanya menentukan selera konsumen dan mempersiapkan perbanyakan bahan tanaman sedini mungkin. Pada tahun ketiga tahap kedua (dan terakhir) dari sirkulasi penyeleksian dilaksanakan berdasarkan evaluasi di multi-lokasi yang dilakukan di kebun-kebun percobaan milik balai penelitian selama dua musim tanam. Lima lokasi dengan kapasitas uji antara 500 - 900 plot untuk kedua sirkulasi penyeleksian ternyata cukup layak digunakan pada tahap akhir evaluasi ini. Manajemen pembibitan tanaman membutuhkan perhatian penuh, karena keberhasilan pelaksanaan program ini sangat tergantung akan ketersediaan bahan tanaman yang cukup.

Dapat pula ditambahkan bahwa penyelidikan plasma nutfah yang diharapkan mungkin dapat mempercepat pemenuhan kebutuhan petani, dan plasma nutfah tersebut kiranya juga dapat dipergunakan sebagai tetua (tetua untuk persilangan) bagi program penelitian yang sudah berjalan.

Dari beberapa aktivitas penelitian yang dikemukakan pada disertasi ini, menghasilkan dua rekomendasi yang berkenaan dengan upaya peningkatan pemuliaan ubi jalar untuk pemenuhan kebutuhan petani-petani miskin yang bersumber daya rendah di Afrika Timur and Sub-Sahara Afrika. Pertama, kami merekomendasikan penyusunan suatu target pendistribusian dan strategi pemeliharaan bagi varitas-varitas yang baru saja dihasilkan, yang meliputi perhitungan akan tingkat adaptasinya luas atau spesifik, dan yang kedua, kami mengusulkan untuk menerapkan suatu "prosedur cepat" bagi partisipasi petani di dalam penyeleksian varitas. Parameter-parameter ini mungkin dapat menghindari kekecewaan yang cukup serius terhadap varitas yang baru saja dilepas di suatu daerah, di mana varitas tersebut kurang mendapatkan pengujian yang tepat, atau meskipun berpontensi produksi yang tinggi varitas-varitas tersebut ditolak oleh petani karena tidak sesuai dengan pilihan mereka.

## Curriculum vitae

Putri Ernawati Abidin (Erna Abidin) was born on 7th February 1958 in Padang, Indonesia. In December 1976, she completed the senior high school SMA Negeri XI, Bulungan Jakarta. Immediately after high school, on invitation, she studied Agronomy with specialization in Plant Breeding at the Bogor Agricultural University, Indonesia, where she got her first degree (BSc) in March 1981. During her study, she worked as a Graduate Teaching Assistant at the Department of Agronomy and also was active in the leadership of the students' organization. From 1982 to 1991, she worked at the Directorate General of Estate Crops, Ministry of Agriculture of Indonesia in Jakarta, on the improvement of crop production using technologies and varieties suitable for resource-poor farmers. Additional responsibilities included: (i) vice project leader for the National Coconut Hybrid Production Programme (1984 to 1987); (ii) vice project leader for the Cotton Smallholding Intensification Programme (1983 to 1984); and (iii) secretary for the Cotton Smallholding Intensification Programme (1982 to 1983). She received a Netherlands Fellowship to attend the International Plant Breeding Course at the International Agricultural Centre (IAC) in Wageningen from March to June 1988; and for her Master of Science Programme (1990-1991). She obtained her MSc Degree at the Department of Crop Science with specialization in Plant Breeding, Wageningen University in November 1991. From 1992 to 1994, she lived in Mozambique with her family. From 1994 to 2001, she was a Principal Senior Lecturer at the Arapai Agricultural College, Ministry of Education of Uganda in Soroti. Additional responsibilities while teaching at the college included: (i) Agronomy Department Head; (ii) mobilizing donors for funding requests; (iii) collaborating scientist with the International Potato Center (CIP) and the Ugandan National Agricultural Organization (1996 to 2001). From 1999 to 2001, CIP supported her PhD thesis research on evaluation of sweetpotato germplasm from northeastern Uganda, and the potential for farmer involvement in the selection of superior varieties for national sweetpotato improvement efforts. From 2001 to 2004, she completed her thesis work at the Laboratory of Plant Breeding, Department of Plant Science, Wageningen University and Research Centre in the Netherlands. She had the opportunities to present her research works at international symposia, i.e., the American Society for Horticultural Science (ASHS) in July 2001, and the International Society for Horticultural Science (ISHS) in November 2001. In the future she hopes to continue working with germplasm and diversity enhancement, cultivar development, and resource-poor farmers on participatory research and training in order to improve the livelihood of these farmers.

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