CROP PROTECTION PROGRAMME

Participatory breeding of superior, mosaic disease-resistant cassava: validation, promotion and dissemination

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FINAL TECHNICAL REPORT

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Executive Summary

The aim of the project is to improve Ghanaian farmers' access to a diversity of superior, disease-resistant cassava clones appropriate to the needs of farmers and other end-users, validating for the first time in Africa a participatory approach to breeding a major staple food crop which is propagated primarily vegetatively. A first phase of the project had developed a process whereby farmers and scientists collaboratively selected superior genotypes during a seedling and first clonal generation in communities in Ghana. An early activity of the current phase of the project was to harvest the trials of the second clonal generation. Analysis of data on phenotype and disease resistance of clones selected by farmers' and scientists' over all three generations indicated that the project approach to participatory breeding enabled farmers and scientists to work together beneficially. Results have been reported in working papers, in a PhD thesis and in a paper presented to an international root crops meeting in Kenya. A major benefit of the approach is that superior clones are selected quickly because validation by farmers, a cassava breeder and plant pathologists is achieved simultaneously rather than sequentially. It is appreciated that cassava clones selected by our participatory approach need to be released officially if they are to benefit from wide dissemination through official means. The project team has reviewed documentation required for release and has identified and planted the additional trials needed to achieve this. The current importance of cassava as a cash crop sold largely for processing into different traditional foods and the apparent potential for sales for processing into non-traditional foods, livestock feed and non-food uses made the project team aware that these end-users needed to be include in future breeding activities. Surveys have identified the main characteristics of current cassava end-users in Ghana, potential and expanding uses in non-traditional foods, livestock feed and non-food uses, and how cassava breeding in Ghana currently interacts with such end-users and with post-harvest researchers. Results have been collated and reported in working papers to provide early distribution in Ghana. Arrangements have been developed whereby farmer and scientist-selected clones are being trialled on farms owned by two medium-scale food processors and whereby flour derived from clones selected by the project has been characterised biochemically. A side-effect of this has been to improve links of conventional breeding in Ghana with end-users such that starch pasting characteristics have been included for the first time in a cassava variety release document in Ghana.

Background

Cassava (*Manihot esculenta* Crantz) is a significant part of the diet of many people in Africa. Ghana is the second largest (after Nigeria) producer in Africa (FAOSTAT), the crop contributing about 22% of Ghanaian agricultural gross domestic product (Otoo, 1998). About 80% of the population rely on it as their main starch staple, consuming on average 148 kg *per capita per annum* (PPME, 1991) to provide 18% of dietary energy, more than any other crop. The crop also occupies more farmland than any other crop in Ghana (Nweke *et al*., 1999). About half the production is consumed fresh in such local products as *fufu* (pounded into a thick past) and the remainder processed, for example, into *gari* or *kokonte*, dried products which may be stored for long periods and are also relatively easy to transport to distant markets. Cassava is the cheapest starch staple available and so it is particularly important for both the rural and the urban poor. Cassava is also important as a source of food security: Ghanaian villages growing cassava as the dominant food staple reported famine less frequently than villages where other crops predominated (Nweke *et al*., 1999). A situation analysis (under project R7565) of two communities in different parts of Ghana indicated that cassava growing had originally started in response to food shortages (CRI/NRI, 2002a). In response to population growth, limited access to land, declining soil fertility, famine/hunger and market demands, cassava production in Ghana is increasing, replacing yam, cocoyam, plantains, grains and other crops (Nweke *et al*., 1999). Cassava also provides a significant source of income both through sales of the storage roots and by employment in small processing (e.g., *gari*) units. Limited markets and the need to add value to cassava have been identified by needs assessments led by NRI and funded by the DFID Crop Post Harvest Programme (CPHP). In response, DFID CPHP have funded cassava research work in Ghana which has identified opportunities to market cassava starch locally as a substitute for imported flour, industrial starch (plywood glue, paper production) and animal feed. In all cases, poor farmers will benefit if more productive cassava varieties enable them to better supply these markets but they may also benefit directly, e.g., by raising livestock. An important economic activity in rural and urban areas is the processing of cassava to make *gari.* Grating the cassava is generally done using small grating machines and roasting is done on large metal sheets/containers over open fires. This process is done locally, often as a village-based enterprise. It is almost always carried out by, largely poor, women providing an important source of income, but depends on a relatively cheap supply of cassava. A President's Special Initiative has recently launched a cassava-based starch production industry targeting mainly export markets. The Government of Ghana's recognition of the importance of this crop is also indicated by the Roots and Tuber Improvement Programme (funded by IFAD and led by MOFA) which aims to enhance food security and increase the income of resource-poor farmers. One of the key elements to achieve this aim is through increasing the availability of improved cassava planting materials.

Major pests and diseases of cassava include cassava mosaic geminiviruses (CMGs), *Cassava brown streak virus* (CBSV), anthracnose (*Colletotrichum gleosporiodes*), cassava bacterial blight (CBB) (*Xanthomonas campestris*), cassava green mite (CGM) (*Mononychellus tanajoa*) and cassava mealybug (CMB) (*Phenacoccus manihoti*) and a diversity of weed species. CMGs are the main biotic constraint of cassava throughout Africa, diminishing production by an estimated 15% to 24% or 12 to 23 million tonnes *per annum* (Thresh *et al*., 1997) and cassava mosaic disease (CMD) is the most damaging, insect-borne disease of African food crops (Fauquet & Fargette, 1990; Geddes, 1990). CMGs are transmitted by the whitefly *Bemisia tabaci* (Gennadius)(Homoptera: Aleyrodidae) and are also perpetuated in stem cuttings taken from diseased plants. Although CMGs affect cassava crops throughout Africa, the disease has also been associated with epidemics flaring up every few decades to devastate crops nationally or regionally. Such an epidemic is currently devastating cassava production in East and Central Africa and threatening West Africa (Otim-Nape *et al*., 2000; Legg, 1999; Neuenschwander *et al*., 2002). There is little published information of traditional farmer knowledge of cassava pests and diseases. Our work (R7565) in two communities in Ghana (CRI/NRI, 2002a) suggests that farmers know much about the symptoms and causes of insect pest damage and of the symptoms of various diseases but little of causes of diseases including the cause of CMD, resembling farmers in many other developing countries (Bentley & Thiele, 1999). Farmers reported that cassava needs to be weeded during at least its first six months. Hoeing out weeds is particularly arduous in Ghana's hot and humid climate, to the extent that farmers mentioned it even affected their health. Farmers therefore gave high priority to cassava genotypes that branched to give a dense canopy once a maize intercrop had matured, both to reduce weeding and to ensure a good harvest.

Cassava's position as a cheap staple food for poor people has made the use of expensive inputs to address these constraints negligible throughout Africa except weeds against which herbicides and tractor-drawn implements seem increasingly to be used in Ghana, though starting from a relatively low base. Pesticides have never been used widely for controlling pests and diseases on cassava and this situation seems neither likely nor desirable to change. Self-maintaining introduced biological agents have been used primarily to control exotic pests and host plant resistance has been the main means of combating the diseases. Breeding for resistance to CMGs was begun during the Colonial period, particularly in Madagascar and at the Amani Research Station in what is now Tanzania, (Jennings, 1960). Resistance was identified within ceara rubber (*M. glaziovii*) (Nichols, 1947) and resistant clones with satisfactory yields were developed from the inter-specific crosses. Breeding work in Tanzania was terminated in the late 1950s, but a selection transferred to IITA became the basis for a series (Tropical *Manihot* species, coded TMS) of agronomically improved CMD-resistant cassava clones and seed from superior crosses released to national programmes in Africa (Hahn *et al.,* 1989). These have provided the main control strategy in Africa for several decades (Mahungu *et al*., 1994). More recently, resistance has been identified in some West African landraces, controlled by a dominant gene (Akano *et al*., 2002), leading to the TME (Tropical *M. esculenta*) series of clones.

Modern varieties (MVs) of cassava bred for superior attributes including disease resistance have had most impact in Africa in Nigeria, the base country of IITA (Nweke *et al.,* 1994) and, more recently, in Uganda following the CMG epidemic largely eliminating CMD-susceptible landraces (Gatsby Charitable Foundation 1997). In Ghana, however, when this project started in 2000, only four MVs of cassava have been released in the last few decades. Three are IITA clones (TMS 4(2)1425, TMS 30572 & TMS 50385) bred in Nigeria and the fourth is a result of mutation breeding: adoption by farmers has been relatively poor for all the varieties (Nweke *et al*., 1999). Since 2002 a number of new varieties have been released by SARI, KNUST and CRI, but it is too early to assess uptake by farmers. Landraces remain the main means of cassava production in Ghana as in much of Africa. Their origin has been poorly understood but work done under R7565 has shown that, whilst one or two farmers in a community may actively experiment with a few cassava seedlings, most farmers ignore seedlings as a source of new varieties. Most new landraces may result from unplanned use of seedling as planting material, for example, when there is a shortage of planting material or by chance when a seedling happens to grow close to where a cutting had been planted but died. Such new clones may then be maintained as new landraces if they possess desirable attributes.

Improving farmers' access to a diversity of cassava germplasm which is pest, weed and disease resistant and appropriate to the needs of farmers and other end-users addresses a significant biotic constraint, will increase productivity of varieties with desirable attributes and potentially lead to the development of new markets for cassava. National research in Ghana aims to produce high yielding, pest and disease resistant varieties that meet end-user requirements. Farmers are keen to adopt new varieties (Nweke *et al*., 1994) and are actively seeking varieties with a range of attributes which will meet their household consumption and marketing needs (CRI/NRI, 2002a). However, conventionally bred cultivars have had little success in Ghana or most other African counties, whereas landraces have been very successful and remain the main means of growing cassava (Nweke et al., 1999). In Ghana, the four varieties of cassava currently released were either conventionally bred at IITA in Nigeria (TMS 4(2)1425, TMS 30572 & TMS 50385) or result from mutation breeding: there has been low adoption of them by Ghanaian farmers (Nweke et al., 1999). Despite this, evidence from community-based trials and evaluations (CRI/NRI, 2003) suggests that the introduction of a wide range of germplasm is valuable to farmers in providing the range of attributes needed for appropriate new varieties and farmers are instead adopting (and in some cases discarding) landraces, usually introduced through members of their own community (CRI/NRI, 2002a). Farmers' choices of cassava varieties are determined by a range of pre and post harvest attributes, including a high yield of storage roots which are poundable when cooked to make *fufu* (a traditional main food in Ghana) and have a vigorous high canopy both to suppress weeds and achieve the high yield.

Table 1: Varieties, Year of release and their corresponding attributes

Variety	Who Released	Year released	Pre-release key attributes	Postharvest release constraints
Farmers varieties**	Not applicable	Before 1930	Not released therefore not applicable	Susceptibility to diseases and pests
C50 and C282	Dept. of Agric.	1930	Cooking qualities, average yield, tolerant to ACMVD	Susceptibility to ACMVD
Ankra	Dept. of Agric.	1935	Cooking qualities, average yield, tolerant to ACMVD	Susceptibility to ACMVD
GCH7	Dept. of Agric.	1940	Average yield, tolerant to ACMVD	Susceptibility to ACMVD
K Series	CRI	Before 1950	Not known	Not known
Afisiafi (TMS 30572) *Abasafitaa* (TMS 4(2)1425 *Gblemoduade* (TMS 50395)	CRI	1993	'Processing', High yield, tolerant to ACMVD, CBB, CAD	Susceptibility to ACMVD, CBB, CAD. Poor cooking qualities, low DM for 50395
Tekbankye	KNUST	1997	Cooking qualities, High yield, tolerant to ACMVD, CBB , CAD	Susceptibility to ACMD
Eskamaye *Filnidiakong* *Nyerikobga*	SARI	2002	Early maturity, average yield, tolerant to ACMVD, CBB, CAD, good for traditional food preparation for the consumers in the northern part of Ghana	Not yet known
Nkabom IFAD	KNUST	2003	Cooking qualities, High yield, tolerant to ACMVD, CBB , CAD	Not yet known

In more industrialized countries, agriculture has been dominated by on-station-bred MVs for much of the last century. However, low adoption of many MVs in developing countries has led to the development of a more participatory breeding approach in which farmers are active partners in breeding at an early stage in the selection process, so as to ensure that their requirements receive high priority. General reviews of this subject and specific examples include: Sperling *et al.,* 1993; Joshi & Witcombe, 1996; Sthapits *et al.,* 1996; Witcombe, 1996; Witcombe & Joshi, 1996; 1996; Tripp & Heide, 1996; Baidu-Forson, J. 1997; Berg T. 1997; Sperling & Scheidegger, 1997; Thakar, R. 1997; Witcombe *et al.*, 1996; Almekinders &

Louwaars, 1999; Ceccarelli & Grando, 2000. Participatory varietal selection (PVS) for cassava was spearheaded by CIAT in S. America. Key factors enabling the success of the project (Iglesias & Hernandez, 1996) were:-

- participatory evaluation of genotypes early in the breeding cycle allowed early multiplication of superior clones in a crop with both a long cropping cycle and a low propagation rate;
- farmers received training in the selection and improvement of planting material as a part of the procedure;
- a broadening of the genetic base of the crop;
- feedback of information to formal plant breeders;
- selection of numerous varieties (rather than the release of probably just two from CPB), each with specific adaptations to particular combinations of environment, cropping practices and market preferences.

IITA and a few national programmes (e.g., Uganda) have followed this lead in Africa and established cassava breeding programmes in which clones are selected by farmers on-station at an early stage in the breeding cycle for further testing on-farm by farmers. However, a participatory breeding approach in which cassava seedlings are grown by farmers within their own community as the first step of a collaborative breeding scheme involving researchers and farmers appears to remain unique to R7565.

Outputs of participatory breeding for cassava within R7565 The very early inclusion of farmers in cassava selection by R7565 is yielding dividends; Ghanaian scientists, including the Crops Research Institute cassava breeder, consider that this method may succeed in identifying clones superior to current varieties from seed within just 5 generations. During the first phase of the project farmers and scientists have:

- Developed a participatory breeding system in which farmers and researchers collaborate to assess large numbers of diverse cassava genotypes;
- Identified a range of acceptable pest, weed and/or disease-resistant cassava clones;
- Learnt about farmer perceptions and practices in relation to cassava propagation (including seedlings), selection (including mosaic resistance) and exchange;
- Learnt how to carry out PPB on cassava.

A CRI/NRI hosted workshop held in Elmina in October 2002 with a range of stakeholders including public sector research, public sector extension, farmers and CPP/ CPHP representation. Participants strongly supported a broad participatory plant breeding (PPB) approach for cassava but identified that weaknesses in PPB include that:

- Farmers could participate more effectively in the breeding process if they were more aware of cassava diseases to (CRI/NRI, 2002b).
- Although farmers identify a need for better markets (CRI/NRI, 2002a), they are poorly positioned to recognise new opportunities (DFID CPHP, undated).

Other requirements that were recognised in the development of the proposal for R8302 were:

- Scaling out the PPB approach by which farmers and researchers develop cassava varieties appropriate to local needs and conditions.
- Improving communication between end-users of cassava and those working on varietal development so that germplasm improvement enhanced cassava utilization, leading to sustained adoption
- Seeking appropriate compromises between an inclusive breeding approach and the current official variety release requirements so that national cassava distribution systems to be involved in widespread dissemination of germplasm improved through PPB.

An important economic activity in rural and urban areas is the processing of cassava, e.g., to make *gari.* This process is almost always carried out by women and provides an important source of income, but it is dependent on a relatively cheap supply of cassava, which the more productive cultivars selected by the project supply. By engaging in cassava breeding at the community level, the project aimed to ensure that the needs of village-based enterprises are addressed. Their suitability for other end-users will improve market opportunities which itself will contribute to the welfare of farmers, consumers and other stakeholders as well as to the long-term adoption of these clones.

R8302 built on the above and also more generally on previous work on participatory plant breeding funded by the Plant Science Research Programme, work on weeds and cassava mosaic disease in East Africa funded by the Crop Protection Programme and work on improving cassava utilisation by the Crop Post-Harvest Programme notably R8268.

Existing baseline information is included in the following COSCA and CRI/NRI working papers:

- Nweke et al. (1999) Cassava production in Ghana: A function of market demand and farmer access to improved production and processing technologies. COSCA Working Paper No. 21.
- A situation analysis in the two villages where the project is working with farmers (CRI/NRI, 2002a)
- Results of farmers and scientists evaluations of cassava germplasm over two years (CRI/NRI, 2003).
- A survey of 10 villages in all the major cassava-growing agro-ecologies of Ghana of farmers' knowledge, perceptions and practices with respect to cassava, with particular emphasis on varieties (CRI/NRI, 2003).

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Project Purpose

Overall aim: Improving farmers' access to a diversity of superior, disease-resistant cassava clones appropriate to the needs of farmers and other end-users*.

Summary: The project continued the validation process and promoted (through MOFA facilitated by other donors) a method by which farmers and researchers work together to develop cassava varieties appropriate to local needs and conditions, including resistance to pests, weeds and diseases, particularly cassava mosaic. In response to farmers' identifying limited markets as a problem, the project identified opportunities for improving communication between end-users and those working on varietal development so as to enable germplasm improvement to enhance cassava utilization. The project also examined how the participatory breeding approach can fit within official variety release requirements, the latter being required to achieve widespread dissemination of cultivars

***** *The term "end-user" is used in this report to identify the person or institution providing demand for the cassava product. Thus, the final consumer may be the farmer and his family eating it, it may be the gari producer and urban gari consumers, a chicken feed manufacturer and chicken farmer etc.*

Research Activities

Many of the project activities described in this FTR build directly on project activities in the previous project R7565. In this, a close collaboration between NRI and CRI scientists enabled participatory cassava breeding trials to be initiated in two communities in Ghana, Aworowa in the Forest Transition Zone, Brong Ahafo Region and in Nkaakom in the Forest Zone in Ashanti Region and also an on-station trial at Kwadaso, again in the Forest Zone in Ashanti Region. Seeds of different families were provided by IITA.

Table 2. The female parent of the 18 half-sib families used in the experiments planted at Nkaakom, Aworowa and on-station at Kwadaso.

Accession number	Source	Nkaakom	Aworowa	Kwadaso
TME 1	Nigerian landraces	+	+	+
TME 3		+	+	+
TME 4		+	+	+
TME 9		+	+	+
TME 47		+	+	+
TME 117		+	+	+
TME 279		+	-	+
TME 497		+	+	+
TME 246	Togolese Landraces	+	+	+
TME 396		-	+	+
TME 398		+	-	+
TME 411		-	+	+
TME 270	Ghanaian Landraces	+	+	+
TME 633		+	+	+
TME 644		+	-	+
TMS 30572	IITA-bred clones	+	+	+
TMS 4(2)1425		+	+	+
TMS 92/0326		+	+	+

Seedlings planted in these trials in 2000 had been monitored for one year and selected at harvest by a) farmers, b) the CRI cassava breeder and c) CRI plant pathologists. Cuttings from all selected plants had been replanted in a first clonal generation trial in 2001 at each location using 12 cuttings from each plant in single replicate plots, alongside plots of local and released varieties included as checks (Figure 1). Harvesting and associated data collection was completed in 2002 and a second clonal generation was planted at each site as before plus about a further 30 trials each of 5 clones + check clones at individual farms in both villages. Both the communal trials and the smaller 'baby' trials were monitored for pests (mainly mealybugs, whiteflies and cassava green mites) and diseases (mainly CMD and cassava bacterial blight (CBB)) quarterly during R7565 but their harvest, associated data collection and further selection remained as important activities for R8302 to complete so it is at this point that novel results are being reported in this present FTR.

Output 1.Inclusive systems for identifying disease-resistant cassava varieties meeting farmers' needs from seedlings or clones (including landraces) validated and promoted

Establish and monitor clones in new trials By the time contracts had been agreed for R8302, there was an urgent need to plant new field trials in Ghana, both because the current trials needed harvesting and because the new trials needed to established during the 2003 rains. Meetings were therefore held June – July 2003:

- amongst the CRI/NRI team in Ghana and in UK with NRI postharvest researchers involved with projects based in Ghana,
- with the head of the GTZ Sedentary Farming Systems project in Sunyani,
- with Ministry of Food and Agriculture (MoFA) officials based in Techiman, Attebubu and Sunyani, and
- with the World Vision team based in Kumasi and Attebubu

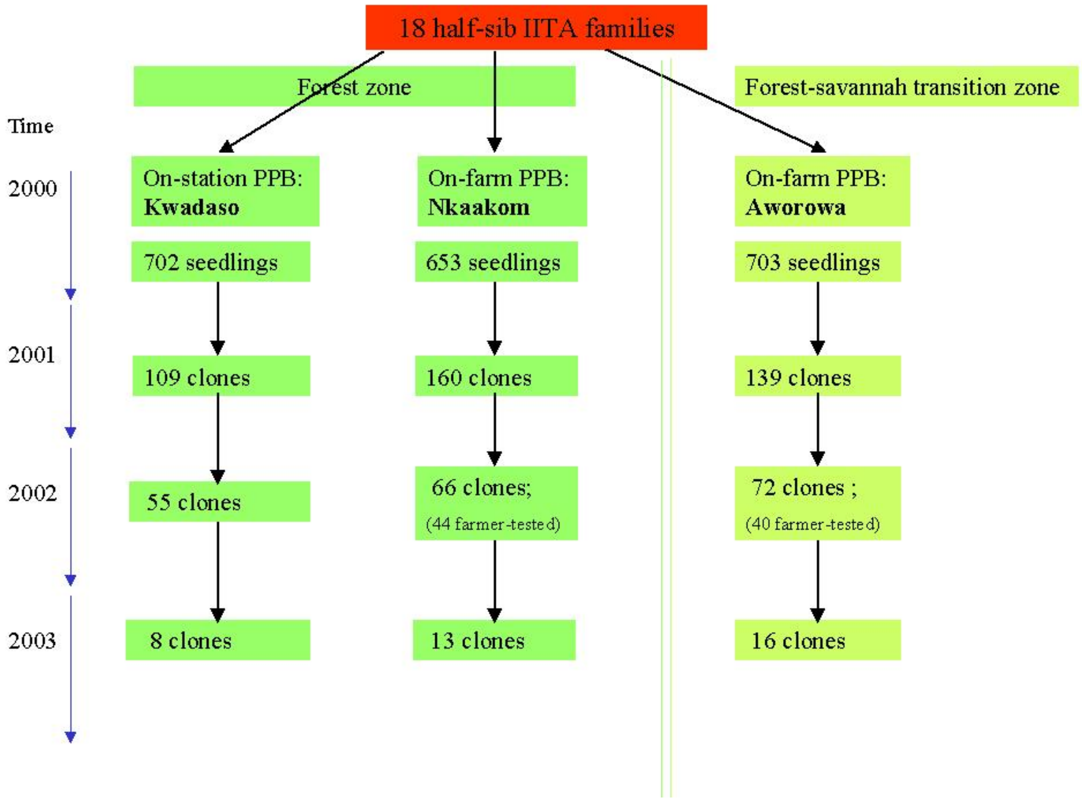
to ensure relevant individuals were fully aware of the activities and achievements of the previous phase of the project, particularly the diversity of new cassava genotypes available to be tested. It was explained that one of the aims of the current project was to test this material in a wider agro-ecological framework but another aim was to link with partners, particularly ones such as MoFA, with a longer time horizon and who could encompass a more sustained approach. Therefore, situations were sought with these partners where we could link with their own activities so as to gain both partnerships and synergisms. One of the final activities of R7565 was the Elmina Workshop where participants had emphasised the need to include end-users within the participatory approach. At the time when we were identifying partners, we had not had time to do the survey of end-users (See Output 2). It was, however, already clear that flour production is potentially an important 'new' use for cassava and so an additional aim was to include a community where rural high quality flour was being manufactured.

At harvest, farmers, the Root Crops Programme breeder and other scientists including pathologists selected 37 clones across all trials (but also two landraces) to retain for a further trial in each community. Reasons why farmers selected or rejected clones were recorded as were measurements and observations on foliage and storage roots by scientists. Selected clones were again planted in a single replicate trial at each site during September 2003. Because clones were now fewer, it was possible this time to include clones selected at all three sites at each of the trials – so, for example, the communal trial at Nkaakom now also included material selected by farmers in Aorowa and Kwadaso. Local landraces, superior landraces selected from within Brong-Ahafo Region and nationally released varieties were again included as checks.

New trials were established with a further 8 communities 3 in Ashanti and 5 in Brong-Ahafo during September and October 2003. As at Nkaakom and Aworowa, these were planted in a single replicate trial at each site and again included all 39 clones selected by farmers in Aorowa, Nkaakom and Kwadaso. Local landraces, superior landraces selected from within Brong-Ahafo Region and nationally released varieties were again included as checks. These field trials together with the trials at Nkaakom, Aworowa and Fumesua (the Kwadaso on-station trial was transferred to the main station at nearby Fumesua) therefore comprised a randomised block design replicated 10 times. The location of these sites involved consideration of synergies with partner organisations (MoFA, GTZ and World Vision), a desire to include a community making cassava flour and advice from Secretary to the Variety Release Committee Mr E. Asiedu, and the CRI cassava breeder of the need to establish a certain number of trials within the agro-ecologies we were targeting for variety release. Trials are being monitored quarterly by CRI and/or MoFA staff for plant survival, pests and diseases; it is expected that they will be harvested in May 2004.

A further two trials were established late in October 2004 with farms associated with medium-scale enterprises: with an industrial starch and flour manufacturer at Abura Dunkwa in Central Region and with a cassava food manufacturer at Ayikai Doblo in Greater Accra Region. These trials involved only 15 of the farmer-selected clones – reduced partly as a result of positive selection on the basis of healthy foliage and partly because of limited planting material – but each trial comprised 3 replicates.

Figure 1. Diagram illustrating the sequence by which 37 clones were selected by farmers and scientists.



Validation of participatory breeding approach Field data obtained over the entire breeding cycle were analysed in order to examine the impact of decisions by farmers, the CRI breeder and the CRI plant pathologists on the retention of particular genotypes. This was conducted within Mr J Manu-Aduening's PhD thesis.

Promotion of participatory breeding approach. The main activities associated with promotion of the participatory breeding approach for cassava involved preparation of working papers for early distribution to key stakeholders mainly within Ghana and presentation of project achievements to an international symposium on root crops in Africa.

Output 2.Opportunities and constraints for Improved communication between markets (of which there is extensive documented knowledge) and cassava breeding systems identified

Identifying case studies of actual and potential markets

A significant amount of work has been done on identifying market opportunities for cassava. In this activity existing literature and key informants were consulted to identify case studies. There were three main components to this activity: a review of existing literature (CRI/ NRI 2005), consultations with post-harvest researchers (CRI/ NRI 2005) and consultations with actual end-users (CRI/ NRI 2004).

The aim of the literature review was to identify current and potential utilization of cassava in Ghana and implications for variety development. An important element in the process was that the review was carried by the NRI CRI Cassava breeder. Published and grey literature were reviewed. Access to grey literature posed a problem, but key informants in Ghana and UK proved very helpful.

A total of 14 post-harvest researchers were consulted These included scientists from: Food Research Institute (FRI), Accra, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi and Natural Resources Institute, UK. These organizations already have links with private sector individuals and organizations and this provided opportunities to work closely with on-going initiatives.

The overall aims of the consultations with end users were to scope the range of cassava end-users, carry out a preliminary assessment of their current situation in general and assess their perceptions and preferences with regard to varietal attributes in particular. This was used to help identify case studies of actual and potential markets and provide a preliminary understanding of the information needed on cassava characteristics by end-users. The findings also provided some ideas on opportunities and constraints for improving communication to enable germplasm development to improve cassava utilization.   A joint NRI/ CRI team drew up an initial checklist of questions to guide discussions. A cassava breeder from CRI and a social scientist from NRI then carried out consultations, mainly during March 2004. End-user stakeholders were identified through existing reports, contacts in research organizations, regional MOFA offices and through asking those being consulted to recommend other end-users.   A range of stakeholders with an interest in cassava utilization in the limited time were available. A total of 19 stakeholders were consulted and from these 12 were interviewed using the full checklist.

Comparing user information needs with information provided (or available) by those involved in variety development

The above surveys allowed a preliminary identification of the information needed on cassava characteristics. Official variety release documents provide a detailed report of the information made available on new varieties when they are released.   In a meeting at CRI, the project team reviewed variety release documents from SARI, KNUST and CRI to assess whether attributes identified by end-users had been reported. The team then discussed the practicality of screening materials according to the criteria identified by end-users as part of the breeding process.

Practicality of screening and making available information needed by existing and potential users by testing a sample of storage roots from PPB trials

The main possible options for testing a sample of storage roots were FRI in Accra and KNUST Biochemistry Department in Kumasi. Eventually, largely through personal contacts (??) and negotiation it was decided that CRI would provide project funds and set up an informal agreement with FRI to carry out the analysis. Storage roots from clones selected in Nkaakom and Aworowa were dried and sent/ delivered to FRI for analysis. A total of 27 clones in the form of cassava flour were sent for analysis. In September 2004 the project team reviewed variety release documents from SARI, KNUST and CRI to discuss the practicality of screening material according to the criteria identified by end-users as part of the breeding process.

Assessing opportunities and constraints for improving communication between stakeholders to enable germplasm development to improve cassava utilization

The above process identified a range of individuals and organizations who have an interest in cassava utilization and variety development. Through the reviews, the overall interaction, the specific case studies and the screening of materials means of improving communicate the demand for preferred cassava attributes and the supply of attributes of different cassava types is emerging. In a meeting at CRI, the project team built on these activities and brainstormed on opportunities and constraints for improving communication to enable germplasm development to improve cassava utilization.

Additional activity – Planning and Initiating Joint trials

In September 2004 we held discussions with a number of stakeholders with a view to planning joint trials. We met separately with Dr Paa Nii Johnson (FRI) and Jonathan Anaglo (PhD student based in Dept of Agric. Extension, University of Legon, Accra) both working on an NRI-led EU project. Follow-up visit were made to: The Feed and Flour Co manager in Eastern Region (Charles Quartey) at Amanfro; Mr D.J. Harrison, Ghana National Association of Farmers Okper Branch – group of 35 members run a kokonte factory using their own varieties; Adom Cassava flour group, Nyame Bekyere, Central region. Processing gari (previously flour, but no market), fufu (home consumption). This group is involved in an NRI-led EU project. Welcomed new varieties, but were more interested in *fufu* types. Mubasmus Ventures, Abura Dunkwa, Central region making flour and low grade starch. Amasa –Agro (Motherwell farms), Ayika Doblo, Greater Accra. Making four, kokonte, grits, gari.
See Table 25 for details.

The following working papers have been prepared:

- A review of current and potential utilisation of cassava in Ghana and its implication for cassava development.
- Participatory cassava breeding in Ghana: Consultations with post-harvest cassava researchers.
- Participatory cassava breeding in Ghana: Survey of cassava end-users.

Output 3. Implications of participatory plant breeding for official variety release, including requirements for pest and disease resistance, assessed.

Members of the project team prepared a short briefing document for the Ghanaian Variety Release Committee (VRC) explaining the type of information which has been collected through the PPB method. This was to be circulated informally by the secretary (who is based at CRI) and other members of the Variety Release Committee as a first step to identifying any shortcomings.

Based on feedback from this document and from examination of previous variety release documents, activities under output 1 were re-visited to ensure the process meets current VRC requirements. This process led to the planting of a series of on-farm multi-locational trials. Further analysis of the strengths and weaknesses of the PPB method, as compared to conventional breeding methods, were analysed as part of a PhD

Outputs

Overall aim: Improving farmers' access to a diversity of superior, disease-resistant cassava clones appropriate to the needs of farmers and other end-users.

1. Inclusive systems for identifying disease-resistant cassava varieties meeting farmers' needs from seedlings or clones (including landraces) validated and promoted

Establish and monitor clones in new trials Part of the activity of this phase of the project has involved continuing the process of selection by farmers and the CRI/NRI team of scientists, as described in the FTR for the previous phase of this project, for a further generation. Selection during the harvest of the community trials in Nkaakom and Aworowa in

2003 resulted in the identification of 37 superior clones in total (Figure 1). Two landraces from amongst the checks were also selected. These 39 clones were planted in replicated trials with 8 new communities (5 in Brong Ahafo and 3 in Ashanti regions) as well at the 3 original sites (Nkaakom and Kwadasol in Ashanti Region and Aworowa in Brong Ahafo Region) as part of a final screening and assessment for Output 3. These trials were established only in the latter part of the 2003 rains. Harvest has been delayed until the start of the next rains in April/May 2005, so that cutting material can be utilised in further trials. Pests and diseases have been monitored quarterly: although some selected clones initially had CMD, all recovered during the growing season, unlike the local landrace checks. Analysis of this data will therefore be presented on completion of the final phase of the project.

Validation of participatory breeding approach Scientists voiced concerns at the beginning of the participatory breeding programme that farmers might have difficulty in selecting the best genotypes when presented with a large choice (about 700 at each site) of widely differing seedlings. These concerns included whether farmers were likely to be consistent in their selection. Examination of the results for the first two selection cycles (for which there were relatively large numbers of genotypes) showed that there was considerable agreement amongst the different selectors, farmers, the breeder and the pathologists often choosing the same genotypes even though their choices were made quite independently. This agreement also appeared, if anything, to increase from the first to the second cycle. Thus, on four occasions when the farmers, the breeder and the pathologists selected within the communal trials at Nkaakom or Aworowa, at least half the selections involved at least two of the different sets of selectors agreeing, there was considerable overlap particularly between farmers and the breeder and about a quarter of all selections involved all three sets of selectors agreeing (Figs 2 and 3).

The selection procedure adopted by the project was an inclusive one, whereby any clone selected by any set of selectors was automatically retained. It had the effect of maintaining diversity, providing a ‘safety net’ for clones with attributes particularly appreciated by just one of the sets of selectors. There was no ‘expected’ proportion of overlap between the choice of the different groups of selectors but it would have been investigated with considerable interest if the selections by the farmers differed hugely from those by the scientists, particularly the professional cassava breeder. In actuality, the farmers’ unique selections (‘Farmers only’) were generally similar in number to those of the unique selections by the scientists (the combination of ‘Breeder only’, ‘Pathologists only’ and ‘Breeder & Pathologists’) (Figures 2 and 3). Only in one case (‘Farmers only’ at Nkaakom in the first selection cycle) did these unique selections of the farmers exceed a quarter of the total number of clones selected altogether.

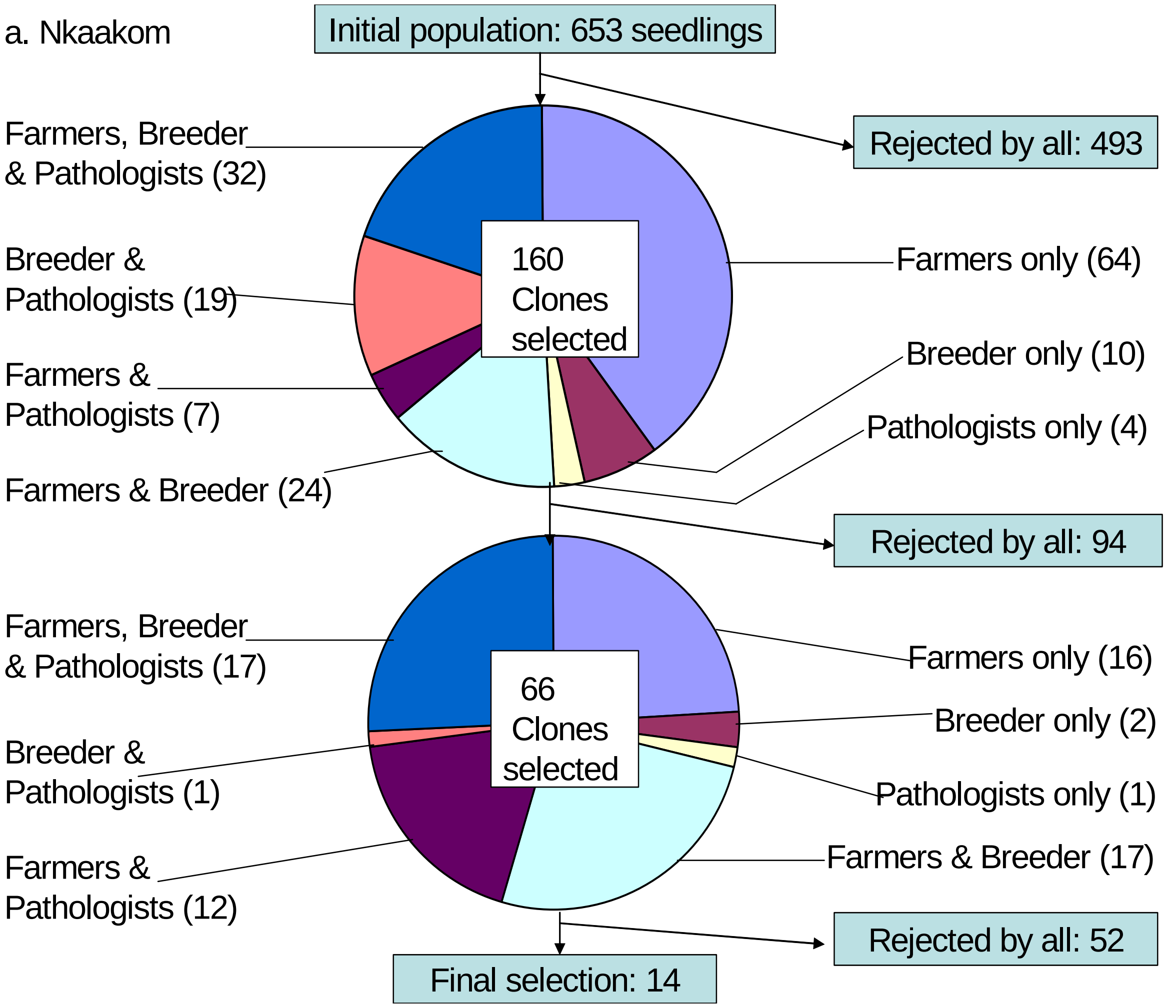
Potentially, the safety net (retaining any clone selected by any set of selectors) could have slowed down the process of eliminating unsatisfactory genotypes to an excessive extent. Instead, 1356 seedlings were reduced to just 29 over 3 cycles of selections, a rate comparable to that obtained in conventional cassava breeding (Fig. 6).

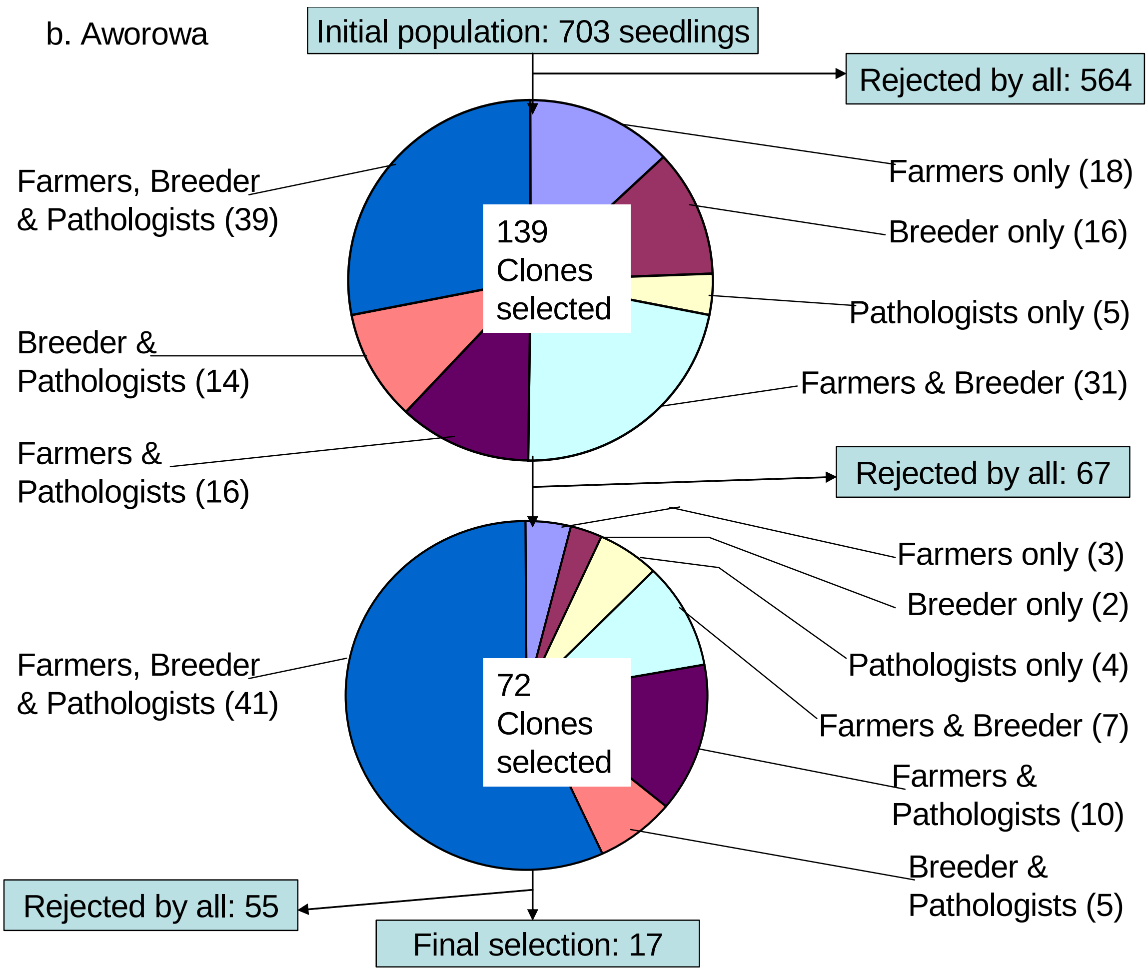
The final selections of 14 clones at Nkaakom and 17 clones at Aworowa (Fig. 1) each included one of the landrace check clones (hence the seedling genotypes selected at each site were 13 and 16 respectively, making 29 seedling selections in total). Both these check clones were superior landraces (NK009 and WCH009) selected from amongst a wide diversity of germplasm by Prof Safo Kantanka (Kwame Nkrumah University of Science & Technology, Kumasi, Ghana) as part of his breeding programme rather than released varieties.

Because our approach was an inclusive one in which everyone’s selections were kept, it was also possible using the data collected to examine how consistent the farmers, breeder and plant pathologists were in making their selection between the generations. Thus, if farmers, for example, are completely consistent in their choice of genotype, one would expect all their selections in the second generation to be reselections from amongst those they had selected in the previous generation rather than obtained from amongst the selections chosen only by the others (Breeder and Plant pathologists).

Clearly one might expect some changes in choice because some clones might, for example, become affected by CMD and other clones might, just by chance, be located in an advantageous position one season and a less advantageous position in the next. Furthermore, the decision as to whether to accept or reject a genotype was often very difficult so a genotype just rejected by one group of selectors might just be selected by another. Nevertheless, a trend towards reselecting genotypes should be evident for any group of selectors if that group had unique and consistent characteristics of selection. There was, however, no clear indication of bias towards reselecting previous choices amongst any group; indeed, the only group which showed even an indication of such bias were the farmers (Figures 4 and 5). It is possible that the breeder had unconsciously been changed in his selection by his close contact with farmers. Some plants that had escaped CMD in the seedling generation 1 had become severely affected by generation 2 and this may have affected the choice of the plant pathologists in particular.

Figure 2. Summary of progression of selections by farmers, breeder and pathologists over 3 generations

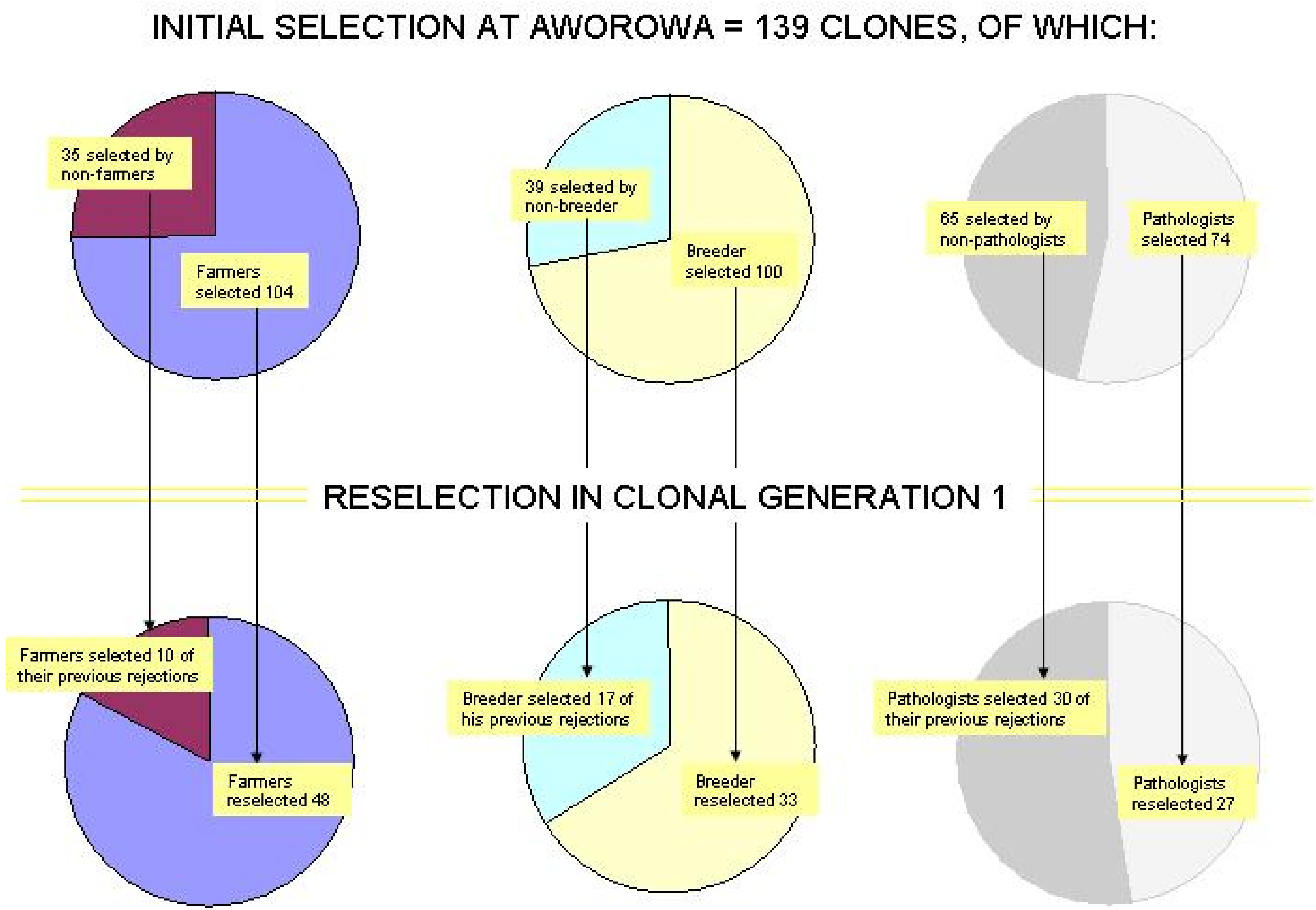


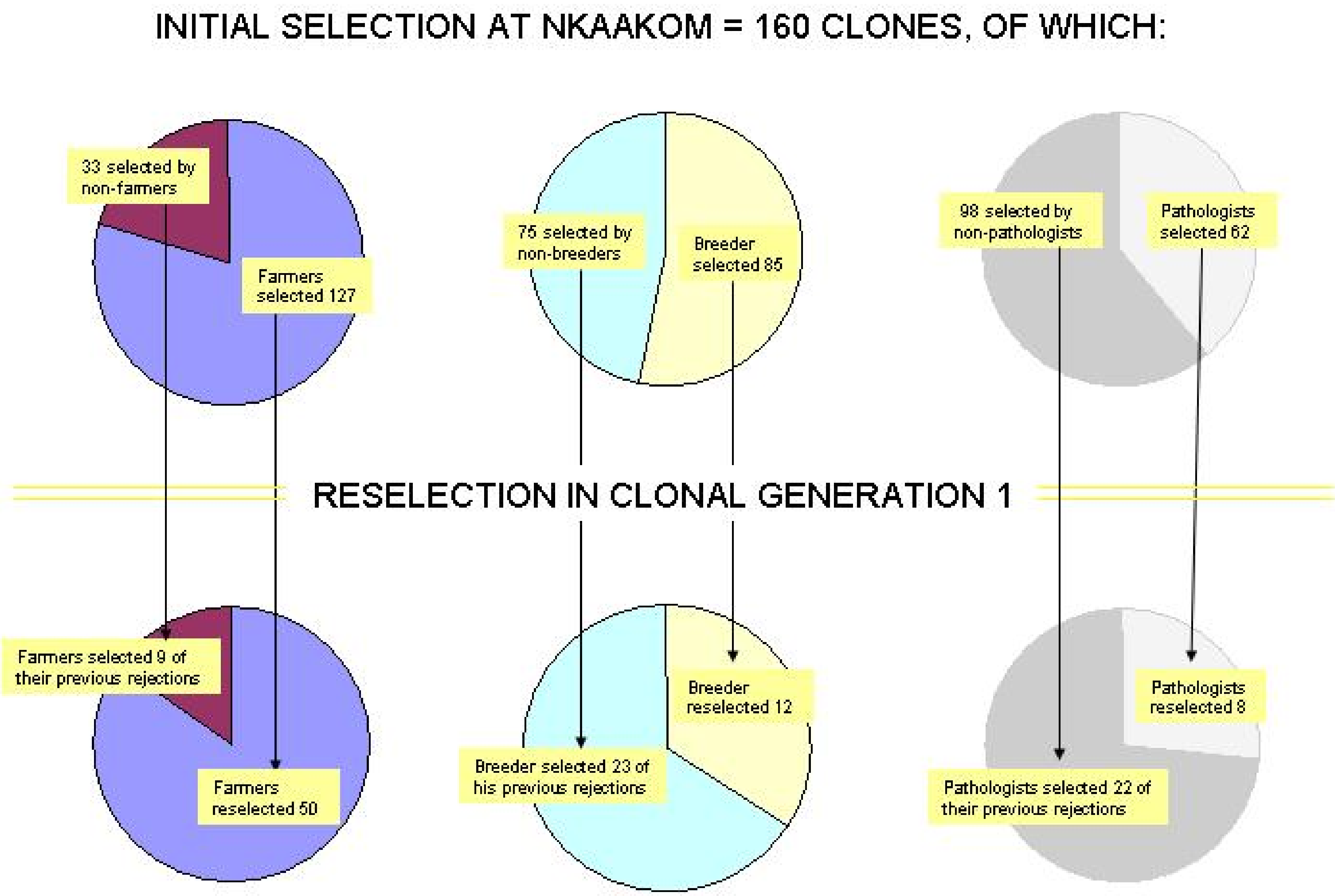


OVERLEAF

Figure 4. Consistency of selection by farmers, breeder and plant pathologists between the first seedling selection and the first clonal generation at Aworowa. The figure illustrates in the upper row of pie charts the proportions of seedlings initially selected by either farmers, breeder or plant pathologists and then, in the lower set of pie charts and for each group of actors, whether they reselected these genotypes or selected genotypes previously selected only by the other two groups of actors

Figure 5. Consistency of selection by farmers, breeder and plant pathologists between the first seedling selection and the first clonal generation at Aworowa. The figure illustrates in the upper row of pie charts the proportions of seedlings initially selected by either farmers, breeder or plant pathologists and then, in the lower set of pie charts and for each group of actors, whether they reselected these genotypes or selected genotypes previously selected only by the other two groups of actors


INITIAL SELECTION AT AWOROWA = 139 CLONES, OF WHICH:
35 selected by non-farmers
Farmers selected 104
39 selected by non-breeder
Breeder selected 100
65 selected by non-pathologists
Pathologists selected 74
RESELECTION IN CLONAL GENERATION 1
Farmers selected 10 of their previous rejections
Farmers reselected 48
Breeder selected 17 of his previous rejections
Breeder reselected 33
Pathologists selected 30 of their previous rejections
Pathologists reselected 27


INITIAL SELECTION AT NKAAKOM = 160 CLONES, OF WHICH:
33 selected by non-farmers
Farmers selected 127
75 selected by non-breeders
Breeder selected 85
98 selected by non-pathologists
Pathologists selected 62
RESELECTION IN CLONAL GENERATION 1
Farmers selected 9 of their previous rejections
Farmers reselected 50
Breeder reselected 12
Breeder selected 23 of his previous rejections
Pathologists reselected 8
Pathologists selected 22 of their previous rejections

The 31 genotypes selected in total at Nkaakom and Aworowa at Nkaakom comprised 29 clones selected from amongst the original seedlings plus two clones selected from amongst landraces included as checks. Table 3 below illustrates the consistency of selection by the different selectors.

Table 3. The numbers of times during 3 generations that different groups of actors selected the final 29 seedling clones chosen at Nkaakom and Aworowa

Frequency actors selected a clone	Aworowa			Nkaakom		
	Farmers	Breeders	Pathologists	Farmers	Breeders	Pathologists
3X	11	4	3	7	4	0
2X	3	7	10	5	1	6
1X	2	4	3	1	8	5
0X	0	1	0	0	0	2

Farmers were relatively constant in their selection, selecting nearly two thirds of the final 29 selected genotypes continuously (3X). Another outcome of analysing the history of these 29 clones is that a relatively high proportion were retained because of the project's selection 'philosophy' that a genotype was retained as long as it was selected by at least one of the groups of selectors. It is appreciated that too detailed an analysis of the role of the different actors in this selection of the few current finalists is unwise because there were relatively few clones involved, even fewer of which are likely to be retained long-term for dissemination either by farmers informally or through official release (The project team includes the Ghanaian national cassava breeder and he along with other members of the team is optimistic that some will be adopted). None of the previously released varieties included as checks was selected by either farmers or scientists.

Conclusions on farmers' overall effect on selection. The overall conclusions from the data presented in Figs 2 – 5 and in Table 3 are:

- That farmers were consistent in their selection of different genotypes
- Farmers' and scientists' choices coincided to an extent indicating that their respective criteria, although different, often resulted in the selection of the same clones
- Farmers' selections included a sufficient proportion of unique choices to make their inclusion worthwhile
- The project's 'safety-net' approach of retaining all selections by all actors did not slow selection excessively

The above data therefore validate that the approach developed by the project created the circumstances for an effective working partnership between farmers and scientists.

It is also important to consider whether the effect of farmer selection was/is **beneficial**. This is a difficult question, partly because the answer can only really be measured through the long-term adoption of clones. The following section instead attempts to examine this through the impact the different groups of selectors had on the selection of different genotypes.

Effects of selection on some quantifiable agronomic attributes. The mean values of a range of quantifiable agronomic attributes for accessions selected by farmers, breeder and or pathologists are given in Table 4 – 7. Values are compared using the z test considering 'All accessions' to be the main population and selections as sub-populations, to test whether the different selectors chose plants differing in these attributes.

Storage root yield is one of the most obvious, most easily and commonly measured quantifiable agronomic attribute and is important in that the storage roots are the main purpose of growing cassava. Generally, all three categories of selectors including farmers preferentially selected genotypes with greater yields/plant. Although the data is not presented here, local farmer varieties and released varieties generally yielded less than did the selected clones.

Plant height, branching height, canopy area and fractional light interception are all indirect measures of plant vigour and ability to compete with and/or shade out weeds. Generally, all categories of actors selected taller plants with relatively large and dense canopies.

Stem girth was measured because farmers said they used it as an indicator of yield potential and they did appear to select for genotypes with thicker stems at Nkaakom.

In conclusion, records of a range of quantifiable agronomic attributes are consistent with all categories of selectors preferentially selecting genotypes with high storage root yields and tall, large, dense canopies. This outcome is consistent with previous results that farmers and scientists overlapped in their choice of genotype.

Table 4. Mean yields and plant heights of cassava seedlings for the three groups in seedling generation. Means of the different sub-populations were compared with the means of the whole population using one sample z-test

a. Nkaakom

Selectors	Plant height (m)				Yield (kg/plt)			
	Mean	N	z-value	P- values	Mean	N	z-value	P-values
Farmers	2.8	127	1.715	0.043	2.9	127	3.333	0.001
Breeder	2.6	85	1.443	0.075	2.2	85	0.054	0.481
Pathologists	2.5	62	2.169	0.015	2.0	62	1.204	0.107
Selected (all)	2.7	160	0.211	0.417	2.6	160	2.811	0.002
All accessions	2.7	653	-	-	2.2	653	-	-

b. Aworowa

Selectors	Plant height (m)				Yield (kg/plt)			
	Mean	N	z-value	P-values	Mean	N	z-value	P-value
Farmers	2.4	104	6.798	0.000	4.0	104	7.111	0.000
Breeder	2.3	100	6.000	0.000	2.7	100	3.054	0.001
Pathologists	2.3	74	5.162	0.000	3.1	74	4.483	0.000
Selected (all)	2.3	139	7.079	0.000	2.9	139	4.716	0.000
All accessions	2.0	439	-	-	1.9	439	-	-

Table 5. Means of tuber yield and other growth and development variables of clones selected by farmers, breeder and pathologists in clonal generation 1. . *Means of the different sub-populations were compared with the means of the whole population using one sample z-test*

Nkaakom

Selectors	Plant height (m)				Yield (kg/2plts)			
	Mean	N	z-value	P-value	Mean	N	z-value	P-value
Farmers	2.4	63	3.139	0.000	6.2	63	1.569	0.059
Breeder	2.3	36	1.291	0.098	6.7	36	1.695	0.045
Pathologists	2.3	31	1.219	0.112	4.2	31	2.091	0.018
Selected (all)	2.2	66	0.203	0.409	5.7	66	0.762	0.224
All accessions	2.2	160	-	-	5.4	160	-	-

Selectors	Branching height (m)				Canopy area (m^2)			
	Mean	N	z-value	P-value	Mean	N	z-value	P-value
Farmers	0.8	63	0.156	0.441	0.8	63	1.418	0.088
Breeder	0.8	36	0.129	0.448	0.8	36	1.122	0.131
Pathologists	0.7	31	1.219	0.112	0.6	31	1.601	0.054
Selected (all)	0.8	66	0.203	0.409	0.7	66	0.203	0.409
All accessions	0.8	160	-	-	0.7	160	-	-

a. Aworowa

Selectors	Plant height (m)				Yield (kg/2plts)			
	Mean	N	z-value	P	Mean	N	z-value	P-values
Farmers	1.8	61	0.163	0.436	6.1	61	1.657	0.048
Breeder	1.9	55	1.569	0.058	5.5	55	0.758	0.224
Pathologists	1.8	60	0.162	0.436	5.5	60	0.647	0.261
Selected (all)	1.8	72	0.212	0.417	5.7	72	1.886	0.029
All accessions	1.8	139	-	-	5.1	139	-	-

Selectors	Branching height (m)				Canopy area (m^2)			
	Mean	N	z-value	P-values	Mean	N	z-value	P-values
Farmers	0.7	61	1.628	0.052	0.7	61	1.628	0.052
Breeder	0.7	55	1.326	0.092	0.6	55	3.139	0.000
Pathologists	0.7	60	1.943	0.026	0.7	60	1.618	0.048
Selected (all)	0.7	72	2.123	0.013	0.7	72	2.123	0.013
All accessions	0.6	139	-	-	0.8	139	-	-

Table 6. Means of tuber yield (kg/2 plants) of clones evaluated in the second clonal generation.

Grouped by	Aworowa		Nkaakom	
	Mean	N	Mean	N
Farmers	12.7	16	4.3	14
Breeder	11.6	15	4.9	8
Pathologists	12.0	9	5.3	5
Selected (all)	11.1	17	4.2	16
All accessions	7.8	72	3.6	66

Table 7. Comparison of yields (kg/plant) of selected clones, farmer varieties and released varieties tested by farmers in their own fields.

	Aworowa			Nkaakom
Variables	Mean	N	Mean	N
Selected clones	4.7	14	3.1	11
*Farmer variety**	*5.5*	*3*	*2.9*	*2*
Landraces**	4.8	3	-	-
Released var.	3.0	2	2.9	2
Overall mean	**4.6**	**22**	**3.0**	**15**

* Unlike most other trials in which farmer varieties usually performed very poorly, here the farmer varieties did not and we suspect it was because planting material of all other categories had been stored for some time whilst that of the farmer varieties was fresh.
**NK 005, NK 015 and WCH 037, the landraces selected amongst germplasm from Brong Ahafo region

The different qualitative attributes used by different categories of selectors. The plant pathologists selected entirely for genotypes lacking diseases particularly on the foliage and particularly CMD and cassava bacterial blight (CBB). The plant breeder selected mainly for the genotypes with a high yield of large tubers with a medium to long neck so that they can be harvested easily. He also selected for absence of major diseases but would usually be guided in this by the advice of the plant pathologists. These quality attributes were also adjusted by a factor best perhaps described as 'overall good appearance'. He also attempted to measure starch content and bitterness by chewing a small quantity of tuber (as did some of the farmers). Farmers wrote down the attributes they used to make their selections and the outcomes are presented in Table 8 Only those attributes listed in Table 8 were obtained at harvest and were presumably those used in the retention of genotypes. Whilst the yield of storage roots and their shape and appearance was obviously important, canopy characteristics, notably a high (therefore produced later than a low canopy to allow intercropping) wide (suppressing weeds) canopy supported by a thick stem, were clearly considered important. Pest and disease resistance was considered but also the converse, namely nice-looking healthy leaves. The latter positive selection contrasted with the rejection of diseased plants by plant pathologists. The farmers' mentioned both a positive selection for healthy-looking plants and a rejection of diseased ones. In the final generations of selection, farmers were also invited to taste the cooked tubers.

In conclusion, it is clear that both farmers and the cassava breeder placed a priority on the storage root yield whereas the pathologists put priority on pests and disease resistance. The farmers also included a wide range of other characters and this appears to be their unique contribution to the selection process.

Table 8. Attributes of above-ground characters of cassava mentioned and ranked at harvest by farmers and their apparent relative value, 1 being the highest.

	Nkaakom			**Aworowa**	
	Generation			**Generation**	
Attribute	**Seedling**	**Clonal 1**	**Clonal 2**	**Seedling**	**Clonal 2**
High tuber yield	1	1	1	1	1
More branches	2	3	5	2	2
Big stem girth	2	4	6	2	6
Suitable for fufu/ampesi	4	2	2	5	3
Medium to large tuber shape	8	-	3	4	4
Weed suppression	5	8	10	7	5
Healthy (green) leaves	7	7	4	6	7
Suitable for intercropping	6	9	9	9	9
Processing into gari	8	-	-	7	-
Marketable size	12	5	-	10	-
Average neck length	8	17	-	10	-
Red/pink tuber skin colour	12	16	12	14	-
Resistant to lodging	12	11	-	10	-
Poundable all year	12	-	-	14	-
Early maturity	8	10	-	14	10
Non-rotten tubers	12	13	11	10	11
Non-fibrous tubers	18	15	-	14	-
Drought tolerant	19	-	-	-	-
Disease and pest resistant	12	6	8	-	8
Planting material	-	14	-	-	-
Round tuber shape	-	12	-	-	-
Big canopy	-	-	7	-	-
Number of farmers	***51***	***46***	***30***	***25***	***26***

- Means not mentioned/ranked

Selection by different groups of actors of disease-resistant genotypes. There were no major pests evident at any harvest in any location, though cassava green mite caused damage to leaves during the dry season. Cassava mosaic disease (CMD) caused by cassava mosaic geminiviruses was very damaging to individual genotypes including the local check varieties and in farmers' crops. Cassava anthracnose disease (CAD) and cassava brown leaf spot (BLS), both fungal diseases, were also common in the trials in both villages. CAD appears as canker (sore) on the stems and bases of leaf petioles causing shoot dieback in severe cases whilst BLS appears as small brown spots with dark borders on the upper leaf surfaces: BLS is a very obvious disease but is not generally associated with large yield losses. Root rotting associated with water-logging in some sites, perhaps early maturity and susceptibility to root rot pathogens, was also evident at some sites.

CMD CAD and BLS were common in the trials in both Nkaakom and Aworowa (Tables 9 - 16). Cassava bacterial blight was occasionally locally common. BLS infected almost all plants with only one uninfected plant at Aworowa and about 85% of plants at Nkaakom infected. There was comparatively more CAD infections at Nkaakom than Aworowa. Those accessions selected by farmers, the plant breeder and the plant pathologists seldom differed significantly in the proportion infected or severely affected by these diseases, amongst each other. Overall, those that were selected also did not differed significantly in the proportion infected or severely affected by these diseases from those that were rejected. These results support earlier observation of the importance attached to characters associated with high yield rather than with diseases affecting the aboveground parts when selecting suitable cassava cultivars. Despite this, the plants selected by the pathologists did tend to have the fewest diseased plants and low severity of disease. Perhaps the underlying conclusion of this section is that the plant pathologists had an important role in the project in ensuring that disease-resistant genotypes were retained, especially from the early generations when potentially CMD-resistant but apparently low-yielding genotypes might have been eliminated.

Table 9. Number of clones with/without CMD symptoms and the severities of accessions chosen by different categories of selectors at clonal 1 generation. Values in parentheses are percentages. Null hypotheses are that the proportions of CMD-free and CMD-infected clones and the proportions with each score are the same amongst the different groups. A score of 1= asymptomatic

a. Nkaakom

	CMD incidence			CMD severity scores				
Groups	With	Without	% infection	1	2	3	4	5
Farmers	48	15	76	15 (24)	23 (36)	22 (35)	3 (5)	0
Breeder	33	3	92	3 (9)	12 (34)	20 (54)	1 (3)	0
Pathologists	15	16	48	16 (52)	9 (29)	6 (19)	0	0
χ^2 value$_{(df = 2)}$ = 16.502; P = 0.000				χ^2value$_{(df = 6)}$ = 20.13; P = 0.003				
Selected (all)	48	16	75	16 (25)	23(36)	22 (34)	3 (5)	0
Non-selected	93	11	89	11 (11)	26 (26)	47 (47)	16 (16)	0
χ^2 value$_{(df = 1)}$ = 6.110 P = 0.013				χ^2 value$_{(df = 3)}$ = 11.725; P = 0.008				

b. Aworowa

	CMD incidence			CMD severity scores				
Groups	With	Without	% infection	1	2	3	4	5
Farmers	32	29	53	29 (47)	13 (21)	14 (23)	5 (8)	0
Breeder	31	24	56	24 (43)	12 (22)	13 (24)	6 (11)	0
Pathologists	29	31	48	32 (53)	14 (23)	14 (23)	0	0
χ^2 value$_{(df = 2)}$ = 0.743; P = 0.690				χ^2 value$_{(df = 6)}$ = 6.66; P = 0.353				
Selected (all)	35	32	52	32 (48)	15 (22)	14 (20)	6 (9)	0
Non-selected	69	5	93	5 (7)	17 (23)	28 (38)	24 (32)	0
χ^2 value$_{(df = 1)}$ = 30.546; P = 0.000				χ^2 value$_{(df = 3)}$ = 35.033; P = 0.000				

Table 10. Number of clones with/without CAD symptoms and the severities of accessions chosen by different categories of selectors at clonal 1 generation. Values in parentheses are percentages. Null hypotheses are that the proportions of CMD-free and CMD-infected clones and the proportions with each score are the same amongst the different groups. A score of 1= asymptomatic

a. Nkaakom

Groups	CAD symptoms			Severity score of CAD				
	With	Without	% infection	1	2	3	4	5
Farmers	41	22	65	22 (35)	20 (32)	10 (16)	11 (17)	0
Breeder	22	14	61	14 (39)	7 (19)	13 (36)	2 (6)	0
Pathologists	12	19	39	19 (61)	8 (26)	4 (13)	0 (0)	0
χ^2 value$_{(df = 2)}$ = 6.157; P = 0.046				χ^2 value$_{(df = 6)}$ = 17.907; P = 0.006				
Selected (all)	41	23	64	23 (36)	20 (31)	10 (16)	11 (17)	0
Non-selected	78	26	75	26 (25)	38 (36)	23 (22)	17 (16)	0
χ^2 value$_{(df = 1)}$ = 2.294; P = 0.130				χ^2 value$_{(df = 3)}$ = 2.812; P = 0.421				

b. Aworowa

Groups	CAD symptoms			Severity score of CAD				
	With	Without	% infection	1	2	3	4	5
Farmers	47	14	77	14 (23)	27 (44)	14 (23)	6 (10)	0
Breeder	43	12	78	12 (22)	29 (53)	14 (25)	0 (0)	0
Pathologists	45	15	75	15 (25)	32 (53)	13 (22)	0 (0)	0
χ^2 value$_{(df =2)}$ = 0.169; P = 0.919				χ^2 value$_{(df = 6)}$ = 12.239; P = 0.057				
Selected (all)	52	15	78	15 (22)	32 (48)	14 (20)	6 (9)	0
Non-selected	55	19	74	19 (26)	23(31)	15 (20)	13 (18)	4 (5)
χ^2 value$_{(df =1)}$ = 0.208; P = 0.649				χ^2 value$_{(df = 3)}$ = 4.493; P = 0.213				

Table 11. Number of clones with/without BLS symptoms and the severities of accessions chosen by different categories of selectors at clonal 1 generation. Values in parentheses are percentages. Null hypotheses are that the proportions of CMD-free and CMD-infected clones and the proportions with each score are the same amongst the different groups. A score of 1= asymptomatic

a. Nkaakom

Groups	BLS symptoms			Severity score of BLS				
	With	Without	% infection	1	2	3	4	5
Farmers	49	14	77	14 (22)	29 (46)	12 (19)	8 (13)	0
Breeder	32	4	89	4 (11)	15 (42)	11 (31)	6 (16)	0
Pathologists	21	10	68	10 (32)	14 (45)	6 (19)	1 (3)	0
χ^2 value$_{(df = 2)}$ = 4.442; P =0.109				χ^2 value$_{(df = 6)}$ = 7.855; P = 0.249				
Selected (all)	49	15	77	15 (23)	29 (45)	12 (19)	8 (13)	0
Non-selected	87	17	84	17 (16)	22 (21)	36 (35)	29 (28)	0
χ^2 value$_{(df = 1)}$ = 1.292; P = 0.256				χ^2 value$_{(df = 3)}$ = 16.411; P = 0.001				

b. Aworowa

Groups	BLS symptoms			Severity score of BLS				
	With	Without	% infection	1	2	3	4	5
Farmers	61	0	100	0	28 (46)	23 (38)	10 (16)	0
Breeder	55	0	100	0	25 (45)	22 (40)	8 (15)	0
Pathologists	60	0	100	0	29 (48)	22 (37)	9 (15)	0
χ^2 value$_{(df = \ )}$ = N/A				χ^2 value$_{(df = 4)}$ = 0.219; P = 0.994				
Selected (all)	67	0	100	0	29 (43)	23 (34)	15 (22)	0
Non-selected	73	1	99	1(1)	38 (51)	30 (40)	6 (8)	0
χ^2 value$_{(df = 1)}$ = 0.912; P = 0.340				χ^2 value$_{(df = 3)}$ = 6.561; P = 0.087				

Table 12 Number of clones with/without CMD symptoms and the severities of accessions chosen by different categories of selectors at clonal 2 generation. Values in parentheses are percentages. Null hypotheses are that the proportions of CMD-free and CMD-infected clones and the proportions with each score are the same amongst the different groups. A score of 1= asymptomatic

a. Nkaakom

Groups	CMD incidence			CMD severity scores				
	With	Without	% infection	1	2	3	4	5
Farmers	10	4	71	4(29)	5(36)	3(21)	2(14)	0
Breeder	6	2	75	2(25)	5(63)	1(12)	0	0
Pathologists	2	3	40	3(60)	2(40)	0	0	0
χ^2 value$_{(df = 2)}$ = 0.851; P = 0.653				χ^2 value$_{(df = 6)}$ = 5.218; P = 0.516				
Selected (all)	10	4	71	4(29)	5(36)	3(21)	2(14)	0
Non-selected	43	9	83	9(17)	20(39)	16(31)	7(13)	0
χ^2 value$_{(df = 1)}$ = 0.885; P = 0.347				χ^2 value$_{(df = 3)}$ = 1.072; P = 0.784				

b. Aworowa

Groups	CMD incidence			CMD severity scores				
	With	Without	% infection	1	2	3	4	5
Farmers	12	4	75	4(25)	10(62)	2(13)	0	0
Breeder	10	5	67	5(33)	9(60)	1(7)	0	0
Pathologists	5	4	55	4(44)	5(56)	0	0	0
χ^2 value$_{(df = 2)}$ = 1.000; P = 0.606				χ^2 value$_{(df = 4)}$ = 1.994; P = 0.746				
Selected (all)	12	5	71	5(29)	10(59)	2(12)	0	0
Non-selected	42	13	76	13(24)	28(51)	10(18)	4(7)	0
χ^2 value$_{(df = 1)}$ = 0.231; P = 0.631				χ^2 value$_{(df = 3)}$ = 1.885; P = 0.597				

Table13. Number of clones with/without CAD symptoms and the severities of accessions chosen by different categories of selectors at clonal 2 generation. Values in parentheses are percentages. Null hypotheses are that the proportions of CMD-free and CMD-infected clones and the proportions with each score are the same amongst the different groups. A score of 1= asymptomatic

a. Nkaakom

Groups	CAD incidence			CAD scores				
	With	Without	% infection	1	2	3	4	5
Farmers	10	4	71	4(29)	6(43)	4(28)	0	0
Breeder	4	4	50	4(50)	4(50)	0	0	0
Pathologists	2	3	40	3(60)	1(20)	1(20)	0	0
χ^2 value$_{(df = 2)}$ = 1.911; P = 0.385				χ^2 value$_{(df = 4)}$ = 4.096 P = 0.393				
Selected (all)	10	4	71	4(29)	6(43)	4(28)	0	0
Non-selected	23	29	44	29(56)	15(29)	8(15)	0	0
χ^2 value$_{(df = 1)}$ = 3.264; P = 0.071				χ^2 value$_{(df = 2)}$ = 3.367; P = 0.186				

b. Aworowa

Groups	CAD incidence			CAD severity scores				
	With	Without	% infection	1	2	3	4	5
Farmers	7	9	44	9(56)	4(25)	2(13)	1(6)	0
Breeder	5	10	33	10(67)	3(20)	2(13)	0	0
Pathologists	1	8	11	8(89)	1(11)	0	0	0
χ^2 value$_{(df = 2)}$ = 2.805; P = 0.246				χ^2 value$_{(df = 6)}$ = 4.134; P = 0.659				
Selected (all)	7	10	41	10(59)	4(24)	2(12)	1(5)	0
Non-selected	24	31	44	31(56)	13(24)	9(16)	2(4)	0
χ^2 value$_{(df = 1)}$ = 0.320; P = 0.858				χ^2 value$_{(df = 3)}$ = 0.351; P = 0.950				

Table 14. Number of clones with/without BLS symptoms and the severities of accessions chosen by different categories of selectors at clonal 2 generation. Values in parentheses are percentages. Null hypotheses are that the proportions of CMD-free and CMD-infected clones and the proportions with each score are the same amongst the different groups. A score of 1= asymptomatic

a. Nkaakom

Groups	BLS incidence			BLS severity scores				
	With	Without	% infection	1	2	3	4	5
Farmers	6	8	43	8(57)	5(36)	1(7)	0	0
Breeder	5	3	63	3(37)	5(63)	0	0	0
Pathologists	2	3	40	3(60)	1(20)	1(20)	0	0
χ^2 value$_{(df = 2)}$ = 0.950; P = 0.622				χ^2 value$_{(df = 4)}$ = 3.666; P = 0.453				
Selected (all)	6	8	43	8(57)	5(16)	1(7)	0	0
Non-selected	23	29	44	29(56)	20(38)	2(4)	1(2)	0
χ^2 value(df = 1) = 0.008; P = 0.927				χ^2 value$_{(df = 3)}$ = 0.559; P = 0.906				

b. Aworowa

Groups	BLS incidence			BLS severity scores				
	With	Without	% infection	1	2	3	4	5
Farmers	11	6	69	6(35)	6(35)	4(24)	1(6)	0
Breeder	9	6	60	6(40)	6(40)	3(20)	0	0
Pathologists	6	3	67	3(33)	6(67)	0	0	0
χ^2 value$_{(df = 2)}$ = 0.129; P = 0.938				χ^2 value$_{(df = 6)}$ = 4.922; P = 0.554				
Selected (all)	11	6	65	6(35)	6(35)	4(24)	1(6)	0
Non-selected	49	6	89	6(11)	27(49)	20(36)	2(4)	0
χ^2 value$_{(df = 1)}$ = 5.560; P = 0.018				χ^2 value$_{(df = 3)}$ = 5.971; P = 0.113				

Table 15. Number of clones with/without CBB symptoms and the severities of accessions chosen by different categories of selectors at clonal 2 generation. Values in parentheses are percentages. Null hypotheses are that the proportions of CMD-free and CMD-infected clones and the proportions with each score are the same amongst the different groups. A score of 1= asymptomatic

a. Nkaakom

Groups	CBB incidence			CBB severity scores				
	With	Without	% infection	1	2	3	4	5
Farmers	No symptoms observed			No symptoms observed				
Breeder								
Pathologists								
Selected (all)								
Non-selected								

b. Aworowa

Groups	CBB incidence			CBB severity scores				
	With	Without	% infection	1	2	3	4	5
Farmers	1	16	6	16(94)	1(6)	0	0	0
Breeder	1	14	7	14(93)	1(7)	0	0	0
Pathologists	0	9	0	9(100)	0	0	0	0
χ^2 value$_{(df = 2)}$ = 0.602; P = 0.740				χ^2 value$_{(df = 2)}$ = 0.602; P = 0.740				
Selected (all)	1(6)	16	6	16(94)	1(6)	0	0	0
Non-selected	5(9)	50	9	50(91)	3(6)	2(3)	0	0
χ^2 value$_{(df = 1)}$ = 0.175; P = 0.676				χ^2 value$_{(df = 2)}$ = 0.637; P = 0.727				

Table 16. Percentages of accessions, landraces and released varieties showing symptoms of CMD, CAD and BLS on farmers' fields. The number (n) of individual accessions, farmer varieties and released varieties are in brackets.

Diseases	Aworowa			Nkaakom		
	Accessions (n=90)	Farmer variety (n=12)	Released variety (n=8)	Accessions (n=79)	Farmer variety (n=12)	Released variety (n=11)
CMD	54	92	50	90	100	46
CAD	38	75	25	72	91	67
BLS	83	92	75	65	58	55

Promotion of participatory breeding for cassava Two working papers derived from work done during R7565 were finalised during early project activities:

- Informal exchange of cassava genotypes and farmers' knowledge and use of sexual propagation of cassava. 53pp
- Participatory breeding for superior mosaic resistant cassava in Ghana: two years of seedling/clonal evaluation by farmers and scientists. 54pp

A presentation on our participatory cassava breeding work was made to the International Society for Tropical Root Crops – Africa Branch meeting in Mombasa in November 2004.

Mr J Manu-Aduening completed the collation and analysis of his PhD study entitled 'Participatory breeding for superior mosaic-resistant cassava in Ghana'

2. Opportunities and constraints for improved communication between end-users and those working on varietal development

Introduction
Farmers interviewed in situation analyses of project villages identified a lack of adequate markets for their current cassava production as a major issue, yet research by CPHP has identified opportunities for large scale import substitution by cassava in extensive markets such as glue for the large plywood industry in Ghana, in paper manufacturing, flour and animal feeds. Participants at the Elmina Participatory Cassava breeding Workshop (CRI/NRI, 2002b) indicated that this apparent lack of market for cassava partly resulted from cassava varieties not being selected according to end-user criteria. R7565 addressed the need to include farmer criteria in cassava selection but appreciated the need to include other end-user criteria only as a result of project activities (CRI/NRI, 2002c). Identifying means by which end-user criteria are included in cassava breeding, identifying key criteria for different end-users and validating the means by which (the needs of) cassava end-users are included in cassava breeding through worked examples are essential for ensuring that new varieties will be suitable for a wider and therefore larger market.

Current Utilization of Cassava in Ghana

In Ghana (and elsewhere in Africa), cassava is used almost exclusively as food (either directly or sold for consumption) for people (95% of cassava production, after accounting for waste, was used as food in Africa in the early 2000s compared to 55% in Asia and 40 percent in South America Farmers and food processors in Africa, market five common groups of cassava products: fresh roots, dried roots (called *kokonte* in Ghana and *lafun* in Nigeria), pasty products (called *agbelima* in Ghana and *akpu* in Nigeria), a granulated roasted/dried product (called *gari* in both Ghana and Nigeria), and cassava leaves. The roots are also processed into fermented dough and used in the preparation of *banku* and *akple*. Among these staples, *gar*i is the most common form in which cassava is marketed and it is gradually becoming the most common food of the urban population in Ghana. Nweke et al. 2002 reported that roughly 60 percent of the cassava planted in Ghana is now being sold as a cash crop. *Gari* has a long shelf-life, a year or more as long as it is not exposed to moisture, explaining its wider acceptance by the urban consumers.

Processing of cassava into various shelf-stable and semi-stable products is a widespread activity carried out by traditional cassava processors and small-scale commercial processing units. Cassava root which contains about 70% water must be dehydrated to reduce the cost of transporting the product from the rural areas to urban centres. During processing, the cassava tuber also is transformed from a highly perishable root into a convenient, easily marketable, shelf-stable product which meets consumer demand for a staple food. Processing may improve the palatability of the product, reduce waste and also reduce the level of cyanogenic glucosides in the tuber thereby detoxifying the product. Products fermented by some species of lactic acid bacteria such as *agbelima* and *gari* may gain anti-microbial properties. The traditional methods for processing cassava involve combinations of various processes including peeling, grating, dehydration and dewatering, sifting, fermentation, milling and roasting. The major products are *agbelima, gari* and *kokonte*.

Emerging Processing and Marketing of Cassava in Ghana
Cassava has technical potential as a raw material for several agro-industrial products. To be successful as an industrial raw material, cassava supplies must be sufficient to meet the needs of both the traditional food markets and the new industrial markets. Furthermore, this supply must be reliable and thus, must take account of potential fluctuations in supply and demand within the traditional food markets. Utilization of processed and semi-processed cassava products can be put into three main groups: livestock feed (usually in the form of peels, fresh and dry root, chips, pellets and sometimes flour), food for people and industrial (non-food) uses. The last two utilization forms usually require high quality cassava flour (HQCF) and/or starch.

Food for People- the potential use of cassava as an industrial raw material is highest in the food industry. The food industries are one of the largest consumers of starch and starch products, yet the amount of cassava used for food manufacture by large-scale food industries in Ghana is insignificant. In addition, large quantities of starch are sold in the form of products sold in small packages for household cooking. Unmodified starch, modified starch and glucose derived mostly from wheat or maize are currently used in the food industry. Specifically, the food processing category includes bakeries, biscuit manufacturers, food processors, confectionery and millers. Products include: alternative flour to wheat flour in bakery products; glucose or dextrose sugar; commercial caramel production; dried yeast; confectioneries; canned fruits, jams and preserves; monosodium glutamate (MSG). The largest market potential for cassava flour in the medium to long term in Ghana lies in food applications (Day et al., 1996). Cassava flour could potentially substitute for large amounts of wheat flour currently used in bread, snacks and other food items. The possibility of replacing up to 20% or more of imported wheat flour with cassava flour is very attractive (Ofori et al., 1997).

***As Livestock Feed* -** cassava is an energy source well suited for animal feeds, as demonstrated by its utilization in many countries. In 1994, about a quarter of the global cassava production was estimated to be used as an ingredient in pork, poultry, cattle, and fish feeds (IFAD/FAO, 2000). However, there are wide differences in utilization between continents. In Africa and Asia, only about 6% of the cassava production is used for animal feed. This is in spite of the fact that substantial amounts of research into cassava utilization in feed rations have been carried out in Africa during the last three decades. In Latin America and the Caribbean, feed utilization is about 47%, mainly due to high usage in Paraguay and Brazil. In Ghana, the amount of cassava and its products fed to animals as scraps must be fairly large, but there is no way of estimating it. Free range fowls, goats and pigs probably consume cassava roots and leaves regularly in many parts of Ghana, but a true livestock feeding industry based on cassava is yet to be developed. However, cassava cannot be used as the sole feedstuff because of its deficiency in protein and vitamins, but must be supplemented by other feeds that are rich in these elements.

Research in many parts of the world has demonstrated that dried cassava can substitute for part of the cereal-based energy component of livestock feed rations. The major factors that could influence the realization of this opportunity are:

• The animal feed industry in Ghana requires large quantities of cassava
• Animal feeds have relatively low quality specifications.
• Little investment is required to realize the opportunity.
• The long-term prospects of the Ghana's livestock industry appear favourable because there are large domestic markets.
• Potential for export of dried cassava to similar industries in neighbouring countries.

***For Industrial uses* -** industrial uses of cassava are largely non-existent in Ghana. The industrial products which can be obtained from cassava are starch and cassava flour. Starch is high value product, which can be used for many activities in industries. There are potential uses as follows: Textile industry; Adhesives; Corrugated cardboard manufacture; Plywood; Paper industry; Remoistening gums; Wallpaper and other home uses; Foundry; Industrial alcohol; Pharmaceuticals; Biodegradable plastics from starch; Well drilling; Laundry starch; Starch as filler in soap and detergents; Particle board from cassava stalks.

Plywood, paperboard, and textile industries have potential of using cassava flour as it is already accepted by many of the industries involved in these sectors. Day et al., 1996 reported of a significant market potential for unfermented cassava flours as partial or total replacement for wheat for the manufacturing of plywood and paperboard industries in Ghana. In the short term, the application of cassava flour could replace wheat flour which is used by the plywood industry as glue extender, and possibly the industrial starch used in paper board. The major factors that could influence the realization of this opportunity are:

• Cassava flour is already accepted by industry.
• Industries in Ghana have relatively low quality requirements.
• Little investment is required to realize the opportunity.
• Potential for export of cassava flour to similar industries in neighbouring countries

Industries in Ghana are likely to utilize cassava for the production of other industrial products eg., alcohol, confectionaries, laundry starch if there would be sustainable production of the HQCF and the starch that are being promoted. Although there could be the possibilities of industries or consumers utilizing cassava products for MSG, cosmetics, oil drilling, biodegradable there is no potential for its utilization taken Ghana's technological development into consideration.

Table 17: Import (quantity and value) of some selected products in Ghana

Product	1998	1999	2000	2001	2002
	Quantity in mt (value in $1000)				
Cassava flour		1 (1)			
Maize	4,026 (1489)	86 (28)	6,352 (913)	10,589 (1,545)	22,386 (2,312)
Maize Flour	26 (9)	49 (19)	20 (15)	299 (75)	811 (177)
Wheat Flour	2,130 (674)	1,737 (456)	19,602 (5,459)	28,693 (7,395)	45,421 (13,979)
Glucose & Dextrose	655 (386)	768 (375)	998 (410)	1,012 (491)	882 (631)
Potato Flour	1 (1)	13 (9)	378 (207)	984 (406)	1,644 (1,095)
Poultry Meat	8,812 (7,588)	19,199 (17,043)	16,034 (12,041)	11,827 (8,714)	25,694 (17,746

Source: FAOSTATS (printed in 29/02/04)

Developing industrial opportunities for cassava

Industrial markets for agricultural products can appear highly attractive to potential investors, as they appear to offer the promise of steady and large demand, stable prices, and prompt payments, especially when compared to traditional markets for the commodity. However, experience in Ghana has shown that the relationship between the supplier of the raw material and the end-user may break down if certain factors are not taken into account. Discussions with representatives of Ghanaian industries have highlighted the following as the most important points to take into consideration (Graffham, 2000 cited in Graffham et. al., 2003):

- Manufacture of products to meet the required quality specifications: Before starting production of a cassava-based product, it is important to determine the customer's requirements on quality and for producer and user to agree to quality standards.
- Reliability in maintaining quality: When a quality specification has been agreed upon, it must be maintained at all times. The use of adulterants and short cuts to reduce costs and process times must be avoided.
- Reliability of supply (quantity): Processors must never promise more than they can produce by the agreed delivery date, as the end user will be planning his production on the basis of having the necessary quantities of raw materials.
- Timeliness of delivery: Realistic delivery dates are a must for commercial success.
- Price competitiveness: Industrial users want a local product that is cheaper than the imported alternative. However, reduction in price must not be achieved at the expense of quality.

Ofori et al., (1997) identified the following as the main issues needed for the development of industrial utilization of cassava in Ghana. Processing plants should be sited at vantage points in the cassava producing areas. The plants should be within reach in order to reduce the cost of transportation to processing centres to enable processors to have access to organized market. In addition to organized markets for the fresh roots, the establishment of processing facilities around areas of intensive production could encourage increased production, stabilize prices and enhance value added processing into flours. Commercial production of cassava chips calls for processing equipment that has high efficiency. Available data suggest that Ghana has a comparative advantage at the farm gate for cassava. However, this advantage is quickly eroded further down the marketing chain due to poor road and transport infrastructure and the associated high transport costs, as well as the comparative inefficiency of marketing systems (Day et. al., 1996).

Consultations with cassava end users involved in cassava utilization.

Aims, interests, and activities of end users

Stakeholders involved in cassava utilization may be grouped according to the type of enterprise and cassava products they are working with (Table 18). A preliminary classification was based primarily on scale using throughput of fresh cassava per annum and number of workers as indicators. This classification is only indicative, however, as more extensive data are required. The groupings are as follows:

- Very small family run enterprises
- Groups/ Associations/ Cooperatives
- Small scale enterprises
- Medium scale private limited companies
- Large scale private limited companies

Very small family-run enterprises We interviewed two different types of family-based enterprises. One comprised a family living in peri-urban Duakoro village, Cape Coast town, known as an *Ewe* community, originating from Volta Region. Many women in this community process and sell *gari* to earn income as a major part of their livelihood strategy, together with other non-farm activities such as selling coconut oil, trading fish and biscuits (made from wheat flour). They are not involved in farming. The other comprised an urban-based family-run chop bar in Suhum (Eastern Region), selling a variety of food, including *fufu* and *banku.* In general, *gari* may be produced near the source of fresh cassava or the market, in rural or urban localities. *Fufu* is processed near the market and will almost always involve buying cassava

Groups/ Associations/ Cooperatives A number of different types of village-based groups were identified with an interest in cassava processing. The RTIP MOFA Cassava Multiplication Group in Assin Dawomako (on Cape Coast – Kumasi road) planted newly released varieties and moved into *gari* production as a way of making use of the tubers. The Lolo Soo Group (Volta region) has 55 members, all women. Their main aim is to make money and they are currently doing this through growing maize and cassava, and processing cassava into gari. Ghana Traditional Caterers have an association which appears to be nationwide. We visited the weekly meeting of the Suhum branch. This is potentially an important means of communicating with caterers, such as chop bar owners. The Adidwan Food Farming and Marketing Cooperative Group was formed in 1984, with an original focus on maize. It has 58 members (28 women). They became involved in planting of the newly released cassava varieties and initially sold the tubers to a *gari* processing group. However, they were receiving a low price for the tubers, so decided to move into *gari* production as a means of adding value. They received processing equipment on credit from IFAD/ RTIP (MOFA). They have also started to produce low quality starch and flour.

Table 18. Stakeholders consulted grouped according to type of enterprise and cassava products in which they have an interest

Type of enterprise	Stakeholders consulted	*Gari*	*Fufu*	Flour	Starch	*Kokonte*	*Agbelima*	Grits
Very small family run enterprises	Small scale peri-urban gari processor, Duakoro village, Cape Coast	✓						
	Agye Nyame Chop Bar, Suhum		✓					
Groups/ Associations/ Cooperatives	RTIP MOFA Cassava Multiplication Group, Assin Dawomako	✓						
	Lolo Soo Group	✓						
	Adidwan Food farming and marketing Cooperative Group	✓		✓				
Small scale enterprises	Woraso Co	✓			✓			
	S.N. Cole, Cassava processing	✓			✓	✓		
	Mubasmus Ventures, starch processor, Abura Dunkwa			✓	✓ lower quality			
Medium scale private limited companies	Feed and Flour (Ghana) Ltd			✓				✓
	Elsa Foods Ltd	✓	✓	✓		✓	✓	
	Amasa Agro-processing Company Ltd (Motherwell Farms)	✓		✓		✓	✓	
Large scale private limited companies	Ayensu Starch Company Limited				✓ high quality			

Small scale enterprises Three enterprises which may be considered small scale were consulted. We were directed to a newly established initiative in Woraso village. The owner was based in Asante Mampong town and was in the process of establishing a small cassava factory in Woraso after planting new cassava varieties and realizing that the existing factory was too far away. They are a private company apparently linked to a cooperative. They are interested in *gari,* industrial starch and using residue for livestock feed. At this stage they are only producing *gari*. S.N. Cole Cassava Processing started in 2002 and processes mostly *gari*, with a little *kokonte* and starch. Mubasmus Ventures is owned by a dynamic individual who initially started processing *gari*, but found he was not breaking even. 3-4 years ago he hosted an RTIP demonstration and then saw a television programme produced by CSIR on how to add value to cassava. Currently he is producing low quality starch and high quality flour (on request) and the residue is sold as livestock feed.

Medium scale private limited companies Three of the organizations visited were private limited companies: Feed and Flour (Ghana) Ltd; Elsa Foods Ltd and Amasa Agro-processing Company Ltd (Motherwell Farms) The director of Feed and Flour Ltd used to work for TNCG, the company which exported cassava chips to Europe in the 1990s. The company is focusing on cassava grits and flour, buying both fresh cassava and grits from farmers in Eastern region and renting a plant originally used for *gari* processing. Elsa Foods Ltd is a well established company based in Tema producing 16 different food products using a variety of crops. Cassava products include: *agbelima*, cassava flour*, banku, kokonte, fufu* (instant)

a) Very small, family-run, peri-urban gari processor, Cape Coast, Central Region;
b) Chop bar, pounding fufu, Suhum, Eastern Region;
c) Gari processing group, near Mafi-Kumase, Volta Region;
d) Small scale starch and flour processor; bagging starch for industrial use, Abura Dunkwa; Central Region;
e) Medium scale multi-purpose processing, milling flour, near Amasaman, Greater Accra Region;
f)   Large scale starch processing, bagging of high quality starch, Awutu-Bawjiase, Central Region.

and *gari* (bought and then packaged), Amasa Agro-processing have a cassava factory producing *gari*, high quality cassava flour, *agbelima* and *kokonte*. They grow their own cassava (the farm was a RTIP cassava varieties multiplication site) as well as buying fresh cassava from members of a linked farmers' association.

Large scale private limited companies Ayensu Starch Company Limited is based in Central Region and is the first company to be established under the President's Special Initiative (PSI). The factory is producing pharmaceutical and food grade starch using high tech. equipment and has the capacity to handle 100,000 tonnes of fresh cassava per annum. The company is linked to a farmers association which should provide the fresh cassava at an agreed price. The company also employs extension agents operating in 12 zones around the factory.

Fresh cassava use *per annum* and sources of cassava

The supply of fresh cassava needed by the different individual enterprises appears to vary by a factor of ten between the very small enterprises (tens of tonnes per annum), the small and medium scale enterprises (hundreds of tonnes) and the large scale starch factory (thousands of tonnes). The two very small enterprises we visited were urban-based and buying all the fresh cassava that they were processing (into *gari* and *fufu*) mainly directly from farmers and usually returning to the same villages (but not necessarily the same farmers). The processing groups/ associations were rural-based and generally processing their own fresh cassava, mainly to make *gari*. The three small scale businesses we visited were based in villages/ small towns, with one very much focused on starch for industrial use and the other two primarily *gari*. The starch processor was linked to a cooperative that was supplying 40% of their cassava requirements and the other 60% from two other farmer cooperatives (one of which supplied the cassava already grated and squeezed). For the other two enterprises, one was currently using their own cassava only, but with plans to buy in the future and the other was buying all their cassava (in some cases pre-financing farmers). Each of the three medium scale producers had different arrangements. Food and Flour (plant is based in Amanfrom, Eastern Region) was buying both fresh cassava and grits from farmers. They are providing farmers with drying mats and hope to increasingly buy grits. Elsa Foods – based in Tema - buys fresh cassava, grits (to make flour) and *gari* (which is then re-packaged). The Amasa Agro-processing factory – Ga district, Greater Accra- produces cassava on their own farm, but also buys from other members of the Ga Rural cassava/ Sweet potato Producers' association within 5 km radius of the factory. The PSI starch factory is buying fresh cassava from members of the Ayensu Cassava Farmers Association, but is currently only able to operate at 30% of capacity because of shortages of tubers.

Variations in supply, demand and price of cassava

Two main variations in the supply of fresh cassava were identified by processors, a seasonal variation and 2/4-year cycle. Generally, fresh cassava is more abundant during the wet season and less available during the dry season because of the difficulty of harvesting from hard ground. The demand for cassava for consumption and processing is high during the dry season. This is because other crops are not available and the weather is much better for solar drying. It was also noted that cassava harvested in the rainy season, if it is very wet, is of lower quality. The overall effect is that the price of cassava is generally higher in the dry season. Some organizations have negotiated a uniform price with farmers over a 12 month period. According to some informants, cassava production goes through 2/4 year cycles. Low prices lead to a decline in planting, a drop in production and price increases, but then another year is needed for production to recover. This results in overproduction, price decline etc. In 2003/04, cassava is in a trough. These peaks and troughs are determined by prices and rainfall.

Current markets for cassava products

A range of, mostly domestic, markets exist for cassava products, but export markets are being developed.

Table 19. Products currently produced from cassava in Ghana

Product	**Comments**
Gari	There are examples of *gari* processing at every scale, except the largest enterprises. In most cases *gari* is being sold (although not necessarily consumed) locally to members of the community, local traders, external traders, schools, colleges. The main exception is Elsa Foods, which buys *gari*, re-packages it and then sells to domestic wholesalers and retailers, as well as exporting the product.
Fufu	This is generally produced close to the market. Chop bar customers are a major market including both local consumers and travellers (eg funeral goers). Elsa Foods is producing an instant *fufu* for the local market and more importantly for export.
Flour	Examples were found of a cooperative, small and medium scale enterprises producing cassava flour. In the case of Adidwan Co-op, although they had produced flour they were still looking for a market. Mubasmus Ventures produces high quality flour on request. Feed and Flour and Amasma Agro-processing are currently providing for the domestic market, including providing Elsa Foods. Elsa Foods is serving a domestic and increasingly an export market (eg Angola, Canada, France, Italy, UK, USA, etc).
Agbelima	Elsa Foods and Amasa Agro-processing are producing agbelima –fermented flour.
Starch	Industrial starch was mentioned by all three small scale enterprises visited, but at this stage Mubasmus Enterprises appeared to be the only one consistently producing with a clear market – plywood, paperboard and soap manufacturers. The Ayensu starch company is producing higher grade starch for food and pharmaceutical use. It is being marketed through a Danish Company (International Strach trading, Aarhus, Denmark) which markets the starch under its own name. Occasionally they sell to local markets eg for biscuits.

Links with other stakeholders

In general, the larger the enterprise the greater the number of links with others. All enterprises are either buying fresh tubers from farmers and/ or processing their own cassava i.e. middlemen are generally not involved. The Food Research Institute (FRI) was mentioned by five respondents, including all three of the medium scale enterprises we consulted. This suggests that most effort needs to be concentrated on improving links with small scale end-users.

Main constraints

The constraints faced by stakeholders may be put into 7 main categories. The most frequently mentioned was money (13 responses) and machinery/ equipment (13 responses). This was followed by labour (7 responses), electricity supply (4 responses), marketing and packaging (3 responses), transport (3 responses). Availability/ cost and money to buy cassava tubers if grouped together total 5 responses.

Opportunities

The main perceived opportunity was through increased mechanization of processing. Finance to fund mechanization was a problem across the different enterprises, but some had managed to access loans on a reasonable basis. Two of the larger enterprises talked of a greater involvement of local communities as part of the business. This is a model that the government appears to be promoting.

Information needs on cassava characteristics by end users

Knowledge of varieties and preferred attributes

All of the people consulted were aware of different varieties (See Table 20). The medium – large scale enterprises mentioned, almost exclusively, released varieties (particularly Afisiafi, Abasafitaaa, Tek bankye and Ankra). The majority of smaller enterprises consulted mentioned both local and released varieties. To a varying extent all those consulted were able to characterise at least some of the varieties they used. However, a number of people didn't appear to find it that easy and/ or a high priority to discuss variety attributes (Table 21). Partly because of this, in a number of cases where an enterprise was producing more than one product, we were not able to disaggregate attributes according to specific end-use. Some preliminary observations can be made.

Gari – preferred attributes mentioned: high yielding, early maturity, big tubers, swelling up during processing, not fibrous (related to age as much as varietal differences), cheap, yellowish.

Fufu – swells up during processing, yellowish (otherwise more plantain must be added), easy to pound, not lumpy, not too elastic.

Starch for PSI starch factory- early maturity (10 months would allow a harvest from a piece of land every year), thin skin (maximise starch extraction), regular shaped tubers (to facilitate mechanised peeling).

General – high yield (5 responses), high starch (4), high dry matter/ low moisture (3), big tubers (3), early maturity (3).

Table 20. Cassava varieties mentioned by end users

	V. small family run enterprises		**Groups/ Associations/ Cooperatives**			**Small scale businesses**			**Medium scale private Limited companies**			**Large Ltd Cos.**
Products **Varieties mentioned**	Gari	Fufu	Gari		Gari Flour	Gari Starch	Gari kokonte starch	Starch, Flour Livestock (residue)	Flour Grits	Flour, Fufu Gari Banku Kokonte Agbelima	Flour, Gari Kokonte Agbelima	Starch
Afisiafi			✓		✓	✓		✓			✓	✓
Abasafitaaa			✓		✓	✓		✓			✓	
Tek bankye					✓	✓				✓	✓	
Ankra		✓								✓		
Biafra									✓	✓		
Aba kokoo					✓							
Aba tumtum					✓							
Agric							✓					
Akpagh				✓								
Esi-abeyeme							✓					
Hushivi				✓								
Jamaica		✓										
Local						✓						
Ohyewkaw*								✓				
Rose	✓											
Sosha				✓								
Tuaka		✓										
Valovi				✓								
Wodea-wonyi							✓					

* 6 month variety

Table 21. Cassava products and preferred attributes of varieties reported by end users

	V. small family run enterprises		**Groups/ Associations/ Cooperatives**			**Small scale businesses**			**Medium scale private limited companies**			**Large Ltd Cos.**
Products **Preferred attributes**	Gari	Fufu	Gari		Gari Flour	Gari Starch	Gari kokonte starch	Starch, Flour Livestock (residue)	Flour Grits	Flour, Fufu Gari Banku Kokonte Agbelima	Flour, Gari Kokonte Agbelima	Starch
High yield			✓		✓	✓	✓	✓				
High starch						✓		✓	✓	✓		
Low moisture					✓	✓		✓				
Big tubers	✓			✓							✓	
Early maturity				✓							✓	✓
Swelling up	✓	✓										
Not fibrous	✓						✓	✓				
Yellowish		✓		✓								
Thin skin								✓				✓
Taste							✓			✓		
Cheap	✓											
Easy to pound		✓										
Not lumpy		✓										
Not too elastic		✓										
Good gari					✓							
Good fufu					✓							
Easy to peel						✓						
Fluffiness										✓		
Whiteness											✓	
Regular tubers												✓
Pest tolerant							✓					
Not spongy										✓		
Post-harv. life											✓	

Comparing user information needs with information provided (or available) by those involved in variety development

Breeders and others involved in varietal development collect large amounts of data to inform their decision about selection of new materials. The person / organization which then proposes to release a new variety draws on this information to set out the case for a variety to be released by the Variety Release Committee (VRC). These variety release documents are the main source of information about a new cassava variety emerging through the formal system.

The project team (in September 2004) reviewed three variety release documents to assess whether attributes identified by end-users had been reported. The results are shown in Table 20 below. The varieties which have been recently presented to the VRC have been bred according to specific purposes. For example, SARI aimed to produce early maturing varieties, average yield, tolerant to CMD, CBB, CAD and good for traditional food preparation for the consumers in the northern part of Ghana. KNUST aimed to produce varieties with good cooking qualities, high yield, tolerant to CMD, CBB and CAD. CRI was more concerned with agro-processing qualities eg high starch content. The information made available in variety release documents tends to reflect the uses for which the varieties are intended. For example, SARI provides information about yields after 8 months; KNUST includes information about the poundability of the tubers and CRI provided detailed information about starch. How practical or appropriate would it be to collect and make available information on a wide range of criteria/ attributes in variety release documents or elsewhere?

Table 22. Cassava variety attributes preferred by end-users and whether they are reported in three variety release documents

Variety attributes preferred by end-users	Release documents			Comments
	SARI 2002 -91/02324 -91/02327 -92/0067 First expression	KNUST 2003 -NK2009 -NK2015 -DMA002 -WCH03	CRI 2004 97/4962 97/3982 97/4414 97/4489	
Yield (High)	✓	✓	✓	Higher than local checks plus other attributes that current varieties don't have
Starch (high)	X	✓	✓	
Dry matter/ moisture content (Low)	✓	? X	✓	
Tuber size (big)	X	Dia/ length	Dia/ length	Weight of individual tubers is measured
Maturity (early)	✓ 8 months	X 12 months	X 13 months	This could easily be done by assessing at 8 months
Swelling up during processing	✓ From processing	X	✓ Lab analysis on starch	
Fibre content (low)	Qualitatively	X	✓ Quantitatively	
Colour of tuber flesh	Fresh tuber + Boiled	Fresh tuber flesh + outer cortex	Outer cortex Processed products	
Skin Thickness (Thin)	X	X	X	
Taste	Boiled Processed	Good cooking qualities	Processed	
Price (Cheap)	X	X	X	Determined by many factors
Easy to pound	X – not the focus	✓	X – not the focus	
Lumpiness (fufu)	X	X	X	
Not too elastic (fufu)	X	X	X	
Good for gari	✓	✓	✓	
Good for fufu	X – not the focus	✓	X – not the focus	
Easy to peel	X	X	✓	
Fluffiness (ampesi)	Texture of boiled root	Good for ampesi	X	
Regular tuber shape	✓	✓	✓	
Rodent Field Pest tolerant	Mentioned, but no data	✓	✓	
Not spongy				Same as fibre
Post-harvest life	✓	✓	✓	

Practicality of screening and making available information needed by existing and potential users

Through discussion within the project team a number of points emerged about the practicality of screening material according to the criteria identified by end-users as part of the breeding process. These included the following:

Aims and the nature of the breeding process - the early stages of breeding currently focus very much on pre-harvest factors with associated data collection requirements. If the breeding programme is aiming to produce varieties with a few very specific requirements, then it would be feasible to screen for these criteria at a much earlier stage. Who should decide what criteria are to be included in the screening process and at what point should different criteria be included?

Specific attributes and how they might be addressed

- Tuber size correlates closely with tuber weight which is already measured;
- Maturity period - could be assessed by harvesting at 6, 8, 10 and 12 months. However. environmental factors can influence maturity periods. Could alternative indicators be developed?
- Skin thickness – either actually measure the skin or use a scale. May use a scale to begin with and then make actual measurement when numbers are reduced.
- Post-harvest life – varies between 2 – 7 days depending on variety. Tubers with a high dry matter content store longer.

Other attributes mentioned in release documents – a range of other attributes were mentioned in the variety release documents (e.g. Cyanide content, Glucocytes – for syrups, pH, ash – relates to flow quality and water binding capacity). These terms and their relevance may not always be clear to a non-specialist audience and their meaning needs to be set out more clearly.

Table 23. Analysis of cassava flour samples

Sample	***% Titratable Acidity***	***% Moisture Content***	***pH***	***% Sample Passing through 250µm sieve***
NK 8a	0.6	13.65	6.66	91.59
NK 8b	0.4	13.7	6.56	96.57
NK 6	0.5	13.3	6.60	97.38
KSI 7	1	13.3	5.51	96.24
KSI 10	1.1	12.55	5.70	91.80
KSI 17	0.8	12.85	5.97	95.80
KSI 35a	0.4	13.85	6.52	93.52
KSI 35b	0.4	12.95	6.45	93.06
KSI 25a	0.6	13.8	6.37	90.63
KSI 40	0.9	12.55	5.56	93.57
KSI 48a	0.7	12.65	5.41	97.18
KSI 48b	0.6	13.55	5.55	96.51
AW 9a	0.5	13.65	6.30	95.17
AW 9b	0.5	13.8	6.47	92.68
AW 48	1	13.6	5.48	95.27
AW 2b	0.5	13.25	6.52	95.30
AW 57b	0.6	12.9	5.54	82.13
AW 49	0.8	13	6.41	91.82
AW 68	0.8	12.9	5.91	94.66
AW 63a	0.8	12.95	6.14	93.82
AW 34	0.6	12.75	6.08	97.06
AW 63b	0.5	13.5	6.53	91.51
AW 65	0.7	12.65	6.05	95.07
AW 1	0.5	13.65	6.64	92.49
AW 2a	0.7	12.95	6.02	not done*
AW 64	0.5	13.45	6.30	88.31
AW 57a	0.6	13.5	5.61	89.06

** Insufficient sample for analysis*

Originally, it was planned that a sample of cassava storage roots would be screened for the attributes/ information specified as needed by end users within a limited budget. The information was then to be made available to the case study end-users (and others if possible) and through an iterative approach the most user-friendly means of making information available was to be identified. Cassava flour samples from 27 clones (three from

Nkaakom, nine from Kwadaso and 15 from Aworowa sites) have been analysed by FRI for % titratable acidity, % moisture content and pH. How appropriate these data are to end-users is not yet assessed.

Assessment of opportunities and constraints for improving communication between stakeholders to enable germplasm development to improve cassava utilization

In the above process a range of individuals and organizations who have an interest in cassava utilization and variety development were consulted. Through these consultations, laboratory screening of materials and the exploration of means to communicate the demand for and supply of attributes of different cassava types, an assessment of how to improve communication between stakeholders to enable germplasm development to improve cassava utilization can be made.

Supply versus demand driven enterprises - many enterprises have become involved in cassava processing through planting of released varieties and subsequent increased production. ie new varieties were the means by which many stakeholders have become involved in utilization. This raises concerns that the current system is prone to over-production.

New varieties in the context of existing constraints and opportunities - most stakeholders did not appear to consider the availability of further new varieties an important issue and were apparently satisfied with what they had. Other constraints were generally considered a higher priority eg lack of access to finance, insufficient mechanization and labour shortage.

The potential of new varieties - although most stakeholders did not consider access to new varieties a high priority, new germplasm may offer a means of addressing some of their problems and providing new opportunities. Some users may have specific requirements which may be addressed by closely targeted varieties. For example, the PSI starch factory is facing a shortage of fresh tubers using a variety harvested after 18 months. Access to a high yielding, early maturing variety may help to address this problem. Other attributes may cut across the needs of a broader range of end-users eg high starch and high dry matter content. Achieving the appropriate balance between breeding varieties which are broadly acceptable across a range of end users and agro-ecologies, but perhaps only reach a minimum adequate level for an array of attributes *versus* varieties which are more suited to particular end users and agro-ecologies is an on-going challenge. Improving communication/ links between those involved in variety development and end-users, so that all parties are more aware of the potential that cassava germplasm offers, will contribute towards resolving this issue.

Improving communication between researchers and end-users - there is a wide range of end-users which may have differing needs and require different approaches to improve communication with those involved in varietal development. Members of the project team participated in a recent workshop[1] in Accra which brainstormed on both differences between

[1] The Cassava-SMEs (Small and Medium scale Enterprise) project aims to develop an integrated package of tools, approaches and technologies to enable rural cassava producers and processors/SMEs to produce improved versions of traditional products for which there is proven expanding urban demand. The project takes an interdisciplinary approach so that technologies can be developed that take into account the needs of current processors who depend on the crop and its processed products for their livelihoods. Specific attention will be paid to undertaking the research on a processing/commodity chain basis to ensure the sustainability of recommended approaches. Best practice guidance for SMEs producing the selected products will be established. Food safety and product quality will be optimised through approaches that can be applied at the SME level. This EU- funded project started in 2003 and is due to be completed in December 2005. NRI's partners include University of Ghana, Food Research Institute (FRI) Ghana, University of Agriculture, Abeokuta, Nigeria, Institute of Advanced Studies and Food and Feed Ghana Limited.

and ideas for improving collaboration between the private sector and public sector researchers. This provides some ideas (see below)which on to improve communication. It should be noted that the survey itself is a means of improving communication, especially since it involved the national cassava breeder.

Table 24. Themes, components and indicators of research with the private sector

Theme	Component	Indicator
Research process	- Demand driven - Co-funding - Common needs - Consumer goods focus	Joint plan
Technology	- Cost effectiveness - Consumer acceptability	Consumer acceptability
Training	- Private sector should be trained - Feedback	
Awareness	- Private sector must be aware of research organisations - Private sector need to be aware of research process - Private sector aware of dissemination	
Relationship	- Trust - Common understanding	
Policy	- Favourable policy environment for SMEs	
Legal framework	- Ownership issues (IPRs)	

Links between pre-harvest researchers, post-harvest researchers and end-users - some post-harvest research organizations (eg FRI) have relatively good links with end-users. However, consultations with end-users, post-harvest researchers and others suggest that links between pre and post harvest researchers both within CSIR and between CSIR and others need to be strengthened.

Initiatives involving a range of stakeholders from the early stages would appear to offer opportunities for improved communication and ultimately uptake of new varieties. A number of end-user stakeholders and post-harvest researchers have expressed interest in assessing new germplasm. For example, the Ghana coordinator for 'The development of the small and medium scale enterprise sector producing cassava based products to meet emerging urban demand in West Africa' project (Dr P. Johnson) encouraged us to introduce new varieties into on-going project activities. We explored opportunities for further interaction with this project and strengthened our links with the DFID Crop Post Harvest Programme (CPHP) funded project. A further survey involving the Ghanaian national cassava breeder has been done and this has both further highlighted this issue but also helped, by his involvement, to address it.

Constraints to improving communication

- The activities of the potential partners may have different time spans. For example, breeders require at least five years to develop a new variety whilst post-harvest researcher may require at most two years to research into the suitability of the varieties for the end-uses.
- Inadequate funding would currently prevent post-harvest researchers from screening the usually large numbers of cultivars breeders evaluated at the initial stages of the breeding programme.
- Institutes may compete for funding.
- Although directors of CSIR institutes meet regularly, there is no such forum for scientists to discuss research issues.
- Trust, suspicion and ownership issues
- Post-harvest researchers still need to develop mass screening methods for the early stages of the varietal development process.

Future opportunities

1) Joint activities with post-harvest researchers and end-user stakeholders (including CPHP and EU projects) - joint trials have been planned and two have been initiated (see below). Entries include: PCB selection – approximately 15 clones; local varieties; recently released varieties.

Table 25. The main actors with whom future cassava selection trials have been planned

Who	Where	Region	Focus	When
Mubasmus	Abura Dunkwa	Central region	Flour mainly	November 2004
Amasa –Agro	Ayikai Doblo	Greater Accra	Flour, kokonte, grits, gari	November 2004
Farmers in PCB villages	PCB project current villages	Ashanti	Fufu and other to be identified	April/ May 2005
Adidwan Food farming and marketing Cooperative Group	Adidwan	Ashanti region	Gari , flour	April/ May 2005
Fufu group	Aburaso	Ashanti region	Fufu	April/ May 2005
Farmers in PCB villages	PCB Current villages	Brong Ahafo	Fufu and other to be identified	April/ May 2005
Adom Cassava flour group	Nyame Bekyere	Central region	Gari (previously flour, but no market), fufu (home consumption)	April/ May 2005
Feed and Flour	Amanfro	Eastern Region	Grits, Flour	April/ May 2005
GNAF –Okper branch	Okper (near Boti falls)	Eastern region	Kokonte	April/ May 2005
Farmers supplying/ Suhum chop bar owners Ghana Traditional Caterers Association: Suhum branch	Nr Suhum	Eastern region	Fufu	April/ May 2005

Carry out further targeted consultations with an emphasis on Ashanti and Brong-Ahafo regions (close proximity makes communication easier).

2) Raise awareness of the potential offered by new germplasm to meet the needs of end-users. A number of ideas have been incorporated into a project proposal to be funded by the DFID Crop Protection and Plant Sciences Programmes and due to start in April 2005. This includes a video illustrating how attributes of varieties offer potential to improve cassava utilization. Preliminary discussions have been held with the CRI Communications Officer.

3) Explore existing networks, associations etc as a means of communicating with cassava end-users e.g. Ghana Traditional Caterers Association.

4) Improve access to information about post-harvest analysis eg manual/ leaflet explaining terminology (e.g. ash) and information on what attributes are desirable for given products

5) Improving communication between CSIR organizations – the Research Staff association (RSA) N. Sector has recognized the lack of communication between CSIR organizations and has organized group visits to the different organizations. It is recognized that personal relationships are important and should be encouraged. Joint seminars would provide opportunities for sharing and developi9ng of ideas.
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6) A workshop aiming to strengthen links between cassava varietal development and end-use through sharing of lessons amongst stakeholders especially in West Africa.

7)The Root and Tuber Crops Improvement Project (RTIP) is shifting from a pre-harvest focus in phase 1 to a post-harvest focus in phase 2; and this may help develop links.

3.Implications of participatory plant breeding for official variety release, including requirements for pest and disease resistance, assessed.

Requirements for Variety Release Participatory plant breeding (PPB) needs to be incorporated within the requirements of national variety release systems if it is to be sustainable and if the benefits it offers are to be utilised effectively within the national system. Thus, official variety release is a prerequisite in Ghana for multiplication and national distribution of cassava cultivars by MOFA through, for example, the IFAD-funded RTIP, the GTZ-Sedentary Farming Systems Project and by World Vision. The involvement of CRI, which is an institute within the Ghanaian Council for Industrial Research (CSIR), as one of the two main participants in the Project, provides an opportunity whereby PPB can be incorporated within national cassava breeding activities as CRI is one of the main centres of cassava breeding in Ghana: the national cassava breeder, Mr G Ampong-Mensah, is also a very active member of the Project team. The advantages of this position were further developed by the involvement of Ghanaian Ministry of Food and Agriculture (MoFA) extension officers in all field activities in Nkaakom and Aworowa from the initiation of the project and by involving a wide spectrum of government officials involved in cassava production and utilisation in the Elmina Workshop on Participatory Cassava Breeding: Update and Opportunities, in October 2002. The Secretary of the Ghanaian Variety Release Committee (VRC), Dr Asiedu, is also based at CRI, again enabling the easy exchange of information so as to enable the project to determine key information required by VRC for the release (and hence large-scale national distribution) of cassava clones identified by PPB.

The links with VRC were officially established by the lead scientist of the Project at CRI delivering to Dr E. Asiedu the following letter - which sought to provide the VRC members with detailed description of the project's PPB approach and to request their support.

Dear Dr Asiedu

Varietal release of cassava clones selected through a farmer/scientist participatory process

I have been keeping you aware through occasional briefings of the work we (Dr E. Moses, Dr. A.A. Dankyi, Dr. J.N. Lamptey, Mr. G. Ampong Mensah and myself) have been doing at CRI since 2000, selecting cassava clones through a close collaboration with farmers and local MOFA extension staff. We feel confident that this process is leading us to identify a panel of useful clones of cassava and we realise it will be necessary for the best ones to be officially released through your committee if Ghanaian farmers are going to benefit fully from them. Cassava also takes a long time to grow, so if we go through the process of preparing our material for release yet plant the wrong trials, it could take us more than a year to recover lost ground. Therefore, I am providing you in this letter with some details of the breeding process we have used (as it is somewhat novel) and the data we have managed to obtain so far with the hope that this allows you to help us plan things more appropriately.

I will start by reiterating the underlying philosophy behind the work we have been doing. Farmers have developed some of the most useful cassava varieties (landraces) available in Africa. However, in achieving this, they had several disadvantages: for example, individual farmers have access to only a narrow range of germplasm and they lacked the scientific understanding of the processes including how variation occurs – farmers we interviewed had no knowledge of the role of pollen. Scientists and farmers tend to have complementary strengths and the aim of our work has been to try to draw on the strengths of each. Consequently, we (scientists) provided farmers with access to a diversity of germplasm obtained from IITA yet during our selection process, both farmers and scientists had an equal say in which plants to keep. Thus, during the first few years of selection, anything selected by either farmers or any group of scientists (plant breeder, agronomist, pathologist) was kept for a further year of evaluation. Because this project was part of my PhD work, we also tried two types of locations. One was CRI's farm at Kwadaso in the Forest zone with local farmers coming on-station to make selections and the other was a communal village field - at Nkaakom, also in the Forest zone, and at Aworowa in the Forest-savannah transition zone. The process is illustrated schematically on the final page.

2000/1 growing season. The participatory plant breeding process started in early 2000 when we contacted Dr Alfred Dixon at IITA Ibadan to ask him for seed of 'good' cassava families with special emphasis on:

- Diseases, particularly CMD, resistance;
- High storage root (tuber) yield;
- Ghanaian or at least West African origin.

He provided us with seeds of 18 suitable half-sib families.

We then linked with the villagers in Nkaakom and Aworowa, explaining our plans and doing a 'situation analysis' to help us to work more effectively with them. Then, around June/July 2000, we planted the seeds Dr Dixon had provided us with - at Kwadaso, Nkaakom and Aworowa. The seeds were planted in families (and we have continued to keep careful records throughout the whole process so we know which seed family each plant derives from). In total, we grew 2,042 seedlings over the three sites. We took records over the growing season of both phenotypic characters and disease (cassava mosaic disease (CMD), cassava anthracnose (CA) and cassava bacterial blight (CBB)) and, at harvest in 2001, tuber yield and tuber number. As mentioned already, we all (scientists and farmer groups) inspected the plants and chose those we would like to keep for another year. Scientists selected according to their discipline and farmers made a list of their key selection criteria.

2001/2 growing season. At each of the three locations, 12 cuttings of each selected seedling were replanted in single plots in an unreplicated block. Plots of 12 cuttings of each of two released varieties, Afisiafi (TMS 30572) and Abasafitaa (TMS 4(2)1425), five promising landraces selected from amongst germplasm collected from the Forest/Savannah Transition Zone (Brong Ahafo) and currently being evaluated for national release (DA 002, NK 009, NK 015, WCH 009 and WCH 037) and three popular landraces (Akosombo, Bensre benma and Wenchi bankye at Aworowa and Debo, Bankye kokoo and Bankye green) from each community were also included at each location. Four hundred seedling clones were in total replanted in 2001. The same cycle of observations and recordings throughout the year occurred and the plots were harvested roughly one year later in 2002. Again, scientists and farmers selected; in total, 179 seedling clones were selected.

2002/3 growing season. Another communal trial was replanted at each location for each selected seedling clone, again with the same set of check clones. However, because we now had more planting material, farmers were also encouraged to take cuttings of seedling clones they particularly liked to grow in single plot trials on their home farm. We included these in our observations and recordings in 2002/3. Again, scientists and farmers selected but now, because we realised we were getting near to our goal of identifying clones suitable for variety release, we scientists excluded the few seedling clones that appeared susceptible to CMD, CBB or CA. In fact, very few had to be excluded on these grounds and I should add that selection for CMD resistance was strong at all three sites throughout the three years.

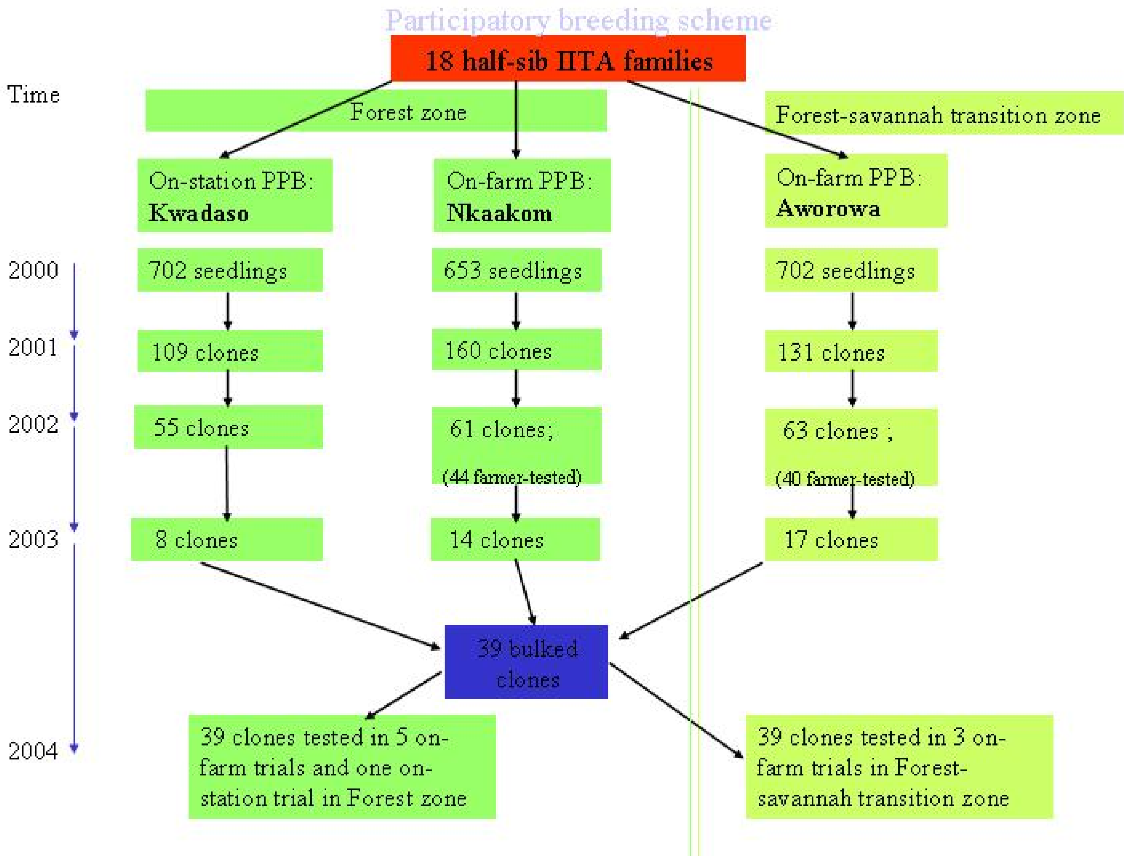
2003/4 growing season. This process of selection has now identified just 39 clones over the three sites and we decided, partly as a result of consulting the documents you provided me with explaining the conventional variety release procedure, that we should concentrate available planting material on multi-locational trials. We therefore planted nine single replicate trials, three in the Forest Savannah transition zone, and six in the Forest zone including one on-station trial at Fumesua. These will be harvested either late 2004 or perhaps at the start of the growing season in 2005.

Please view this letter partly as a way by which we are trying to keep you and the Variety Release Committee informed of our somewhat novel way of selecting new varieties. Of course, we are doing this because we are keen to be able to comply with official release procedures. We would really appreciate any comments you may wish to make on our progress and your advice as to how we can strengthen our case for the release of one or more clones derived from this process. I realise that we are a year or two away from our goal but one big advantage we see for this new approach is that time is saved by getting farmers and scientists to select simultaneously rather than first the scientists and then the farmers. We would therefore like to demonstrate this by achieving early release. I should also add that I have compressed the detailed observations we have made. This is my PhD and you can therefore appreciate that I have had to keep extremely copious records of disease levels, plant phenotype, yields, farmers' criteria etc.

Looking forward to hearing from you,

Yours sincerely

J.A. Manu-Aduening



Along with this letter, the Project team obtained copies of release documents for recently released variety in Ghana. A comparison of these with end-user requirements has already been presented in Output 2 (Table 22). The Project team had previously reviewed to what extent our current (2003) field activities were able to provide the information previously provided in release documents, so identifying areas where additional activities would be required.

Table 26. The main field requirements identified from variety release documents

Required Data	Data currently available or being collected	Additional data required
Multilocational replicated on-farm yield trials across target agroecological zone	Trial data over 3 clonal generations at Nkaakom/Fumesua (Forest) and Aworowa (Forest-Savannah Transition)	YES: Additional trials particularly required in Forest-Savannah Transition Zone
Inspection trial, usually on-station, to validate description of a variety	On-station trial at CRI	NO
There is a need to provide evidence of sufficient supplies of planting material for farmers: to be available in the event of release being approved.	Current trials (see above)	YES: Additional sources of planting material will be needed. However, this is difficult to do for all 39 clones.
Proof that proposed varieties are not unusually susceptible to common pests and/or diseases of the crop	Data have been collected on pest and disease incidence and damage in all trials; clones have been selected for disease resistance.	NO

New trials were established with a further 8 communities 3 in Ashanti (Forest Zone) and 5 in Brong-Ahafo (Forest Savannah Transition Zone) during September and October 2003. As at Nkaakom and Aworowa, these were planted in a single replicate trial at each site and again included all 39 clones selected by farmers in Aorowa, Nkaakom and Kwadaso. Local landraces, superior landraces selected from within Brong-Ahafo Region and nationally released varieties were again included as checks. These field trials together with the trials at Nkaakom, Aworowa and Fumesua (the Kwadaso on-station trial was transferred to the main station at nearby Fumesua) therefore comprised a randomised block design replicated 10 times. The location of these sites involved consideration of synergies with partner organisations (MoFA, GTZ and World Vision), a desire to include a community making cassava flour and advice from Secretary to the Variety Release Committee Mr E. Asiedu, and the CRI cassava breeder of the need to establish a certain number of trials within the agro-ecologies we were targeting for variety release. Trials are being monitored quarterly by CRI and/or MoFA staff for plant survival, pests and diseases; it is expected that they will be harvested in May 2004.

A further two trials were established late in October with farms associated with medium-scale enterprises: with an industrial starch and flour manufacturer at Abura Dunkwa in Central Region and with a cassava food manufacturer at Ayikai Doblo in Greater Accra Region. These trials involved only 15 of the farmer-selected clones – reduced partly as a result of positive selection on the basis of healthy foliage and partly because of limited planting material – but each trial comprised 3 replicates.

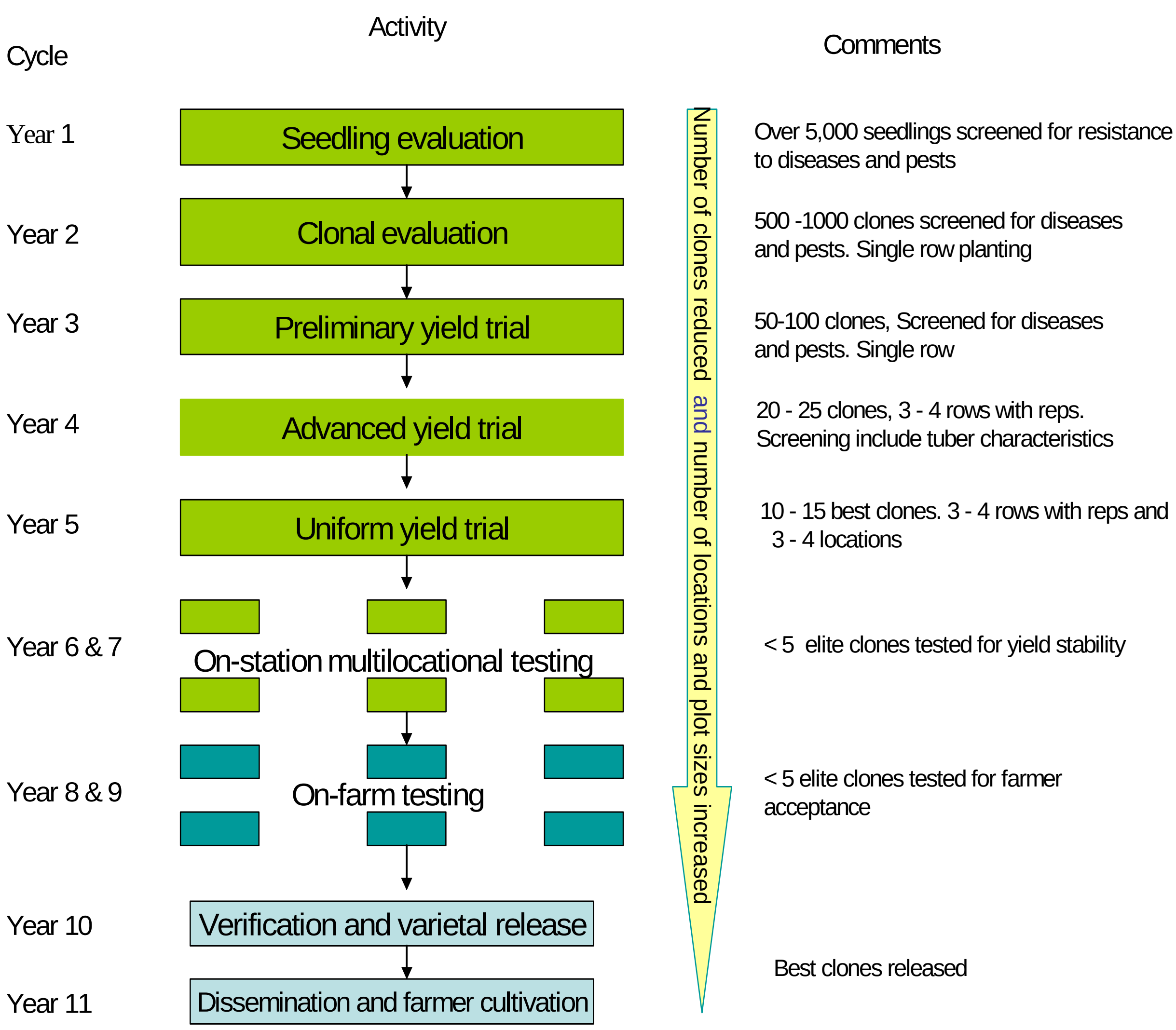
The current on-farm trials will be harvested in May 2005. This is expected to lead to the identification of one or a few clones for release and multiplication of planting material will focus on these.

Implication of PPB for Variety Release Conventional breeding of cassava as currently done at CRI is illustrated in Figure 6. Major differences with 'our' PPB are that:

- almost ten times more seedlings are evaluated at CRI in conventional breeding than at each of the communal village trials, so it would be necessary to scale out PPB either by including more villages or making village trials larger if the same number of seedlings are to be trialled in PPB.
- On-farm trialling only commences in Year 5 and is a verification that the clones for release are appropriate for farmer use.

There is, however, a strong focus in both approaches on resistance to pests and diseases

Figure 6. Conventional breeding scheme used in breeding for superior cassava at CRI in Ghana



The early inclusion of farmers' opinions in 'our' PPB starts on-farm is clearly, with hindsight, part of the explanation how our project can consider applying for variety release within 4 – 5 generations – because the farmer verification is done simultaneously with selection. This seems to be a major advantage of the process as regards documentation required for variety release.

By contrast, one advantage of conventional breeding is that it's slower progress allows opportunity for multiplication of planting material to keep pace with demands for it. By contrast, availability of planting material has been an ever-present problem for our project. This is partly because early involvement of farmers led to some planting material being diverted to satisfy farmer demands rather than trial requirements. It was also that both project timescales (requirement for early evidence of success for ensuring project renewal) and farmer timescales (Farmers were not prepared to wait 11 yrs) required rapid progress, for which the slow vegetative propagation of cassava (perhaps 10x each generation cycle) is inadequate unless enhanced by use of rapid multiplication techniques, for example, using one or two node cuttings.

Overall conclusions on PPB for cassava: successes, failures and how it should be changed in the light of project experiences.

The low adoption of previously released cassava varieties in Ghana and the continued reliance of Africa generally on cassava landraces (see Introduction) make a clear case for the need to introduce some form of enhanced farmer participation in cassava breeding. Participatory plant breeding is not, however, a prescribed process: there is a core approach in that farmers are involved in the breeding process from an early stage but many variations in the detailed format have been included within this broad approach. The project's approach is therefore only one of several which could have been taken and it seems useful at this stage to revisit the process to examine which were the successful and less successful aspects of 'our's'.

- We did take care to obtain seeds of families from crosses made between high-yielding, disease-resistant parents of West African, sometimes of Ghanaian, origin. The crosses were made at IITA-Ibadan in Nigeria. Whilst an important role of scientists in PPB can be to provide farmers with a wider range of genotypes than they could normally access, it seems important for local scientists to be more involved in originating the seeds.
- It is arguable that it could have better if we had started by planting out the seeds on-station and growing the seedlings there. On the plus side, this would have allowed the project to provide farmers with cuttings, their normal planting material but, on the negative side, farmers might have learnt less and understood less about what they were doing if this had happened. It is noteworthy that planting out the seeds in the village did not present any major logistical problems.
- We planted seeds on-station at Kwadaso for one of the trials and invited local farmers to join the CRI scientists in selecting superior genotypes. This was the only trial site at which we lost many plants – due to waterlogging in a low-lying part of the trial – perhaps indicative of the value of farmers' local knowledge at Nkaakom and Aworowa. Farmers here also did not seem to have as much ownership of the trial as farmers at Nkaakom and Aworowa.
- The farmers involved in the on-station trial at Kwadaso were also restricted to those nearby the research station and therefore perhaps less typical of Ghanaian farmers. It would have been difficult to 'bus in' large numbers of farmers from distant locations whereas it was relatively easy for scientists to travel to villages.
- Our inclusive approach whereby everyone's selection is retained seemed effective. It was very inclusive, helped maintain diversity, provided a safety net whereby good genotypes were not easily lost and was easy to apply. It did not slow the process excessively
- Farmers were assisted in making selections at the seedling generation by arranging for them to select within small groups of 20 – 30 plants (a seedling family). Although this allowed farmers to select, apparently effectively, from amongst a total of 650 – 700 seedlings, it is hard to imagine this being successful with much larger numbers. Larger numbers of seedlings could be utilised by simply involving more communities. An alternative might be to make careful selection of superior seedling families by preliminary trials either on-farm or on-station so that fewer seedlings need to be trialled.

- The participatory breeding team included farmers, a plant breeder and plant pathologists. The expanding markets for processed cassava both for food and non-food uses suggests this team is not enough and various options to address this deficiency are being explored.

One common criticism of PPB is that it is very expensive in terms of both farmers' and scientists' time. This was not our experience. Once past the early seedling stage, cassava is robust and did not require frequent monitoring to ensure its survival. Furthermore, the farmers and local extension staff assisted in this. Monitoring of pests and diseases was done quarterly by scientists and this was slightly more expensive than it would have been on-station. Since participatory breeding involved a number of scientists with different disciplines working together, it also resulted in efficiency of evaluation and selection. Harvesting and selection required just one day at each site per year as did replanting, both for farmers and scientists and resources (land, labour) were cheaper off-station. A huge reduction in the duration of the breeding programme, perhaps by 4 years, appears to have potentially been realised by using the participatory approach (Figs 1 & 6). Brennan and Morris, (2001) have shown that the rate at which benefit accrue from an investment in plant breeding significantly affects the rate of return and is usually high if the time to breed a cultivar that is grown by farmers is reduced. For example, Pandey and Rajatasereekul, (1999) showed that the economic benefit of completing a breeding cycle only 2 years earlier was $18 million for rice in Thailand. Although a cost and benefit analysis has not yet been done for this study, these savings in time could more than compensate for travel allowances for scientists which made this process much shorter than using the traditional formal breeding. It is also important to bear in mind the lack of adoption of conventionally-bred varieties to-date in Ghana against the presumption that varieties bred with a large involvement by farmers will be adopted extensively.

Despite these apparent pluses for PPB for cassava, it is worth stressing that some resources are required to ensure its long-term sustainability and this needs to be provided through institutional core funding rather than project-based. Whilst farmers in each of the communities we worked in were keen to continue following through with selection of clones, none suggested that more seedlings should be obtained to start a fresh cycle of PPB. The project has not examined different models by which this could be achieved but it seems feasible that communities might elect one or a small group of farmers to receive a small annual sum to carry on the process each year.

Contribution of Outputs to developmental impact

Achievements and further stages needed

Cassava is the second most important food crop in Africa after maize, providing about 12% of calories but reaching double that in Ghana. It is also a food primarily of poor people. In Ghana, cassava processed, for example, into gari, is one of the cheapest staple food available and our situation analyses identified how cassava is increasingly being turned to as population pressures increase on the land. Thus, the project contributes to DFID's development goal of boosting the sustainable production of food for poor people. However, cassava is also a cash crop, sold fresh, processed into various traditional foods and can produce starch sufficiently cheaply to sustain intensive animal production and act as an industrial feedstock, roles are being developed in Ghana by projects funded through CPHP. By these means, cassava contributes more broadly to sustaining livelihoods of poor people, providing cash to poor farmers, cheap high-energy food to urban dwellers and also employment for those involved in manufactures based on it.

The project contributes to these roles by working with farmers to develop new varieties appropriate to their needs. The project has gradually shifted its focus from production for local use to production for a broad range of end-users, still including local use but now also including uses ranging from micro-scale processing on-farm to medium-scale industrial manufactures, thereby shifting towards a more holistic livelihoods approach. In order to achieve this, it has commissioned studies of end-uses, end-users and researchers working on end-uses of cassava in Ghana. These have been conducted primarily by the Ghanaian cassava breeder with the intention that it should achieve the additional secondary target of involving him with these subjects. **The reports have identified opportunities for strengthening links between cassava breeders, cassava post-harvest researchers and cassava end-users**. **The process of preparing the reports has also already to an extent achieved this**: Evidences for this are that the cassava breeder has commenced a PhD study within this target area and such starch quality characteristics as its pasting characteristics, provided by the Food Research Institute of Ghana, are included in cassava variety release documents, certainly for the first time for Ghana and perhaps for the whole of Africa.

The main aim of the project is to use participatory approaches to develop new cassava cultivars which are adopted by Ghanaian farmers to such an extent as to have a broad beneficial effect on livelihoods. This may eventually be achieved by farmers themselves identifying superior clones, growing them themselves and passing them to neighbours and so on. However, a quicker way to achieve mass uptake is through official distribution. This requires release through the Ghanaian Variety Release Committee (VRC). **The current project has established links between participatory breeding and official variety release in Ghana and to set in motion the trials necessary for providing the documentary evidences required by the VRC.** Remaining targets include

- to achieve the documentation required for variety release
- to prove through successful submission that participatory breeding can quickly achieve release of new cassava varieties
- to disseminate the utility of participatory breeding to breeders of other crops.

Those superior clones that have been identified have been selected by scientists and farmers working in farming conditions – so the farmer has been the assumed end-user. This is consistent with current practice in conventional breeding, final validation of varieties being done in multilocational trials on farmers' fields. This procedure in both cases ignores the reality that farmers' households are often not the ultimate end-user of the product; much cassava is sold on often for processing. **The project has already established two field trials on farms belonging to medium-scale end-users.** A further remaining target is therefore:

- to incorporate, in addition to farmers, other end-users in a participatory breeding process.

It is planned to achieve these remaining targets during an extension to the current project.

Part of the process of achieving inclusion of the participatory approach to plant breeding schemes which receive some external support (government, NGO or international funds, for example) is documentation of the process. This has been achieved in project working papers, academic publication (see below) is partially achieved, enabling less formal publications soon to be written. However, a system also needs to be developed whereby PPB is somehow established more permanently through inclusion in some long-term process. An example might involve the use of the village-based government agricultural extension agent. Perhaps such a person in strategically-located villages could be funded on a long-term basis to manage the equivalent of the community trials developed by our project, farmers in the village being involved in variety selection. Testing the utility of different variants of such a scheme will involve small, long-term funding probably best achieved through national programme activities.

Disseminations

Two working papers derived from work done during R7565 were finalised during early project activities:

- *Informal exchange of cassava genotypes and farmers' knowledge and use of sexual propagation of cassava.* 53pp

- *Participatory breeding for superior mosaic resistant cassava in Ghana: two years of seedling/clonal evaluation by farmers and scientists.* 54pp

A presentation *Combining the interests of farmers and scientists in a participatory approach to breed for superior mosaic resistant cassava* was made to the International Society for Tropical Root Crops – Africa Branch meeting in Mombasa in November 2004.

Mr J Manu-Aduening completed the collation and analysis of his PhD study entitled '*Participatory breeding for superior mosaic-resistant cassava in Ghana'*

Three further working papers based on surveys and other activities undertaken during the current project have been prepared:

- *Participatory cassava breeding in Ghana: survey of cassava end-users*
- *Participatory cassava breeding in Ghana: a review of current and potential utilization of cassava in Ghana and its implication for varietal development*
- *Participatory cassava breeding in Ghana: survey of cassava post-harvest researchers*

One manuscript entitled *Cassava diversity and evolution in Ghanaian farming systems* has been submitted for publication to Euphytica

Two further publications in academic journals are being prepared, one on participatory breeding for cassava and another on the use of participatory breeding for disease resistance.

I confirm that the biometric issues have been adequately addressed in the Final Technical Report:

Signature:
Name (typed):
Position:
Date: