Euphytica (2008) 159:217–228
DOI 10.1007/s10681-007-9477-4

Working with farmer groups in Uganda to develop new sweet potato cultivars: decentralisation and building on traditional approaches

Richard W. Gibson · Emmanuel Byamukama · Isaac Mpembe · James Kayongo · Robert O. M. Mwanga

Received: 14 August 2006 / Accepted: 4 June 2007 / Published online: 4 July 2007

Abstract Scientists and farmers in Uganda identified preferred sweet potato: (1) varieties through participatory varietal selection (PVS); and (2) new clones from seedling populations through a participatory plant breeding (PPB) approach. During these two processes, farmers identified 51 attributes of their landraces and of released varieties and used 21 criteria to select clones from amongst the seedling populations. Scientists had, in publications, listed attributes (11 main attributes identified), morphological descriptors (11) of released varieties and varietal needs (23) of sweet potato farmers. One released variety (NASPOT 1) was selected by farmers during PVS, mostly for its high and early yield of large, sweet and mealy roots, and several clones were selected through PPB amongst the seedling populations for a wider range of attributes. Some varietal attributes needed by farmers were not included by scientists either because they were very laborious, for example, selecting on-station for clones suitable for sequential piece-meal harvesting, or because occurrence of important abiotic or biotic stresses such as drought or pest damage were difficult to predict. Farmers seldom mentioned disease resistance but did mention pest resistance, consistent with easy visibility of both the causes of and the damage due to pests. Unlike scientists, farmers made no mention of a need for cultivars to have perceptually distinct features, despite this being a common attribute of landraces of most crops.

Keywords Participatory plant breeding · Selection criteria · Varietal attributes · Perceptual distinctiveness · Disease resistance · Pest resistance

R. W. Gibson (✉)
Natural Resources Institute, University of Greenwich, Central Avenue, Chatham Maritime, Kent ME4 4TB, UK
e-mail: r.w.gibson@gre.ac.uk

E. Byamukama · I. Mpembe · J. Kayongo · R. O. M. Mwanga
Namulonge Agricultural and Animal Production Research Institute, P.O. Box 7084, Kampala, Uganda

Present Address:
E. Byamukama
Department of Plant Pathology, Iowa State University, Bessey Hall 351, Ames, IA 50011, USA

Introduction

Processes for the genetic improvement of crops are particularly diverse in developing countries (general reference; Tripp 2001). Already >30×10^6 ha of crop varieties developed through genetic modification are being grown there (Anon. 2006); formal plant breeding (FPB) dominates international and national crop improvement programmes; participatory plant breeding (PPB) (Sperling et al. 1993) and participatory varietal selection (PVS) (Witcombe et al. 1996) are widely used, especially for food crops and by NGO-led projects; and indigenous plant breeding

(IPB)-derived landraces of many major crops are still widely grown, for example, maize, cassava, yams and sweet potato, in Africa. Addressing the diverse needs of resource-poor farmers in developing countries has been both the main target and success of PPB (Friis-Hansen 1992; Sperling et al. 1993; Witcombe 1996; Berg 1997; Sperling et al. 2001). PPB usually requires farmers, scientists and perhaps other stakeholders to collaborate (Sperling et al. 1993) in a decentralised approach (Ashby and Sperling 1994; Berg 1997) and, unlike FPB, germplasm, information and skills are transferred to local farmers and other local stakeholders (Humphries et al. 2005). PPB, particularly when involving a range of farmers and agro-ecologies, requires a decentralised organisation and sharing resources, accountability and rewards (Ashby and Sperling 1994; Berg 1997): a shift from FPB to PPB requires some concomitant transfers of the latter (Manu-Aduening et al. 2006).

Witcombe et al. (2005b) identified high client orientation as the main purpose of PPB and supported Morris and Bellon (2004) in arguing that this purpose may be achieved more efficiently if breeding remains largely on-station. Such an approach avoids major reorganisation of breeding programmes, costs associated with off-station sites and disruption of farming activities, which may be particularly problematic for the poorer farmers at which PPB/DPB is generally aimed (Tripp 2001). However, there are doubts as to whether on-farm environments, particularly those of rainfed marginal agriculture, can be simulated adequately on-station (Ceccarelli 1994) and whether even national scientists can appreciate the needs and circumstances of largely subsistence farmers (Manu-Aduening et al. 2006). Sweet potato breeding in Uganda, which seems to involve none of the caveats for on-station highly client-orientated breeding (Weltzien et al. 2003; Witcombe et al. 2005a; and see Context), is used in this paper to examine the ability of scientists to identify adequately the needs of client farmers and then simulate these centrally on-station. It also reports PPB from seedlings for the first time for sweet potato, the third most important root crop in sub-Saharan Africa. The PPB programme specifically addressed weaknesses identified in IPB of sweet potato in East Africa in accessing large and diverse seedling populations (Gibson et al. 2000), delaying the development of superior landraces resistant to sweet potato virus disease (SPVD), the main disease of the crop in the region.

Context of the study

Uganda, a predominantly agriculture-based developing country (Anon. 1993; Earthtrends 2006), has the greatest production of sweet potato in Africa (FAOSTAT 2006). The crop is grown mostly by women and by most Ugandan rural households, the fresh roots being mainly boiled or steamed for daily family food, with limited sales of the fresh storage roots in urban markets (Bashaasha et al. 1995). Uganda's Sweet Potato Programme (USPP) is based at Namulonge Agricultural and Animal Production Research Institute (NAARI) located in Central Uganda, an area where sweet potato is grown extensively. Its scientists have access to further on-station sites, notably Serere Agricultural and Animal Production Research Institute (SAARI) in Eastern Uganda and Kalengyere Agricultural Research Development Center (KARDC) in south-western Uganda, both in major sweet potato growing areas (Fig. 1 The national allocation of resources, importance of the crop and its fairly limited main uses suggest an appropriateness for centralised, highly client-orientated selection (Weltzien et al. 2003; Witcombe et al. 2005a). USPP released six varieties (NASPOT 1–6) in 1999

Fig 1 Map of Uganda showing the districts in which farmer groups were based and sites (★) of NAARI and partner institutes

(Mwanga et al. 2003) that had been bred on-station, Dr Mwanga participating in a survey of farmers' needs (Bashaasha et al. 1995) and using local varieties in parental germplasm to achieve high client orientation.

Materials and methods

Key attributes of released sweet potato varieties as identified by scientists

Scientists' identification of key varietal attributes (Table 1) was obtained from a research publication describing the recent release of six station-bred varieties, NASPOT 1 to NASPOT 6 (Mwanga et al. 2003). Farmers' needs identified by scientists in a prior survey were collated from Bashaasha et al. (1995) (Table 2, column B).

Key attributes of landraces and released sweet potato varieties as identified by farmers during PVS

The PVS trials were incorporated into activities of two farmer groups based in adjacent areas of Masaka and Rakai Districts (Fig. 1) and developed by the Buganda Cultural and Development Foundation (BUCADEF), a Ugandan NGO working mainly with small-scale farmers. All farmers grew sweet potato mainly for their own consumption in gardens close to their homes. Ten trials, each a single replicate, were done in gardens managed by different members of each group in each of three rainy seasons, 1999–2000 (there are two rainy seasons in Central Uganda). Although the trials were shifted slightly each season for phytosanitary reason, individual farmers were encouraged where possible to manage trials throughout the three seasons so that they became well-acquainted with the varieties; overall, 14 of the

Table 1 The range of morphological descriptors and key attributes of sweet potato varieties as identified by scientists (derived from Mwanga et al. 2003). Shaded attributes were also mentioned by farmers, see Table 2

Morphological descriptors	Particular quality possessed
Plant type	Spreading
Vine pigmentation	Green, some with underlying purple
Mature leaf shape	Lobed, with 5–7 moderate to very deep elliptic—linear lobes
Abaxial leaf vein	Green
Foliage colour	Green, some with purple immature leaves
Petiole colour	Green
Storage root shape	Obovate-round elliptical
Storage root surface defects	None-longitudinal veins
Storage root skin colour	Cream or purple
Storage root flesh colour	White, cream, pale yellow or orange
Flower colour	Pale purple limb with purple throat
Attributes	
Dry matter of roots	High; 29–35%
Cooked texture of roots	Somewhat dry–dry
Sweetness of roots	Moderate-sweet
Field reaction to weevils	Susceptible-moderately resistant
Field reaction to *Alternaria* stem blight	Susceptible-resistant
Field reaction to SPVD	Moderately resistant–resistant
Field reaction to weeds	Suppressive
Days to maturity	120–150
Root yield (t/ha)	18–29
Storage root shape	Good
Consumer acceptance	Excellent

Table 2 Numbers of times particular attributes were mentioned by farmers (a) during variety ranking exercises following PVS and (b) when selecting different clones during PPB

Attribute	B	Variety ranking				During PPB			
Districts*		M + R	L	K	Total	Mp	L	K	Total
Pre-harvest root** production									
Good root yield	+	17	29	29	75	115	113	157	385
Big roots	+	15	26	23	64	72	81	52	205
Early root maturity		9	16	20	45	15	1	8	24
Continuous root yield for piecemeal harvesting	+	4	15	17	36	2	1		3
Long root storage in soil	+	9	1	5	15				
Good root yield on poor soils	+	1	3	1	5				
Few exposed roots	+	1		1	2				
Few cracks in roots		1	1		2	3	1		4
Yields satisfactorily in poorly-tilled soils		1		1	2	4			4
Doesn't require big ridges/mounds		1			1				
Roots close to surface for easy harvest		1			1				
Many roots				1	1				
Different maturation periods	+								
Suitable for intercropping	+								
Foliage									
Extensive foliage		5	4	1	10				
Good vine establishment			5	1	6				
Nice looking vines			1		1	1			1
Ample planting material		1			1	3	6		9
Lots of foliage for animal feed						3			3
Canopy not spreading much							1		1
Long-lived plants		1		1	2				
Resistance/Tolerance to									
Drought	+	14	29	22	65	18	17	41	76
Weevils	+	11	21	17	49	1		18	19
Caterpillars *Acraea acerata*	+	2	17	4	23				
Rats and other vertebrates	+		3	1	4	6			6
Alternaria	+	2	1		3				
Weeds		1	1		2				
SPVD	+	1			1	40	8	96	144
Rain		1			1				
Diverse weather conditions				1	1				
Millipedes			1		1				
Storage root rot	+								
Mites	+								
Post-harvest									
Roots prior to cooking									
Marketability	+	2	6	4	12		1	1	2
Attractive colour	+	1	3	8	12	29	24	36	89
Non-sappy		2	4	2	8				
No loss of taste with time			4	4	8				

Table 2 continued

Attribute	B	Variety ranking				During PPB			
Districts*		M + R	L	K	Total	Mp	L	K	Total
Long		1	1	1	3	12		2	14
Less *'kigave'* ***			1	1	2				
Straight			1	1	2	27	21	30	78
Soft skin		1			1				
Smooth		1			1				
Easy peeling			1		1		1		1
Thin peel		1			1				
Few black spots on skin		1			1				
Hard (solid) storage roots				1	1				
Don't break during harvest				1	1				
Orange/yellow fleshed	+					4	31	28	63
Good shape	+					1		5	6
Roots after cooking									
Sweet	+	15	24	27	66	NA	NA	NA	NA
Mealy		7	26	27	60	NA	NA	NA	NA
Non-fibrous	+	4	4	6	14	NA	NA	NA	NA
Soft texture		1	5	1	7	NA	NA	NA	NA
Nice looking at table				5	5	NA	NA	NA	NA
Nice flavour	+		5		5	NA	NA	NA	NA
Easy/quick to cook		1	1	2	4	NA	NA	NA	NA
Attractive flesh			1		1	NA	NA	NA	NA
Not too sweet				1	1	NA	NA	NA	NA
Not watery		1			1	NA	NA	NA	NA

Shaded attributes were also mentioned by scientists, see Table 1. Items marked + in column B were identified in Bashaasha et al. (1995)

* M + R = Masaka + Rakai, L = Luwero, K = Kiboga, Mp = Mpigi

** The term 'root' is used to refer to storage roots

*** *Kigave* describes an internal blackening of fresh storage roots

NA = Not applicable because it was only practical to cook samples during the later stages of selection when only a few clones remained

farmers were women and 8 were men. Each trial comprised a single plot of each of 6–8 new varieties recommended by USPP plus a plot of each of two landraces selected by the farmer of each garden, cultivars allocated randomly to plots. Scientists' recommendations changed slightly during the trials but NASPOT 1, 2 and 3 were included in all trials; farmer-chosen landrace checks were Somba busero, Kampala or Old Kawogo. Farmers made traditional mounds of soil using hoes, each mound about 0.5 m high and occupying about 1 m^2. Three cuttings of a single cultivar were planted in each mound. Clusters of 8 mounds planted with one cultivar comprised a plot. SPVD-affected plants were recorded and the percentage of affected plants in each plot calculated; damage by the fungal disease *Alternaria* (the next most damaging disease of sweet potato in Africa after SPVD) to the foliage and by weevils (the main insect pest of sweet potato in Africa) to the roots were recorded using a 0–5 scale for the whole plot, '0' representing no damage and '5' representing all the foliage/roots affected. Data were recorded by scientists aided by farmers during field days (Table 4). For analysis, each on-farm trial was treated as a single replicate of a randomised block design, aggregating data from the 10 trials in each district each season in six separate analyses. Harvested roots and vines and unharvested guard mounds remained with the farmers to eat, sell or provide planting material.

Nine farmers (6 women, 3 men) in each district who had hosted variety trials were interviewed in 2001 in both Masaka and Rakai Districts. BUCADEF had also previously provided other farmer groups in Luwero and Kiboga Districts (Fig. 1) with planting material of the different NASPOT varieties; 30 and 28 farmers (about 70% women) respectively who had received these were also interviewed. All farmers were interviewed on their farm, generally as a family group. To identify key attributes, samples of each of the different cultivars (both local and introduced) of sweet potato grown on the farm were used as prompts to ask what was special about each. All bad attributes were changed into corresponding good attributes, any duplicates were removed and the list of attributes was confirmed by farmers (Table 2). Farmers ranked these attributes and then, for each attribute, ranked their cultivars (Kapinga et al. 2001). Farmers grew different numbers of cultivars and ranks were afterwards standardised to ten. As expected, more important attributes were mentioned by correspondingly larger numbers of farmers ($P < 0.001$). For attributes for which sufficient responses were obtained (Table 2), values were arcsin transformed and means compared using Student's t-test. Although most farmers each grew only 2 to 4 different landraces, the farmers in Masaka + Rakai, Kiboga and Luwero respectively mentioned totals of 33, 45 and 40 different cultivars; Table 3 focuses on the data obtained for just NASPOT 1 to 4.

In 2003, farmers in 7 BUCADEF groups were surveyed for adoption of NASPOT varieties, two groups from each of Luwero, Mpigi, Kiboga and one group from Masaka district. In each community, 10 group members and 10 non-members were interviewed (about 70% were women) and asked which if any of the NASPOT varieties they were growing. In 2004, farmers who had hosted the 1999–2000 trials in Masaka and Rakai were again asked whether or not they were still growing the NASPOT varieties and why.

Key attributes of sweet potato clones as identified by farmers during PPB

In 2003, 3 other BUCADEF farmer groups in Luwero, Mpigi and Kiboga districts were asked whether they would like to collaborate in sweet potato breeding. Generally, about 20 farmers in each group participated in activities; one of the group leaders was a woman and approximately 60% of members also were women. All members were poor, small-scale farmers. The farmers were informed about how seeds are a source of variability and hence of new cultivars and that the scientists wanted

Table 3 Mean rank (standardised to be out of 10 so 5.5 was the 'average' against which to compare) for attributes of released varieties commonly mentioned by farmers in variety ranking exercises with popular local landraces (The lower the figure, the higher the ranking)

District	Rakai + Masaka			Luwero			Kiboga		
Attribute	1*	2*	3*	1*	2*	4*	1*	2*	4*
High root yield	2.0	3.6	7.2	2.4	5.8	8.3	2.4	5.2	6.8
Drought tolerance	6.7	6.0	3.8	5.0	4.3	5.6	4.6	5.7	6.3
Large root size	1.0	6.0	5.4	2.6	6.4	8.1	2.7	6.9	8.0
Sweet roots	3.3	4.8	6.6	2.7	6.1	6.4	3.0	6.8	7.4
Mealy roots	3.9	3.3	8.2	2.9	5.2	5.4	3.7	6.7	7.3
Weevil resistance	5.2	5.7	5.0	3.7	3.4	5.0	3.7	5.8	6.0
Early root maturity	1 .2	3.3	7.1	3.6	6.2	8.1	2.5	5.0	6.1
Sequential root production	7.7	7.4	7.3	6.4	3.5	7.6	3.9	5.7	5.5
Overall rank of cv	*2.0*	*3.6*	*8.1*	*2.4*	*5.6*	*8.1*	*2.4*	*5.2*	*6.7*

*NASPOT 1; 2; 3; 4.

(light shading)	Attribute was ranked significantly (P < 0.05) greater or less than the mean rank, 5.5
(dark shading)	Attribute was ranked significantly (P < 0.01) greater or less than the mean rank, 5.5

to work with them to select cultivars of types the farmers needed. Farmers in all groups offered land and labour. Seeds provided were of three half-sib families obtained from SPVD-resistant and/or high yielding Ugandan landraces, New Kawogo, Bunduguza and Wagabolige, pollinated naturally in a crossing block at NAARI which included other superior parental genotypes. Each group received about 6,000 seeds pre-treated by scientists to break dormancy. The seeds from these families were planted in shallow furrows made in a seed-bed about 1 × 6 m. Some 2 months later, a single cutting was taken from each surviving seedling and these were planted about 30 cm apart along ridges (about 1 m from ridge to ridge) the farmers had made with hoes for the communal trial on a group member's farm. At harvest, farmers selected accessions they wished to keep, writing down their reasons for each selection.

Cuttings of selected accessions were planted in further trials in repeated cycles of selection and replanting continued over 4 clonal generations (Fig. 2). In both Kiboga and Luwero, farmers continued using ridges whereas farmers in Mpigi made mounds about 1 m^2, planting 3 cuttings of the same clone in it. As the number of clones decreased, the number of cuttings of a clone planted along a ridge was increased from 5/plot in clonal generation 1 to 10/plot in Luwero and Kiboga and from 1 mound/plot to 6 mounds (each with 3 cuttings)/plot in Mpigi. In clonal generation 3 onwards, although plot size remained the same, 3 plots of each clone were now planted in a randomised block design. Why farmers rejected particular plants was also recorded from clonal generation 3 (and these were converted into their equivalent positive reason for selection) to be summed over the generations (Table 2). It was also only practical to cook roots of the large numbers of clones present from clonal generation 3 onwards. Roots of clones selected in the field were steamed in individual plastic bags in a large cooking pot and farmers selected in 'blind' tasting tests those clones that, from their cooked roots, were good enough for final retention; farmers were also encouraged to take cuttings to grow in their own gardens so that they could then assess them for a wider range of properties including those of the roots when cooked individually and eaten as part of normal meals.

After four clonal generations, farmers in the Luwero and the Mpigi groups visited each other and exchanged preferred clones.

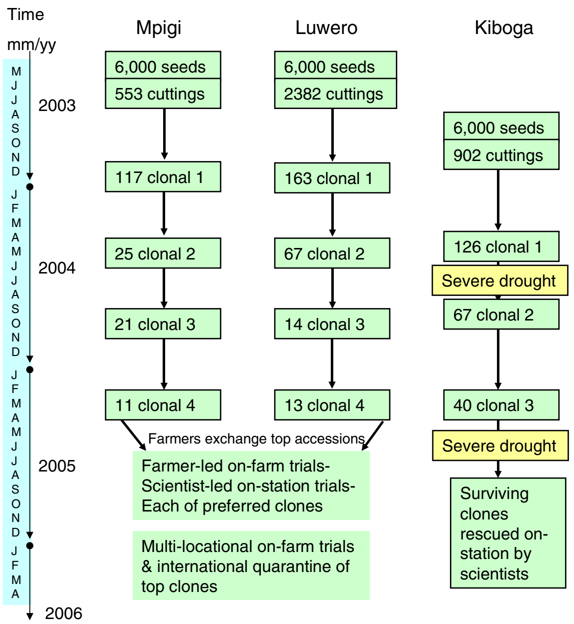

Fig 2 Timing and flow of major events in the sweet potato PPB activities

Results

Key attributes of released sweet potato varieties as identified by scientists

The criteria identified as significant to scientists from a research publication describing the release of NASPOT 1 to 6 (Table 1) comprised morphological descriptors and attributes which make each variety suitable for purpose. The descriptors included pigmentation and shape of leaves, petiole and storage roots, and flower shape and colour. The attributes included storage root yield, the appearance, taste and texture of the roots and time to harvest, and resistance to weeds, a pest (weevils) and two diseases, SPVD and *Alternaria*. This list excluded some identified as important by farmers (Table 2) such as sequential production of storage roots, good in-ground storage of roots prior to harvest (both attributes facilitate daily piecemeal harvesting of individual roots from plants), good root yield on poor soils, tolerance to drought and resistance to various vertebrate and invertebrate pests.

Key attributes of landraces and released sweet potato varieties as identified by farmers during PVS

The main varietal attributes mentioned by farmers were a high yield of large, sweet mealy roots. The presence of these in NASPOT 1 was identified by farmers (Table 3) during the PVS trials in Masaka and Rakai in 1999–2000 and confirmed by the scientists' yield records (Table 4). Farmers seldom noted (Table 3) the susceptibility to weevils and *Alternaria* of NASPOT 1 recorded by scientists in these trials (Table 4) and previously (Mwanga et al. 2003)—although they did so after growing them in their own gardens (see later). Tolerance to drought and the ability to sustain continuous root yield were the only frequently mentioned attributes for which NASPOT 1 was not considered to be significantly better than average by most farmers. None of the other released varieties were ranked above average either overall or for any specific attribute.

In the 2001 interviews, farmers mentioned 51 varietal attributes (Table 2), frequently mentioning attributes involved the storage roots (large yield, early yield, sweetness, mealiness, sequential yielding and ability to be left in the ground for a long time prior to harvesting), and drought and weevil resistance. Other attributes were mostly mentioned just once or twice. All of the attributes specified by scientists for variety release except different maturation periods were also specified by farmers though relatively few mentioned resistance to SPVD, *Alternaria* or weeds. Unlike scientists, farmers specified no morphological characters the sole function of which was to enable farmers to distinguish clones, though some mentioned root skin colour, which enables customers to distinguish roots of different cultivars, as important in marketing.

In the 2003 adoption survey in Luwero, Mpigi, Kiboga and Masaka districts, 22 of a total of 70 group members and 16 of 70 non-group members interviewed were growing NASPOT 1, stating this was mainly because of its high yield and sweet roots. No other NASPOT variety was specified by farmers. In the 2004 survey, 7 farmers in the Masaka and 7 in the Rakai groups were identified for re-interview. NASPOT 1 was still being grown by 5 of the Masaka farmers but only one of the Rakai farmers. Only small amounts of any of the other NASPOT varieties were being grown and only by one or two of the farmers. Several farmers had lost all planting material of NASPOT 1 during drought which had affected the whole East African region; farmers also mentioned its susceptibility to *Alternaria* as another reason for non-adoption.

Many large fields of NASPOT 1 were evident when travelling along the main road from Masaka to Kampala in 2005 and 2006 and its roots are now

Table 4 Yield and disease and pest resistance of NASPOT cultivars and landraces as recorded by scientists in on-farm trials, averaged over trials done in 3 growing seasons (1999–2000) in both Masaka and in Rakai districts

Cultivars	Relative yield*		Mean weevil damage scores**	SPVD incidence (%)	Mean *Alternaria* disease scores***
	Total	Marketable			
NASPOT 1	1.82 (4)	2.34 (4)	1.5 (1)	3.1 (0)	2.7 (4)
NASPOT 2	1.45 (1)	1.59 (1)	0.9 (0)	4.4 (0)	1.4 (3)
NASPOT 3	1.37 (1)	1.72 (3)	0.4 (0)	1.2 (0)	0.0 (0)
NASPOT 4	0.95 (0)	0.98 (0)	1.0 (0)	5.5 (0)	2.1 (4)
Local cultivars					
Old Kawogo	1.0	1.0	0.4	3.9	0.0
Somba busero			0.9	5.7	0.0
Kampala			0.6	8.6	0.3

Numbers in parentheses show how many times a particular variety had a significantly ($P > 0.05$) greater yield or score than the local cultivars during each of these 6 sets of trials

* Local cultivars selected by farmer groups in Rakai and Masaka and test cultivars chosen by scientists changed some seasons and the storage root yields given are averages of different trials recalculated to the average yield of the local cultivars being equal to '1'

** 0 = no damage; 5 = very severe

*** 0 = no damage; 5 = very severe

common in Kampala markets, indicating that NASPOT 1 is now widely grown.

Key attributes of sweet potato clones as identified by farmers during PPB

Activities in Kiboga started later than in Mpigi and Luwero districts (Fig. 2) and severe droughts there resulted in survival under these conditions being the only attribute selected for during two cropping cycles. In both Mpigi and Luwero, SPVD was a particularly important constraint. Trials in these latter districts were also affected by drought but not to the extent that they prevented selection for other attributes. It had been planned that farmers and scientists would make separate selections, as done elsewhere for cassava (Manu-Aduening et al. 2006). However, farmers selected all the clones the scientists selected bar a very few plus a lot more and it was decided to rely on farmer selection only. Farmers specified 21 selection criteria during seedling and subsequent clonal selections (Table 2). This is fewer than the range identified during PVS, partly because postharvest attributes were not included. As in PVS, none provided solely perceptual distinctiveness.

The enthusiasm of farmers diminished over the seedling and first two clonal generation, many commenting that so few of the clones seemed worth keeping. In Kiboga, severe drought finally led to farmers abandoning the trial—scientists rescued the surviving clones, realising they may have useful drought tolerance. By clonal generation 4, however, farmers in the Luwero and Mpigi groups were enthusiastic about some of their remaining clones. Exchange visits and exchanges of selected clones between the Luwero and Mpigi groups also boosted enthusiasm. Farmers started to multiply particular clones and to identify particular niches, for example, for ones with roots attractive in the market, suitable for sequential harvesting, tolerant to drought or producing a high yield of unattractive but sweet roots still appropriate for home consumption.

Initially, group trials included only local cultivars as checks but NASPOT 1 was included in later trials. A few of the selected clones appeared higher yield than NASPOT 1 in preliminary trials and appeared to be more resistant to SPVD, weevils and *Alternaria*. For example, a clone coded NK1081 and selected with the Luwero group had a marketable yield twice ($P = 0.04$) that of NASPOT 1 in clonal generation 4, had also yielded well in previous generations, generally scored well for resistance to *Alternaria* and SPVD and was considered by farmers to have a very attractive storage root suitable for marketing. Farmers are already growing these clones extensively in their gardens and giving or selling planting material to relatives and neighbours. The selected clones have also been tested by USPP on-station at NAARI, SAARI and KARDC and are now being assessed in extensive (>30) multi-locational on-farm trials with initial promising results (Mwanga et al. 2006). The Tanzanian Root and Tuber Programme also requested clones for Kagera Region, which adjoins Uganda and has a similar agro-ecology to Mpigi and Luwero Districts; these have been transferred to them through the regional quarantine centre in Nairobi under the auspices of the International Potato Center (CIP).

Discussion

There was broad correspondence in the attributes of sweet potato cultivars commonly identified by farmers in a previous survey (Bashaasha et al., 1995) and during the PVS and PPB activities (Table 2), suggesting that all three provided valid information about farmers' varietal needs. Despite this, the comprehensiveness of the information remains questionable. Except for the farmers who were involved in PPB activities—who experienced many of the seedlings being severely damaged by SPVD—few mentioned resistance to SPVD as an important attribute. Landraces established in Central Uganda (Aritua et al. 1998) and the released varieties (Mwanga et al. 2003) (Table 4) are all relatively resistant to SPVD and this may have led farmers to overlook SPVD and, in a like manner, other diseases. Abilities to smother weeds and to yield in poor soils are also common features of sweet potato cultivars, presumably much appreciated by most farmers, yet these were seldom mentioned and no precise description of different soils needed to grow different varieties of sweet potato was obtained by any of the approaches. Knowledge of these may have been assumed or farmers may have been unconcerned about their cultivars' responses to either biotic or abiotic environmental constraints because this is part of unconscious or automatic selection (Zohary 2004) being (1) 'an aspect of selection that is efficiently taken care of by natural processes or (2) deliberate selection for yield indirectly selects for resistance to a wide spectrum of environmental conditions' (Boster 1984). Alternatively, although most of the involved farmers had received some training on control of SPVD, they may still have remained relatively unaware of the existence of plant pathogens (Bentley and Thiele 1999) whilst the greater visibility of vertebrate and arthropod pests and the damage they cause enabled farmers to identify them (Bentley 1991) as important (Bashaasha et al. 1995) (Table 2).

Whilst other research has identified the difficulties associated with simulating on-station abiotic aspects of on-farm environments in developing countries (Ceccarelli 1994), our research has identified family needs that are difficult to simulate on-station because they are so time-consuming to assess or their unpredictability requires testing in many locations to ensure their occurrence. Although the family needs are to an extent specific to sweet potato, it seems likely that poor farmers of most crops in developing countries have their similar difficult-to-simulate needs. Thus, attributes frequently mentioned by farmers (Table 2) but not by scientists (Table 1) included were based on the need for sequential harvesting of storage roots practised by >90% of Ugandan farmers (Bashaasha et al. 1995) and drought tolerance and resistance to caterpillars of the sweet potato butterfly, *Acraea acerata*. The first is very labour intensive to assess and constraints such as drought and mobile pests are hard to predict. Although NASPOT 1 is now widely adopted by farmers, this is mainly because of its high and early yield of large, sweet storage roots (Table 3), all relatively easy attributes to select even in large-scale trials (Nevertheless, the development and adoption of this very high yielding variety is important in Uganda where, for example, 26% of children are underweight (Earthtrends 2006).

PPB at the 3 on-farm locations did appear to enable drought-tolerant clones to be selected for. Farmers, however, also largely ignored attributes allowing piecemeal harvesting during PPB (Table 2), like scientists, finding it difficult to assess this in the large communal trials which, for logistical reasons, had only one harvest date (a few farmers attempted to do so by selecting clones which had storage roots at apparently different stages of development). It similarly remained impractical to cook roots from each of the large numbers of clones grown in the early PPB generations. Even in later generations, roots of different clones were cooked together, therefore with a single cooking time, and were tasted with none of the sauces usually eaten with sweet potato, so the conditions did not wholly simulate home cooking and eating. Instead, keen farmers were encouraged to take planting material of released varieties and PPB clones to grow in their own gardens and to cook and eat the roots in their own homes. In this way, time-consuming attributes were cost-effectively examined as part of normal daily activities.

The term 'PPB', especially when the antecedents 'farmer' or 'decentralised' are included, implies an evolution from FPB in which farmers participate. The contrasting opportunity, for scientists to build on indigenous breeding, is also present, especially in Africa where landraces remain the basis of most crop production—and an appreciation that farmers seldom accessed sweet potato seedlings (Gibson et al. 2000) and that scientists could use their knowledge and access to international and national sources of germplasm to provide farmers with large numbers of seeds/seedlings of appropriate diversity to address this weakness provided the initial hypothesis for this project. Our encouragement of farmers to take planting material home to test in their gardens also built on how IPB often involves individual farmers selecting distinctive seedlings out of their own curiosity (Tripp 2001). The farmer groups in our breeding activities required the scientists' support to maintain their enthusiasm, particularly during the middle stages of the process (scientists' enthusiasm was sustained through salaries, travel allowances and other job-associated benefits). IPB is intrinsically self-sustaining and in some Amerindian cultures, is organised through the *shaman* (Salick et al. 1997); involvement of organisations more integral to each community might have sustained our communal activities better.

The propagule for sweet potato in normal cultivation is a leafy cutting; as expected for a vegetatively propagated crop (Zahory 2004), both the original seedling populations and the few clones selected in our breeding activities exhibited diverse phenotypes. Perceptual distinctiveness between landraces, first described in cassava (Boster 1985), is also common amongst other crops (Zeven 2000). It seemed significant, therefore, that the need for selected clones to have distinctive features, both amongst themselves and from current landraces and varieties, was never mentioned by farmers during either variety selection or breeding activities (Table 2). In contrast, scientists used morphological descriptors for the NASPOT varieties (Table 1) and always labelled sweet potato clones in the on-farm trials. Landraces of vegetatively propagated crops may be polyclonal (Elias et al., 2001), resulting from farmers not making a conscious effort to separate phenotypically similar genotypes; scientists involved in PPB may need to ensure there is adequate phenotypic variation within seedling populations.

Our collaboration with farmers to breed sweet potato from seedlings, the first apparently reported in the World, has identified new clones, which farmers are adopting. Some of this success may have been achieved through taking advantage, where possible, of opportunities to build on IPB. There seem to be, however, few studies of IPB for crops in sub-Saharan Africa (Zeven 2000) to provide PPB with supporting knowledge. Ironically, this knowledge of IPB is particularly lacking for those crops introduced from the Americas such as sweet potato, even though developing these crops within just a few centuries to become the main staple foods of Africa is a major technical achievements of African agriculture (Gabre-Madhin and Haggblade 2004).

Acknowledgements We acknowledge the support of the farmers, particularly the late Mr Rajab Ssetyabula of Manyama, Zirobwe, Uganda and critical reading of the manuscript by Mr Richard Lamboll. The project was funded by the UK Department for International Development. However, DFID can accept no responsibility for any information provided or views expressed.

References

Anon. (1993) Uganda agriculture. World Bank Country Study. The World Bank, Washington, DC, USA, 208 pp

Anon. (2006) GMOs. Up from the dead. Economist 379(8476):73–74

Aritua V, Adipala E, Carey EE, Gibson RW (1998) The incidence of sweet potato virus disease and virus resistance of sweet potato grown in Uganda. Ann Appl Biol 132:399–411

Ashby JA, Sperling L (1994) Institutionalising participatory, client-driven research and technology development in agriculture. ODI Agricultural Research & Extension Network Paper No. 49, 21 pp

Bashaasha B, Mwanga ROM, Ocitti p'Obwoya C, Ewell PT (1995) Sweetpotato in the farming and food systems of Uganda: a farm survey report. International Potato Center, Kenya and National Agricultural Research Organisation, Uganda, 63 pp

Bentley JW, Thiele G (1999) Farmer knowledge and management of crop disease. Agric Human Values 16:75–81

Bentley JW (1991)The epistemology of plant protection: Honduran campesinos' knowledge of pests and natural enemies. In: Gibson RW, Sweetmore A (eds) Proceedings of a seminar on crop protection for resource poor farmers. Isle of Thorns, West Sussex, UK, 4–8 November 1991, pp 107–118

Berg T (1997) Devolution of plant breeding. In Sperling L, Loevinsohn M (eds) Using Diversity. Enhancing and maintaining genetic resources on-farm . IDRC Canada. Available online at http://www.idrc.ca/seeds/ev-9290-201-1-DO_TOPIC.html

Boster JS (1984) Classification, cultivation, and selection of Aguarana cultivars of Manihot esculenta (Euphorbiaceae). Adv Econ Bot 1:34–47

Boster JS (1985) Selection for perceptual distinctiveness: evidence from Aguarana Jivaro varieties of *Manihot esculenta*. Econ Bot 39:310–325

Ceccarelli S (1994) Specific adaptation and breeding for marginal conditions. Euphytica 77:205–219

Earthtrends (2006) http://earthtrends.wri.org/

Elias M, Oenet L, Vindry P, McKey M, Panaud O, Robert T (2001) Unmanaged sexual reproduction and the dynamics of genetic diversity of a vegetatively propagated crop plant, cassava (*Manihot esculenta* Crantz), in a traditional farming system. Mol Ecol 10:1895–1907

FAOSTAT (2006) http://faostat.fao.org/

Friis-Hansen E (1992) The failure of formal plant breeding to meet the needs of resource-poor peasants in African arid lands. African Arid Lands; Working Paper Series No 3/92, 12 pp

Gabre-Madhin EZ, Haggblade S (2004) Success in African agriculture: results of an expert survey. World Dev 32:745–766

Gibson RW, Jeremiah SC, Aritua V, Msabaha RP, Mpembe I, Ndunguru J (2000) Sweet potato virus disease may remain a damaging disease of sweet potato in Africa because lack and neglect of seedlings in the traditional farming system hinder the development of superior resistant landraces. J Phytopathol 148:441–447

Humphries S, Gallardo O, Jimenez J, Sierra F (2005) Linking small farmers to the formal research sector: lessons from a participatory bean breeding programme in Honduras. ODI Agricultural Research & Extension Network Paper No 142, 14 pp

Kapinga R, de Steenhuijsen Piters B, Heemskerk W, Chirimi B, Mutalemwa M, Kabissa J, Kapingu P (2001) Participatory research in sweetpotato variety evaluation and selection for the diverse environments of the Lake Zone of Tanzania. Proceedings of the 7th Triennial Symposium of the International Society for Tropical Root Crops-Africa Branch, p 471

Manu-Aduening JA, Lamboll RI, Ampong Mensah G, Lamptey JN, Moses E, Dankyi AA, Gibson RW (2006) Development of superior cassava cultivars in Ghana by farmers and scientists: the process adopted, outcomes and contributions and changed roles of different stakeholders. Euphytica 150:47–61

Morris ML, Bellon MR (2004) Participatory plant breeding research: opportunities and challenges for the international crop improvement system. Euphytica 136:21–35

Mwanga ROM, Odongo B, Turyamureeba G, Alajo A, Yencho GC, Gibson R W, Smit NEJM, Carey EE (2003) Release of six sweetpotato cultivars (‘NASPOT 1’ to ‘NASPOT 6’) in Uganda. Hortscience 38:475–476

Mwanga ROM., Stevenson RC, Yencho CG (2006) Development of high yielding multiple resistant sweetpotato germplasm research progress report: April 1, 2005 through March 31, 2006. http://mcknight.ccrp.cornell.edu/program_docs/project_documents/spu/SPU_progress-rep_05-06_yr10_31may06.pdf

Salick J, Cellinese N, Knapp S (1997) Indigenous diversity of cassava: generation, maintenance, use and loss among the Amuesha, Peruvian Upper Amazon. Econ Bot 51:6–19

Sperling L, Ashby JA, Smith ME, Weltzien E, McGuire S (2001) A framework for analyzing participatory plant breeding approaches and results. Euphytica 122:439–450

Sperling L, Loevinsohn ME, Ntabomvuras B (1993) Rethinking the farmers’ role in plant breeding: local bean experts and on-station selection in Rwanda. Exp Agric 29:509–519

Tripp R (2001) Seed provision & agricultural development: the institutions of rural change. Overseas Development Institute, London, UK, 174 pp

Weltzien E, Smith M, Meitzner L, Sperling L (2003) Technical and institutional issues in participatory plant breeding from the perspective of formal plant breeding. A global analysis of issues, results, and current experience. PPB Monograph No. 1. pp 1–208 + I–XXI. PRGA Program, Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia

Witcombe JR, Joshi A, Joshi KD, Sthapit BR (1996) Farmer participatory crop improvement. I. Varietal selection and breeding methods and their impact on biodiversity. Exp Agric 32:445–460

Witcombe JR, Gyawali S, Sunwar S, Sthapit BR, Joshi KD (2005a) Participatory plant breeding is better described as highly client-orientated plant breeding. II. Optional farmer collaboration in the segregating generations. Exp Agric 42:79–90

Witcombe JR, Joshi KD, Gyawali S, Musa AM, Johansen C, Virk DS, Sthapit BR (2005b) Participatory plant breeding is better described as highly client-orientated plant breeding. I. Four indicators of client orientation in plant breeding. Exp Agric 41:299–319

Zeven AC (2000) Traditional maintenance breeding of landraces: 1. Data by crop. Euphytica 116:65–85

Zohary D (2004) Unconscious selection and the evolution of domesticated plants. Econ Bot 58: 5–10