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Development of superior cassava cultivars in Ghana by farmers and scientists: The process adopted, outcomes and contributions and changed roles of different stakeholders

J.A. Manu-Aduening[1], R.I. Lamboll[2], G. Ampong Mensah[1], J.N. Lamptey[1], E. Moses[1], A.A. Dankyi[1] & R.W. Gibson[2,*]
[1]*Crops Research Institute, P.O. Box 3785, Kumasi, Ghana;* [2]*Natural Resources Institute, University of Greenwich, Central Ave, Chatham Maritime, Kent, ME4 4TB, UK*
*(*author for correspondence: e-mail: r.w.gibson@gre.ac.uk)*

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Summary

A participatory breeding programme involving farmers in two Ghanaian communities and scientists from CRI (Ghana) and NRI (UK) to develop superior cassava cultivars is described. Initial situation analyses of the communities indicated that cassava is increasing in importance both as a food and a cash crop. Most farmers utilised landraces of cassava; modern varieties were scarcely mentioned. Seeds of 16 half-sib families obtained from a crossing block in Nigeria at the International Institute of Tropical Agriculture were planted in a field in each community. During seedling and subsequent clonal generations, accessions selected either by farmers or scientists were retained to the next generation. This selection process has identified 29 superior accessions from amongst 1350 original seedlings. Farmers were relatively consistent in their selection from year to year and their selections corresponded with their stated criteria. Official variety release requires additional multilocational and inspection trials and postharvest assays but otherwise seems harmonious with a participatory breeding approach; our early involvement of farmers may facilitate early release, an important factor in cost-effectiveness. A stakeholder workshop confirmed the need for improved markets for cassava; surveys of current and potential markets have led to field trials with cassava processors. Adoption of a participatory approach, with farmers and scientists taking on new roles and decentralisation of activities, implies a concomitant transfer of influence and resources.

Introduction

In developed countries, cultivars developed by formal plant breeding (FPB) dominate crop production. There, conditions on the research stations where FPB is done are usually similar to those on-farm. Cultivars bred by FPB, often in international agricultural research centres supported by the Consultative Group for International Agricultural Research (CGIAR) or national agricultural research centres, were a key component of the Green Revolution in developing, particularly Asian, countries and are widely grown especially on relatively fertile and/or irrigated lands. In contrast and as illustrated by cassava in Ghana, landraces continue to dominate crop production on rainfed, often marginal, lands in developing countries, especially in Africa (Friis-Hansen, 1992). There, conditions on-farm may differ considerably from those on research stations, genotype x environment interactions resulting in cultivars selected on-station being poorly adapted to conditions on-farm (Banziger & Cooper, 2001; Ceccarelli et al., 2003). Breeders mainly targeting yield can also overlook other key attributes important to farmers (Haugerud & Collinson, 1990; Witcombe, 1996; Baidu-Forson, 1997) or, even when aiming to address farmers' and other end-users' needs, may lack the training needed to elicit them (Morris & Bellon, 2004). Over the last few decades, farmers in developing countries have increasingly participated in breeding new cultivars as an alternative or complement to FPB (Rhoades & Booth, 1982; Sperling et al., 1993; Sthapit et al., 1996; Witcombe et al., 1996). Although CGIAR centres may remain as sources of diversity (Morris & Bellon, 2004), participatory plant breeding (PPB) requires decentralisation of activities (Maurya et al., 1988; Berg, 1997) and a greater role for social scientists (Morris & Bellon, 2004). PPB also requires involvement of more actors than just scientists and farmers (Sperling et al., 2001).

Cassava (*Manihot esculenta* Crantz) is the main starch staple of many people in Africa. It can yield in relatively infertile soils and tolerates long periods of drought, making it particularly important for poor rural households farming marginal lands. In Ghana, a mean *per capita* production of 465 kg/*annum* provides about 20% of calories in the diet, far ahead of any other single crop or animal source (FAOSTAT, 2005). Most cassava produced is consumed fresh as *fufu* but there are many small-scale and a few medium to large-scale enterprises in Ghana processing cassava into diverse foods and starch for industrial uses. Varieties have been released officially in Ghana since the 1930s; varieties developed by the Nigeria-based International Institute of Tropical Agriculture (IITA) were also released in Ghana in 1993 (Ministry of Food and Agriculture Ghana, 2000). These varieties had been selected largely on the basis of their high storage root yield and their resistance to pests and diseases, particularly cassava mosaic disease (CMD). Despite this, cassava landraces remain predominant in Ghana (Nweke et al., 1999; Aduening et al., 2005). PPB has focused mostly on crops which farmers usually propagate by seed such as rice and beans. Tropical root crops such as cassava and sweet potato are, by contrast, usually propagated vegetatively and African farmers use their seedlings (de Waal et al., 1997) only rarely (Gibson et al., 2000; Manu-Aduening et al., 2005), preferring the more certain option of vegetative propagation from known cultivars. In root crops breeding programmes, farmers are usually involved as a final sift and verification of clones and, even in programmes in which farmer involvement has been promoted, they have been involved only after the seedling stage (Thiele et al., 1997; Goncalez Fukuda & Saad, 2000). Here, we report for the first time a cassava breeding programme in which farmers and scientists worked together from the seedling stage; our study also led to the involvement of private enterprise processors. We also describe activities and outcomes of various learning processes and new roles of various actors.

Materials and methods

The study involved surveys of cassava farmers belonging to two communities in the major cassava growing zones in Ghana and of the current and potential markets for cassava, and the evaluation of a selection process at seedling and clonal stages. The communities of Nkaakom and Aworowa were selected to represent the Forest and the Forest-Savannah Transition Zones respectively because cassava is an important crop in both zones and both communities and some links with research and extension had already been established. The two communities also offered some differences in population and geographical size and in production systems (Manu-Aduening et al., 2005), landraces grown, uses and contributions to livelihoods of cassava in the communities. Scientists from CRI and NRI included sociologists, an agronomist, plant pathologists and a plant breeder. The study has spanned >5yrs (Manu-Aduening, 2005) and necessarily was evolutionary, with new activities emerging in response to findings.

Situation analysis

Detailed information on the communities was obtained using participatory rural appraisal (PRA) methods as a needs assessment exercise and to engage with each community. Groups of women and men farmers and village elders provided information on the historical and current production and uses of cassava in each community, the general farming system and important institutions/agencies within each village. Discussions were stimulated using checklists of pre-selected topics and developing historical charts, cropping calendars and drawings linking community structures and facilities.

Participation of farmers

The scientists described to farmers in each village what was involved in cassava breeding and the potential benefits new cultivars could bring to the communities. An invitation was given to all cassava farmers in both communities to collaborate as a group with us. A maize/cassava farmers' association identified at

Nkaakom during the situation analysis provided a focus there but no similar group was identified at Aworowa. In both communities, group membership exceeded forty. Most members were men (60–70%); in Nkaakom, most members were under 30 yrs old whereas at Aworowa, most were 30–50 yrs old.

Seedling trials

Seeds from 16 half-sib families were provided by Dr A Dixon, cassava breeder at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, from his crossing blocks. An underlying aim was to obtain seedlings with a greater genetic diversity than farmers currently had access to, but the families were also chosen on the basis of mother plants having one or more of the following specific attributes:

- CMD resistance.
- High storage root yield.
- Ghanaian or West African origin.

The seedling trials (Figure 1) were done in communal fields which farmers prepared. For the seedling trials, 16 plots measuring 4×10 m were each hand-sown at 1×1 m spacing in June 2000 with seeds of a single family, giving a target population for each family of 40 plants.

Farmer evaluations

Farmer evaluations of the trials were conducted 6, 9 and 12 mth [at harvest] after planting. Each farmer was given an assessment form prepared by the scientists on which farmers recorded 10 plants which they would like to grow in their farms and explained why. The farmers' evaluations at harvest included the roots as well as the foliage: this evaluation determined which accessions were retained for a future trial. Although data from seedling evaluations at 6 mths and 9 mths were not actually used, with hindsight they had an important training role for the evaluation at harvest.

Scientists' evaluation

Two groups of scientists evaluated: (1) the cassava breeder at CRI and (2) two plant pathologists at CRI. The evaluations were done at *ca* 3, 6, 9 and 12 months after planting for each cycle of participatory breeding, though always on different days to the farmers, so avoiding either influencing the other. Farmers evaluated in several small groups to limit

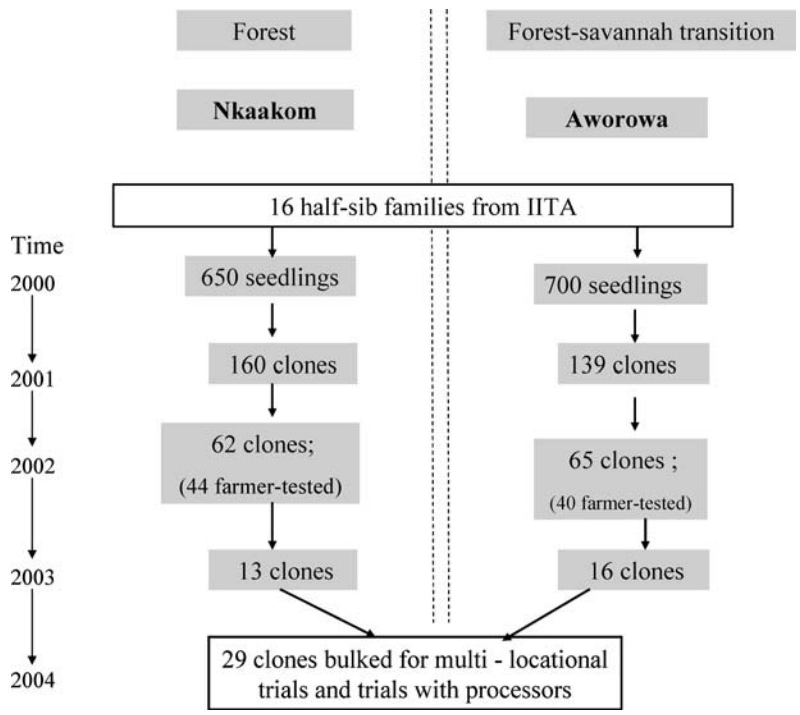

Figure 1. Progression of seedlings and clones tested and selected by farmers and scientists over four years in the two communities.

domination by a few opinion-leaders. The scientists evaluated the accessions as he/they would during FPB at CRI: the pathologists selected accessions for retention using data on disease incidence and severity from evaluations throughout the growing season; the breeder selected solely on the evaluation at harvest.

Selection
After harvest, any accession that was selected by farmers, the breeder or the pathologists was retained for planting in the next trial. This system gives equal weight to the opinion of each set of actors, does not provide opportunities for one group to dominate another and provides a safety net, retaining the maximum number of accessions. It differs from the consensual FPB system used at CRI, in which only accessions agreed by both pathologists and the plant breeder are retained.

Clonal trials

In August 2001, 12 stem cuttings of each selected seedling were planted in separate plots measuring 3×4 m at a communal site in the village where they were selected. In addition to the selected accessions, plots of 12 cuttings of two released varieties (Afisiafi [IITA Tropical Manihot species (TMS) 30572] and Abasafitaa [TMS 4(2)1425]), five landraces (coded DA 002, NK 009, NK 015, WCH 009, & WCH 037) selected by Prof S. Kantanka [Kwame Nkrumah University of Science and Technology, Kumasi, Ghana] from amongst germplasm from the Brong Ahafo Region (Forest-Savannah Transition Zone) of Ghana for evaluation for official release to farmers and three landraces selected by farmers in each village were included as checks. Each plot was clearly labeled. Formal evaluations of the genotypes by farmers were restricted to the harvest day. Roots of accessions selected by farmers or scientists were cooked in individual labelled polyethylene bags for farmers and the breeder to evaluate for palatability and poundability [Poundability refers to the ability of freshly cooked cassava to be pounded in a large pestle and mortar into the traditional food, *fufu*. Poundability was assessed by kneading the cooked cassava by hand]. After harvest at 12 mths, further cuttings of selected clones were made from each clone, selections of the farmers, plant pathologists and the breeder were combined and a further communal trial was planted as before in August 2002. Farmers also selected accessions s/he would like to plant in his/her own farm. Based on this, each farmer was given six cuttings of her/his top five clones. Each farmer taking cuttings back to his own farm was expected to plant these accessions together with one released variety and one local landrace of his choice. The scientists then visited each farmer individually during the growing season to evaluate crop vigour and health status and at harvest. Accessions selected from clonal generation 2 in each community were combined and planted together for a third clonal generation in both of the communities and also in multilocational trial sites in the Forest and Forest Savannah Transition zones (Figure 1).

Surveys of end-users and current and potential markets

During the situation analysis in Nkaakom and Aworowa, farmers emphasised the inadequacy of their current markets for cassava and listed marketability as a major reason for growing a cultivar. During evaluations of accessions, market requirements such as poundability into *fufu*, large well-shaped roots and attractive skin colour were frequently mentioned. A meeting in October 2002 of a broad range of stakeholders (farmers, pre and post-harvest scientists, central and local officers of the Ghanaian Ministry of Food and Agriculture, NGOs) in cassava also emphasised the importance of marketing to non-farmers both for immediate consumption and processing. Two surveys were therefore conducted by the plant breeder and a social scientist. One surveyed current non-farmer users of cassava (Table 5) using a checklist to guide the conversation. The other surveyed potential future markets for cassava in Ghana and was done through consultations with post-harvest researchers at universities, at the Food Research Institute in Ghana and at NRI in UK and from scientific and other reports. Requirements for cultivars and linkages between post-harvest researchers, processors and consumers and those involved in cultivar development were also assessed.

Requirements for variety release

Documents of previous cassava releases in Ghana as well as for other crops such as maize and beans were reviewed to ascertain to what extent our participatory approach to cassava breeding met criteria for release.

Results

Situation analysis

Land/household was generally small, averaging about 0.5 ha in Nkaakom and 1.2 ha in Aworowa, soil fertility was perceived to be declining and access to land had become limited. Cassava was the main food crop and also the main cash crop, the roots being sold fresh into local markets and, in Aworowa, to *gari* (a traditional cooked dried food) processors located in the community or nearby. It was increasing in importance, its high yield even in less fertile soils providing farmers with a means of maintaining food production. Landraces dominated; modern varieties were scarcely mentioned. Attributes needed for cassava cultivars included:

- early vigour to smoother weeds
- early maturing cultivars
- plants that suit intercropping particularly with maize
- high root yields
- good cooking qualities, especially being able to be pounded into *fufu*
- marketability

The main constraints to cassava farming reported by farmers included: labour shortages at peak periods and the hard work involved in land cultivations, access to land, lack of credit, weeds and poor markets. These findings resemble those reported in the COSCA study (Nweke et al., 1999).

Farmers' criteria

Most of the above attributes mentioned during the situation analysis were also mentioned frequently by farmers during their selection of accessions at harvest (Table 1). These same attributes were also mentioned by farmers evaluating the accessions grown in their individual fields (Manu-Aduening, 2005). Thus, a high yield of marketable-sized roots that could be pounded into *fufu* were generally amongst the top cited attributes. Farmers were also concerned about the foliage, frequently mentioning a thick stem (associated by them with a large root yield) and good canopy of healthy leaves, to suppress weeds as well as to generate a high root yield. Generally, farmers retained 'good' accessions for positive reasons rather than rejected 'bad' plants (*cf.* scientists' evaluations). Another interesting aspect was that farmers judged poundability from the

Table 1. Common selection criteria and their rank amongst the top ten according to frequency of mention by farmers during evaluations at different harvests

	Rank					
	Seedling generation		Clonal generation 1		Clonal generation 2	
Criteria	Nkaakom	Aworowa	Nkaakom	Aworowa	Nkaakom	Aworowa
High root yield	1	1	1	1	1	1
Poundability	4	5	2	3	2	3
Large [marketable] roots	8	4	5	4	3	4
Many branches	3	3	3	2	5	2
Thick stem	2	2	4	6	6	6
Suitable for intercropping	6	8	5	10	9	9
Weed suppression	5	7	8	5	10	5
Early maturity	10	–	9	–	–	10
Non-rotten roots	–	10	–	–	–	–
Healthy leaves	7	6	7	8	4	7
Disease free	–	–	6	9	7	8
Root skin colour	–	–	–	7	–	–
Average neck length	9	9	–	–	–	–
Resistance to lodging	–	–	10	–	–	–

– = Not ranked in top ten.

Table 2. Summary of scientists' selection criteria for evaluating cassava accessions

Reasons for rejection	
Breeder	Pathologists
Low yield	High incidence and severity of cassava mosaic, cassava bacterial blight, cassava anthracnose, brown leaf streak and cassava green mite and cassava mealybug
Poor root conformation	
No or short root neck	
Root skin colour	
High diseases and pests incidence	
Rotten roots	
Inadequate canopy	

outward appearance of the fresh tubers, one factor mentioned being a particular skin texture.

Scientists' criteria

The breeder selected against plants with low yield, his understanding of what farmers and consumers would reject including low starch/dry matter content. The pathologists selected exclusively against plants with disease, particularly on the foliage and particularly CMD and cassava bacterial blight (CBB) (Table 2). Both breeder and pathologists generally selected by a process of rejecting unsuitable plants. The criteria the scientists used were either based on predetermined scales (e.g., disease scores) or were measured (e.g., weighing yield: *cf.* the farmers who estimated which plants had good yields). Otherwise, several of the breeder's criteria were similar to farmers' (e.g., yield and canopy characteristics). Conversations with the breeder and the pathologists revealed they often included national interests in their process of rejection. Growing cultivars with a high yield of cassava is important in supplying cheap food to the nation, cultivars with low starch content would be unsuitable for the expanding processing and industrial enterprises and susceptibility to disease could lead to national disruptions to food supply.

Outcome of selections

Generally, both the farmers and the breeder selected a large proportion of the accessions with large storage root yields and with large canopies (Table 3). By contrast, the pathologists selected the greatest proportion of plants bearing no symptoms of CMD (and other diseases – data not shown), the main disease affecting plants in the trials. These results are consistent with the different priorities given to these attributes by the different selectors. There was a trend for the farmers' selection to be slightly better for pounding than the scientists', supporting the farmers' claim to be able to determine this from uncooked tubers. Although

Table 3. Proportions of farmers, breeder's and pathologists' selections which, for some key attributes, were either greater than the mean values of all the selected clones or (for CMD) were symptomless

Attributes		Clonal generation 1 % of accessions selected by:			Clonal generation 2 % of accessions selected by:		
		Farmers	Breeder	Pathologists	Farmers	Breeder	Pathologists
Yield*	Nkaakom	71	61	32	86	80	63
	Aworowa	64	62	33	56	53	45
CMD	Nkaakom	24	8	52	45	25	60
	Aworowa	48	44	60	50	47	55
Canopy area**	Nkaakom	48	53	35	50	62	60
	Aworowa	56	51	53	56	51	67
Poundable root	Nkaakom	49	47	26	71	63	60
	Aworowa	56	53	47	50	47	55

*Mean yields (kg/2 plants): clonal 1 = 5.4 (Nkaakom), 5.7 (Aworowa); clonal 2 = 3.6 (Nkaakom), 7.8 (Aworowa).
** Canopy area: clonal 1 = 0.66 m^2 (Nkaakom), 0.75 m^2 (Aworowa); clonal 2 = 1.16 m^2 (Nkaakom), 1.09 m^2 (Aworowa).

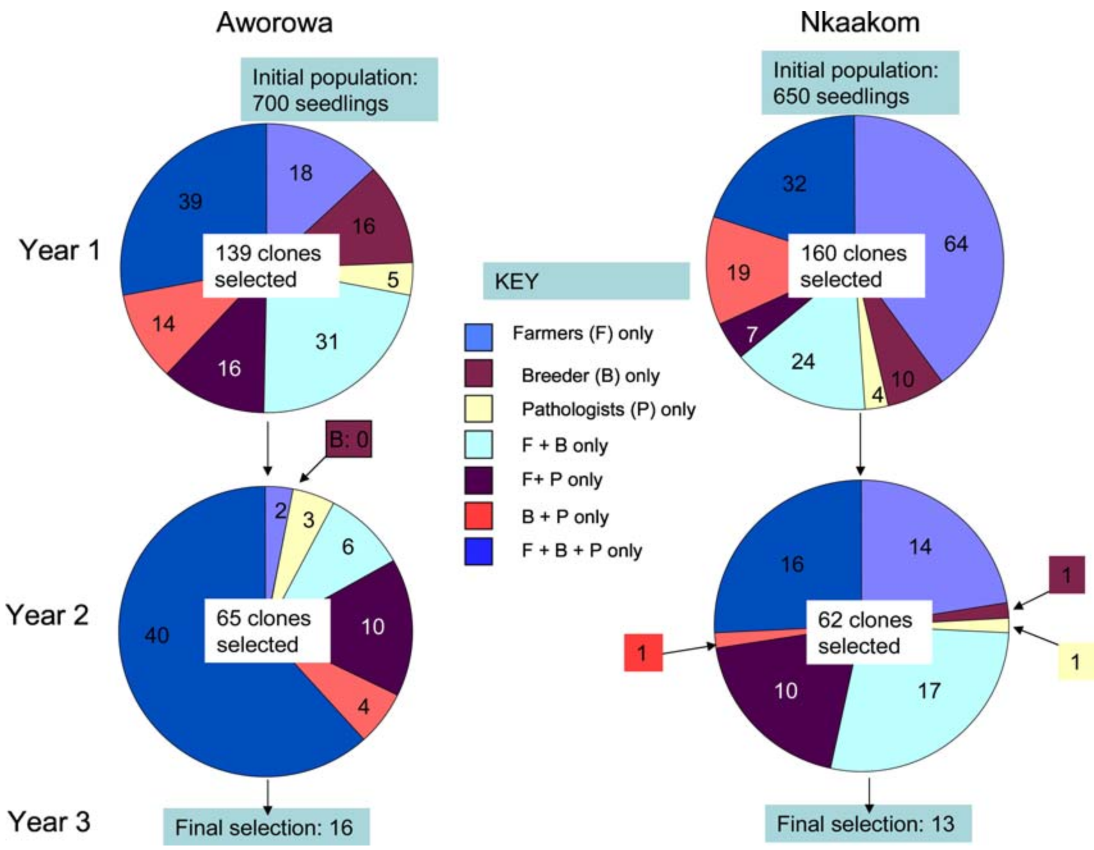

Figure 2. Summary of selection of accessions by farmers, breeder and pathologists over 3 years.

none of the accessions has yet been widely adopted by farmers, the breeder in our team is convinced that several offer major advantages over currently released varieties and all accessions have therefore been taken into multi-locational trials as a final step before submission to the Ghanaian Variety Release Committee (VRC).

Uniqueness of selections

Unique selections by farmers, the breeder or pathologists totaled around a quarter to nearly a half of selection in the seedling and clonal 1 generations, with the farmers generally making the largest number of unique selections (Figure 2). Selections involving farmers plus breeder were generally more than selections involving either farmers plus pathologists or breeder plus pathologists. Selections involving all three groups of actors were generally the most common. Since the main criterion used by the pathologists (disease on foliage) was not amongst the main ones cited by the farmers and breeder (high yield etc), this may be because healthy foliage required by the pathologists enables plants to achieve the criteria required by the farmers and breeder. Amongst the genotypes selected by farmers at Nkaakom and Aworowa were two of the five landraces from Brong Ahafo selected for potential release and included as checks. None of the modern varieties included as checks was selected by either farmers or scientists.

Consistency of selection

Figure 3a and b illustrate the ability of each of the different actors to reselect accessions they had selected previously. An increase in the proportion in the reselected sector implies a bias towards reselecting previous selections, the proportions in each sector remaining the same implies no bias towards repeating the same choice and a decrease in the proportion in the reselected sector implies a change in selection criteria or a change in the plants. In particular, susceptibility to CMD was not fully exhibited in the seedling generation, seedlings which appeared healthy and vigorous succumbing in clonal generation 1 and, to a lesser extent, in clonal generation 2.

Farmers were the most ‘successful’ in re-selecting in clonal generation 1 the accessions they had selected as seedlings. Both breeder and pathologists increased their proportion of reselection in clonal generation 2, although the actual numbers involved were now few. Farmers were also quite consistent in the reselection of the final 29 clones selected at the end of the third cycle (Table 4). By contrast, the pathologists had previously rejected all or most of the accessions they finally selected in clonal generation 2 and the breeder had previously rejected about half.

Surveys of current and potential markets

Table 5 lists the current end-users consulted and important current uses to which cassava is put. Most uses involve processing it in different ways into human food to achieve different tastes, convenience, prolonged storage or other benefits. The survey investigating potential uses for cassava identified opportunities for its increased use as sweeteners in human foods, fillers for various industrial purposes and different preserved livestock feeds (Table 6). Most of these uses require cassava cultivars with a high yield of starch, preferably from roots with a relatively low water content to facilitate transport and drying. Year-round availability is also important for industries. These requirements are all consistent with current breeder and farmer selections. Some of the current and potential uses (Table 6) have defined physicochemical properties (Table 7) but

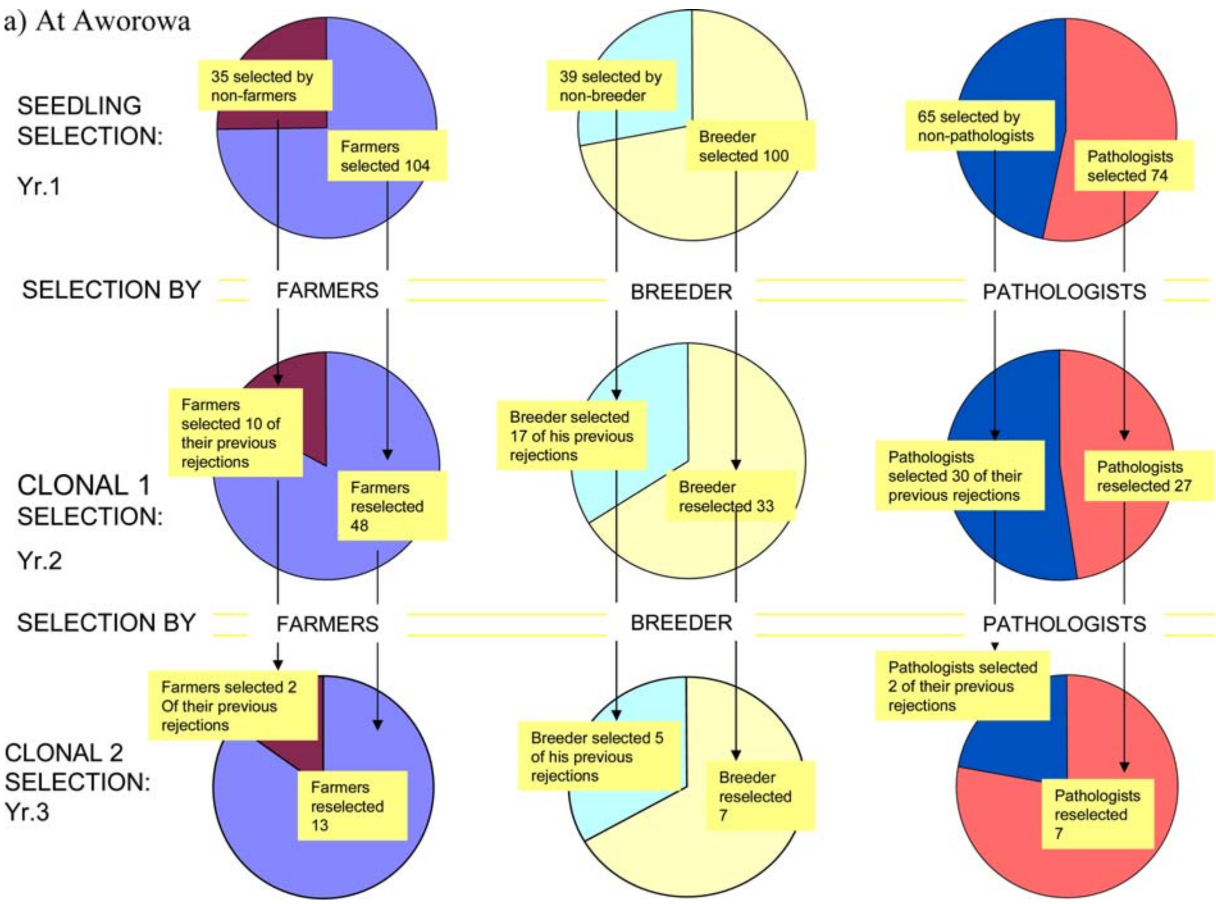

Figure 3. Summary of selection profile of farmers and scientists over three years a) At Aworowa.

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b) At Nkaakom

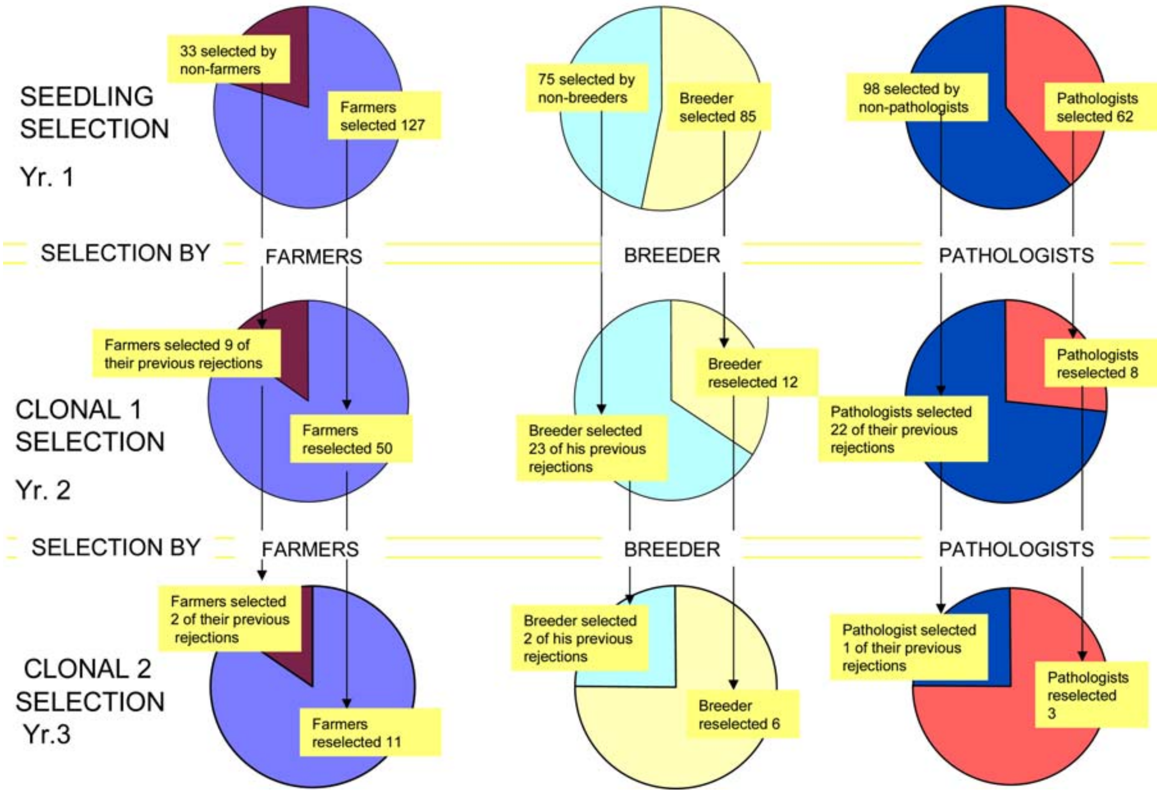

Figure 3. (*Continued*)

no research into how the physicochemical properties of starch affect the suitability of different cassava cultivars for each use was identified.

An achievement of the surveys is that two processors in the Coastal Zone are now hosting trials of twelve of the accessions (Figure 1). These accessions were identified from amongst the remaining 29 based on poundability and palatability scores for the cooked roots, high dry matter yields and tolerance to CMD in both the communal and individual on-farm trials. These trials appear to represent the first variety trials with cassava processors in Ghana and perhaps in Africa. A further achievement is that these surveys directly involved the breeder so that he received firsthand the requirements for cassava of the different markets in Ghana.

Requirements for variety release

Only cultivars released through the Variety Release Committee (VCR) can be distributed using official funds in Ghana. Since this would greatly facilitate scaling out of accessions identified through our participatory breeding programme, a review of previous documentation was done. This indicated that variety release requirements include:

1. A description of the breeding procedure used, origin etc.
2. Phenotypic characterization of the accessions, including resistance to common pests and diseases.
3. Performance of the accessions in on-station as well as on-farm trials across the agro-ecological zone(s) targeted for release
4. An inspection plot (generally on-station) where the potential variety could be inspected and where sufficient planting material was available to demonstrate that release was feasible in practice.
5. A description of post-harvest attributes

Requirements 1 and 2 are already documented in this manuscript. Additional trials of the selected 29

Table 4. The consistency of selection of final 16 and 13 accessions at Aworowa and Nkaakom respectively by farmers, the breeder and the plant pathologists

Aworowa	No. of accessions selected at clonal generation 2 by each group of actors	No. of those accessions previously rejected by different actors at:	
Actors		Clonal 1	Seedling
Farmers	15	2	4
Breeder	14	7	7
Plant pathologists	9	2	6
Combined selection	16	–	–
Nkaakom			
Farmers	13	2	5
Breeder	8	2	3
Plant pathologists	4	1	4
Combined selection	13	–	–

Table 5. Stakeholders consulted grouped according to type of enterprise and cassava products in which they have an interest

Type of enterprise	No. consulted	Traditional foods	Flour	Starch	Grits
Small family-run enterprise	2	√			
Group/Co-operative	3	√	√		
Small-scale enterprise	3	√	√	√	
Medium-scale private company	3	√	√		√
Large-scale private company	1			√	

Table 6. Current and potential uses for cassava in Ghana

Uses	Potential product	Current product
Human food	Sweetener e.g., in canned foods, drinks, and confectioneries	*Fufu, Agbelima, gari*, bakery products
	Fermentation including for monosodium glutamate	
Industrial usage	Filler in adhesives, paper, textiles and pharmaceuticals	Adhesives, syrups, alcohol
Livestock food	Industrial waste (pulp) as livestock feed	Raw peel, leaves and roots
	Chipped and/or pelleted roots as bulk dried feed	
	Whole plant silage as a stored feed	

Table 7. Different cassava food forms and the required attributes of cassava cultivars

Food form	Required attributes of cassava roots/starch
Cooked starch food	High starch content
Thickener (e.g. soup, baby food)	Good paste forming properties
Binder (e.g. sausage)	Good solid binding properties
Stabilizer (e.g. ice cream)	High water binding capacity
Bakery products	Good taste, light texture and golden brown colour when baked

clones have been planted with more communities and on-station across the Forest and the Forest Savannah Transition zones in order to satisfy requirements 3 and 4: these will also be used to select further amongst accessions. Requirement 5 requires on-station laboratory work that is part of the normal practice of CRI for its conventional breeding programme; the scientist component of our collaboration can easily provide this. Our inclusion of different end-user requirements and field trials on processors' farms should also be valuable in meeting this. Table 8 checks for key attributes mentioned by farmers and other end-users in release documents for three sets of cassava varieties submitted to

Table 8. Attributes preferred by end-users [combined farmer or non-farmer] and whether they are reported in release documents from three organisations

	Organisation, year of submission to VRC and reference numbers for accessions		
Attributes preferred by end-users	SARI* in 2002 -91/02324 -91/02327 -92/0067 First expression	KNUST** in 2003 -NK2009 -NK2015 -DMA002 -WCH03	CRI in 2004 97/4962 97/3982 97/4414 97/4489
High yield	√	√	√
High starch content	X	√	√
High dry matter/ low water content	√	X	√
Big storage root	X	√	√
Early maturity	√	Yield only at 12 months	Yield only at 13 months
Suitability for inter-cropping	X	X	X
Weed suppression	X	X	X
Swelling up during processing	√	X	Laboratory analysis on starch
Low fibre content	Qualitatively	X	Quantitatively
Colour of tuber flesh (*gari*)	Fresh+boiled root	Fresh root flesh+outer cortex	Outer cortex+processed products
Thin skin	X	X	X
Taste	Boiled & processed	Cooking qualities	Processed
Price (Cheap)	X	X	X
Easy to pound	Not the focus	√	Not the focus
Lumpiness (*fufu*)	X	X	X
Not too elastic (*fufu*)	X	X	X
Good for *gari*	√	√	√
Good for *fufu*	Not the focus	√	Not the focus
Easy to peel	X	X	√
Fluffiness (*ampesi*)	Texture of boiled root	Good for *ampesi*	X
Regular tuber shape	√	√	√
Rodent/Pest tolerant	Mentioned, but no data	√	√
Not spongy	X	X	X
Long post-harvest life	√	√	√

*Savannah Agricultural Research Institute;
**Kwame Nkrumah University of Science and Technology.
√ = reported; X = not reported.

the VCR. Most attributes were mentioned though not always in all documents and sometimes associated with a particular use envisaged or zone targeted. Attributes not mentioned – such as the thickness of the skin, ease of peeling, and suitability for preparation of local foods such as *fufu* and *gari* – generally involved end-use(r)s.

Discussion

Our study provides the first report of PPB for a vegetatively propagated crop in which farmers were involved from the seedling stage. This report is intended to provide useful information for others working in developing countries so as to assist them to develop similar devolved breeding activities for other vegetatively propagated crops such as yams and round potato. In this Discussion, we analyse the benefits gained by PPB, consider aspects we identify as particularly important in the process we adopted and changes required in the roles of different actors. Figure 4 represents schematically how our activities progressed; Table 9 'cross-cuts' this scheme, identifying key lessons learnt during these activities and changes that should be made.

Identification of the need for '*Improved adoption of better cassava varieties*' and the '*Variety needs*

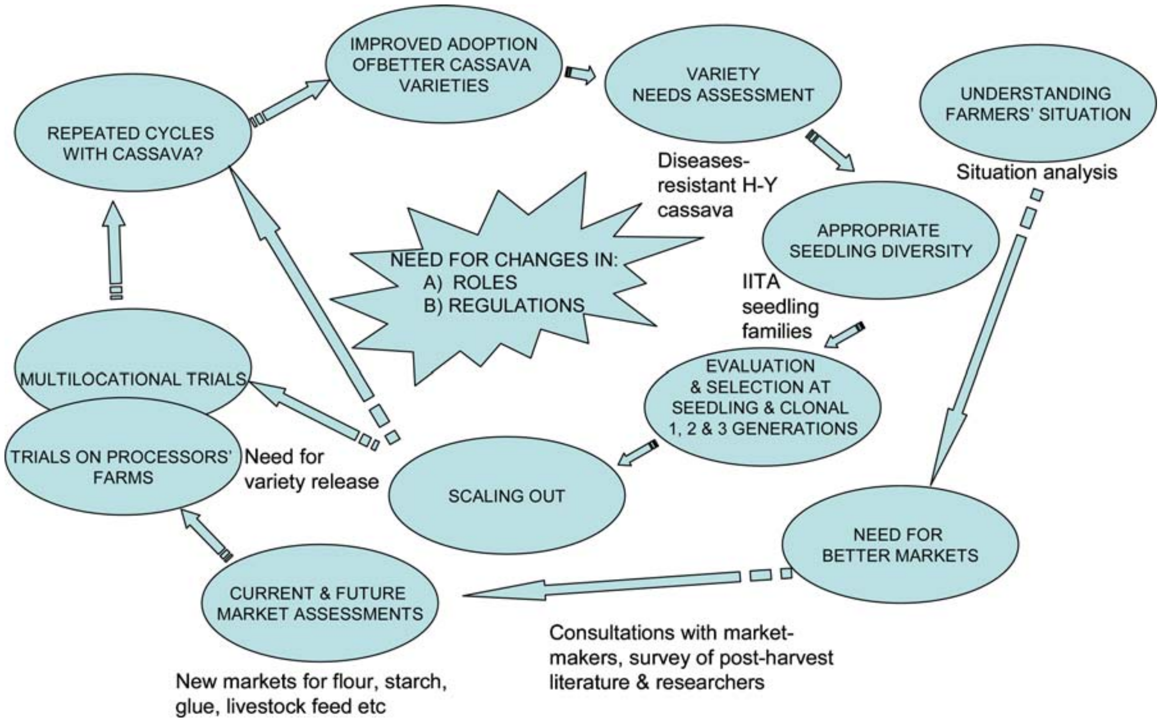

Figure 4. An overview of the processes and outcome of participatory breeding programme involving different stakeholders.

assessment' was largely a UK-based study of the literature leading to a funded project [An initial 3yr phase followed by an extension]; partnerships with Ghanaian scientists were built during this period. '*Understanding the farmers' situation*' used PRA techniques and included both the local cropping system and the broad role of cassava in the communities. A stakeholder workshop held in Ghana identified that cassava farmers had a '*Need for better markets*' and led to surveys of current and future end-use(r)s. Involving the plant breeder in these and the subsequent involvement of processors in variety trials constitute important shifts in roles. That several attributes required by end-users (Table 1, 6 and 7) were not mentioned in variety release documents (Table 8) suggests a need for greater influence/representation of end-users in the VRC. An '*Appropriate seedling diversity*' was addressed by involving a CGIAR centre (IITA in Nigeria) (Morris & Bellon, 2004). The seedlings were phenotypically more diverse than the landraces grown by the farmers and included a very high yield and CMD-resistance; they may even have been too diverse and a greater use of local progenitors might have provided farmers with seedlings addressing their needs more precisely leading to fewer seedlings being rejected.

No major problems were experienced in maintaining the experiments on-farm in the villages. A few scientists visiting the farmers' villages some 3–4 times each crop generation was easy and cheap, probably more so than bringing many farmers once or twice on-station, now a common final step in FPB in Africa. Genotype x environment interactions affect several aspects of cassava yield in Ghana (Sagoe et al., 1998) and perhaps also other key attributes, making selection on-station less inappropriate (Ceccarelli et al., 2003; Witcombe et al., 2003) by generating cassava varieties which have mostly been poorly adopted by farmers (Nweke et al., 1999). '*Evaluation and selection at seedling and clonal generations*' by both farmers and scientists enabled the scientists to know better the attributes required by farmers (Table 1) and their perceptions (for example, that farmers associate stem thickness with high yield). Several of the farmers' selection criteria such as weed suppression and suitability for inter-cropping were not mention in release documents examined (Table 8) suggesting they have received little previous attention from cassava breeders in Ghana. The strategy that a genotype was retained as long as it was selected by at least one of the groups of selectors ensured the opinion of each carried an equal

Table 9. Lessons learnt and implications for changes at different stages of cultivar development

Topic	Lessons from present study	Implications/changes needed
Needs of farmers+other stakeholders	•Need for initial and follow-up surveys •Stakeholder meetings need to be broad •Non-farmer stakeholders must be included	•There is a need periodically to re-examine priorities through stakeholder meetings, surveys etc •Joint activities need to be planned
Diversity	•Scientists can easily access diverse materials	•Accessing diversity should remain as a major role of scientists
Implications of cassava phenotype for PPB	•The sheer bulk of a cassava plant, its slowness to mature and few cuttings generated was a major limiting factor to replication and maintaining farmer interest	•Inclusion of rapid multiplication techniques in breeding process •Cassava breeding could be twinned with other, more immediately satisfying activities for farmers
Sources of individual accessions	•Scientists identifying appropriate seedling diversity need personal knowledge of parental types •Crosses should be controlled so that fewer seedlings matched closely to needs are used	•Production of seed including crossing blocks needs to be done by local plant breeder
Selection	•Farmers were consistent in their selections even amongst large numbers of seedlings •Each player made some unique selections •Considerable overlap in selection critieria between players, especially between farmers and breeder •Even with a team of scientists trying to incorporate farmer criteria into a selection procedure, key post-harvest attributes were systematically excluded	•Farmers could select effectively throughout the breeding cycle. •Selection of cassava accessions can benefit from an increased role for farmers. •Post-harvest attributes should have been included from the beginning
Monitoring and evaluation	•Early M & E so that findings could feedback into the process •Both actual needs and perceptions of needs may change during the breeding programme	•M & E should be a continuing process so that a breeding programme can adapt quickly to changing needs •A system is needed to ensure that lessons learnt from evaluations, e.g., importance of post-harvest attributes to farmers, are not ignored
Roles and responsibilities	•Participatory breeding requires decentralisation at all levels	•Decentralisation of activities requires a decentralisation of resources
Cost effectiveness	•Possible earlier adoption of cultivars due to early and increased farmer involvement. •Involvement of farmers actually added little to costs and provided economies in some aspects	•A more decentralised and participatory breeding programme may be expected to increase cost-effectiveness
Scaling out	•Variety release can facilitate scaling out the product (distribute new varieties). •Transferring the process to other breeders of other crops has been achieved •Transferring the process to other cassava farmer groups in other areas of Ghana has so far not been achieved because of lack of resources	•Requirements for variety release can and should be included within participatory breeding programmes. •PPB needs to be adopted by other actors, e.g., the Ghanaian Ministry of Agriculture if the process is to be scaled out within a crop
Policy and regulations	•Official varietal release can be compatible with participatory breeding	•Changes are needed to give farmers and other end-users a greater official voice
Organisation, incentives and equity	•Participatory breeding involved decentralisation of activities along the IARC's, national agricultural research systems [NARS] to farmers chain •Farmers need some form of recompense for their time and resources •Members of the VRC are experts in the breeding process	•Decentralising roles and responsibilities require rewards, incentives and capacity building to be decentralised too. •VRC membership should encompass all stakeholders, particularly those who will use the released varieties

weight [and also provided quantitative information for analysis of their different choices]. By contrast, seeking a consensus would have provided opportunity for one group to dominate. The farmers usually selected positively for plants with good attributes whilst both the breeder and pathologists operated mainly by rejecting poor plants. These differences in approach are consistent with the inclusion of farmers adding to the selection process (Baidu-Forson, 1997). Farmers were relatively consistent in their selection (Figures 3 and 4), re-selecting more than half of their selection in year 2 from their own previous selections and nearly two thirds of the final 29 selected genotypes (Table 4). This consistency was also reported by Sperling et al. (1993) and Kitch et al. (1998); the farmers may have been assisted by being used to observing crops growing in non-uniform fields. The farmers were also making informed choices: the outcomes of their selections (Table 3) fitted their claimed criteria (Table 1), confirming the effectiveness (Ceccarelli et al., 2003) and counteracting doubts (Thiele et al., 1997) of farmers' ability to select amongst large populations of diverse seedlings.

Consultations with end-users identified attributes needed by cassava for '*Current and future markets*'. These consultations were done with the cassava breeder and led directly to '*Trials on processors farms*' for the first time for cassava in Ghana. Gaining '*Scaling out*' for selected accessions through official release enabling public funding of distribution apparently requires only small modifications of our breeding approach to address the needs of the Ghanaian VRC. '*Scaling out*' the process to another crop [sweet potato] in other countries [Uganda and Tanzania] has occurred through another project. Our PPB process has not yet been scaled out to involve more cassava-growing communities and probably needs involvement of an actor with long term funding, perhaps national ministries of agriculture. There has been an increased farmer involvement in other breeding programmes in Ghana over the period of our project but the extent to which our activities influenced this is unclear.

An underlying feature of participatory breeding is decentralization (Maurya et al., 1988; Berg, 1997). The production of seeds being decentralised to Ghana is one example and selection being done on-farm rather than on-station is another. Concomitant requirements of decentralisation are increased influence and resources of the local actors (Table 9). The participatory breeding approach has increased the influence of farmers within the breeding process but their influence and that of other end-users of cultivars (consumers, processors etc) so far remains unchanged at higher levels, for example, the VRC. Decentralisation of resources has also not yet occurred; how best to recompense farmers for their resources and extra work was an unresolved discussion point within the project team. Downward transfer of influence and resources does not appear to have been resolved by other studies, perhaps an indication of the difficulties involved.

The normal means of vegetative propagation of cassava is slow and delayed progress; the opportunity for rapid multiplication techniques to be incorporated needs to be investigated. Even so, the rapidity of PPB (Witcombe et al., 2003) was confirmed by the selection of a few clones from a large number of accessions within just a few years (from 1,350 seedlings to 299 in year 1, to 127 in year 2 and finally to 29 in year 3). The FPB process in Ghana involves several cycles of selection on-station including preliminary yield, advanced yield and uniform yield trials before multilocational yield trials on-farm. This takes not less than 8 years and still has often not led to wide adoption of released varieties by farmers in Ghana (Nweke et al., 1999; Manu-Aduening et al., 2005) since farmers had still not had full opportunity to evaluate them. Reduction in duration has considerable cost implications. The returns tend to increase as the time to breed a cultivar that is adopted by farmers is reduced (Brennan & Morris, 2001); for example, completing a breeding cycle 2 years earlier accrued $18 million from rice in Thailand (Pandey & Rajatasereekul, 1999).

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