CROP PROTECTION PROGRAMME

Participatory breeding of superior, mosaic disease-resistant cassava: enhancing uptake
R8405 (ZA0633)

FINAL TECHNICAL REPORT

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Executive Summary

Trials of 35 cassava accessions selected by a collaborative process between scientists and farmers had been conducted in nine different sites in the Forest and Forest Savannah Transition Zones of Ghana. Disease incidences and yields in these trials have been recorded and collated. Further trials of 12 accessions selected from these 35 have been planted; these included trials on 2 cassava processors farms planned both as a means of assessing the value of these accessions for the processing industry and as a tool for alerting processors to the opportunities new varieties can provide them. Three of these 12 accessions have been identified as 'front runners' for variety release based on their yield, disease resistance and farmers' preference. These have been planted more extensively in inspection sites for the Variety Release Committee and to provide planting material in anticipation of their official release.

Part of the collaborative breeding process is the establishment a more decentralised breeding approach to cassava in West Africa and cassava crossing blocks have been planted at 2 sites in Ghana predominantly with superior local varieties plus [a few] superior IITA clones so that Ghanaian breeders can themselves develop crosses appropriate to Ghanaian farmers' requirements. The collaborative breeding process has continued to be extended through links with sweet potato breeders in Uganda and Tanzania. The main effort on dissemination has, however, been through publication of the project's approach and achievements in an international peer-reviewed journal, Euphytica, analysis by project members having identified that national agricultural research station breeders needed to be targeted and that this would be a main way they would judge and learn of such work. Once this was achieved, further efforts have been made to ensure their awareness of the work by publishing in more popular articles in African regional newsletters and cross-referencing.

An additional activity has involved two surveys aimed at evaluating the impact of the project's activities and of the cassava accessions within the communities the project's activities were based in. Although 'early days', the outcomes were broadly encouraging.

Background

1. What were the key findings of the previous research or promotion upon which this proposal is based?

The collaborative breeding process for cassava: In a collaborative project with the Crops Research Institute (CRI) in Ghana funded by the Crop Protection and the Plant Sciences Research Programme (PSRP), about 1400 cassava seedlings from superior, CMD-resistant parents have been grown amongst 2 communities of Ghanaian cassava farmers. The two communities were Nkaakom in the Forest Zone and Aworowa in the Forest Savannah Transition Zone. An addition set of seedlings was grown on-station at Kwadaso in the Forest Zone. At all three sites, superior genotypes were selected by farmers and scientists. A process was validated whereby farmers and a multidisciplinary team of scientists collaborated together throughout the initial seedling generation and just four subsequent clonal generations to select out 37 superior diseases-resistant clones acceptable to all three groups of actors. The criteria of each were recorded throughout this process. Although yield was important to the farmers, qualitative criteria were also important. Disease resistance was selected for during this process. This is the first time the latter has been reported during participatory breeding and contradicts the concept that diseases are less ‘apparent’ to farmers than, for example, insect feeding damage. Although farmers, unlike the plant pathologists and breeder, seldom rejected plants on the basis of diseases, they selected for healthy looking leaves, plants with a vigorous canopy likely to control weeds and plants with a high yield, again likely to be ones unaffected by pest or disease constraints. Farmers have been encouraged to take planting material back to their own farms to test themselves. Advice has been obtained from the Ghanaian Variety Release Committee as to the information it requires about material selected through a collaborative breeding process and, based on these advices, the 37 clones have gone forward to multi-location on-farm trials in both the Forest (7 sites) and the Forest-Savannah Transition zone (5 sites). To get to a multi-location on-farm trial stage within six generations with materials that have already been validated by farmers confirms the huge time benefits of the collaborative process. The general success of the approach has encouraged a broad shift towards collaborative activities at the host institute (CRI).

The process has been transferred to sweet potato selection in both Uganda and Tanzania, three communities in each country participating [reported in FTR for R8303]. The generation time of sweet potato is about half that of cassava, leading to these trials ‘catching up’ with the cassava trials in Ghana.

Including non-farmer end-users in the breeding process: The identification by farmers of the importance of markets during initial situation analyses and wider comment provided during our Workshop highlighted non-farmer end-uses. These included the fresh market for homes and restaurants, and small and medium-scale processing such as the starch factories being built under the President’s Special Initiative. Purposely including the CRI cassava breeder in researching such postharvest varietal requirements has increased awareness of market needs. Links to post-harvest researchers at other institutes and processors have also been strengthened by involving them in the final selection of cassava clones.

Indigenous cassava diversity: The evolution and maintenance of cassava diversity by communities in Ghana has been studied for a range of ecological and socio-economic environments. Landraces predominated; communities acquired (and lost) a landrace roughly every decade. Although farmers reported that their landraces had originated from outside their community and they knew little about how new landraces evolved, about a third of farmers had consciously used cuttings from natural seedlings when cutting material was scarce and about 5% had purposely experimented with cuttings from seedlings. A paper describing this work has recently been accepted by the international refereed journal Euphytica.

Purpose

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

Subsidiary to the above, the extension project had two main purposes,:

1. To promote scaling out the outputs of our collaborative breeding programme, scaling out either the product (Activity 1) or the process (Activity 2).
2. To involve a wider range of end users in a collaborative breeding process in Ghana, particularly those involved in processing and in small or medium scale enterprises not closely involving farmers (Activity 3).

Research Activities

Activities involved in scaling out the product (Activity 1) of our collaborative breeding mainly involved conducting field trials identified in the previous FTR as required for presenting superior clones for release through the Ghanaian Variety Release Committee.

Activities involved in scaling out the process (Activity 2) of our collaborative breeding mainly involved developing local infrastructure [two crossing blocks] and linking with others involved in breeding another crop [sweet potato] and in another country [Uganda and Tanzania].

Activities involved in improving communication with a wider range of end users (Activity 3) particularly involved small or medium scale cassava processing enterprises. The underlying aim was to integrate them better in a collaborative breeding process in Ghana.

An additional activity involved evaluating the impact of project activities on farmers in the two communities the project has worked with long-term, particularly in terms of uptake and dissemination of germplasm.

1. Developing data required for varieties developed through PPB to be presented to the Ghanaian Variety Release Committee

1.1 Conduct final multi-locational field trials in an appropriate range of agroecologies.
1.2 Collate data for variety release documents for 1 or more cassava accessions selected by a participatory process.

Nine multi-location trials had been planted by the previous phase of the project, six in the Forest and three in the Forest Savannah Transition Zones in Ghana, testing 35 cassava clones selected in Aworowa, Nkaakom or Kwadaso against released varieties. Disease incidences and yields have been recorded. Partly based on these data, a further four trials have been planted across the two zones, testing 15 clones selected as superior from the outcomes of the previous trials. From these 15 clones, three have been selected as front runners for variety release based on yield, disease resistance and farmer preferences identified during the trials of 37 clones. These have been planted at CRI [Kumasi] and Aworowa in large blocks to provide inspection blocks and sources of planting material, prerequisites for variety release.

2. Wider uptake of participatory breeding process, particularly in Ghana

2.1 Develop a crossing block in Ghana incorporating superior exotic and local cassava germplasm

Crossing blocks incorporating a mixture of 6 exotic (IITA-derived) and 19 Ghanaian landraces have been planted in the Forest Zone at CRI [Fumesua] and in the Forest Savannah Transition Zone at Wenchi.

2.2 Facilitate others to initiate communal trial of seedlings of another crop such as sweet potato or yams for participatory breeding.

The outcomes of participatory breeding with cassava have been transferred directly to sweet potato breeders in Uganda by the leader of this project initiating a similar project in Uganda and Tanzania (See FTR for R8457).

2.3 Prepare a guide on participatory breeding appropriate for the Ghanaian context.
2.4 Review the issues associated with participatory plant breeding, focusing on an evaluation of the process.
It seemed clear that the main actors involved in instigating new participatory breeding programmes in Ghana and elsewhere in the developing world are likely to be scientists, particularly national programme breeders. They are likely to receive knowledge of our participatory breeding work either by scientist to scientist contact or by reading a report. In judging either a verbal or written communication, such individuals also seem likely to judge whether or not to act on such reports through knowledge of whether such reports have been validated by scientific review in a respected international journal. Consequently, these two activities were combined together as part of a process of developing a scientific paper describing in detail and with numerous diagrams the collaborative approach we adopted and its outcomes. Checking the contents of different journals allowed us to identify a widely-read international journal which included plant breeding topics. It was appreciated that publication of the paper in such a journal did not guarantee that most African breeders would automatically become aware of it. Consultations were held with colleagues at NRI and NR International (Dr A Ward) seeking more popular journals which are delivered directly to researchers and their libraries, leading to the identification of two and the preparation of 'popular' articles for them. Discussions with Dr Ben Dadzie, local Crop Postharvest Programme Manager in Ghana, and with Ghanaian colleagues identified a further suitable newsletter.

3. Communication between end users and other stakeholders in variety development in Ghana enhanced

3.1 Collaboratively assess performance with post-harvest researchers and end-users of advanced cassava clones selected through a participatory process and/ or seed in trials.
3.2 Prepare a communication tool promoting the opportunities offered by cassava varietal development.

Based on the concept that 'Seeing is believing', opportunity was taken of offers from two flour/starch processors to plant trials of selected cassava clones developed through participatory breeding, along with released varieties and advanced clones from the CRI breeding programme, at their farms located close to their factories. One of the processors is Amasa Agro-processing Company Ltd (Motherwell Farms) (Plate 1) which is based in the Coastal Zone near Accra. The other is Mubasmus Ventures, starch processors in the Forest Zone near Cape Coast. Two sets of trials were planted at both sites: at each, one set was established towards the end of the 2004 rains and one was established midway during the 2005 rains.

Plate 1. Part of the cassava processing factory of Amasa Agro-processing Company Ltd (Motherwell Farms).

4. Additional activity: assess the impact of breeding activities on the participating communities in Ghana.

Evaluations of impact have been made through two surveys, each involving farmers in both Nkaakom and Aworowa. The first survey aimed mainly to evaluate project activities by investigating farmers' attitudes to the project and its outputs; the second involved trying to track what farmers actually did with planting material derived from the participatory breeding trials and which they took home with them. Both surveys involved farmer interviews guided by a checklist and, where possible – and particularly for the second survey – seeking confirmatory evidence on the ground such as the new genotypes actually being present in farmers' fields.

Outputs

1. Developing data required for varieties developed through PPB to be presented to the Ghanaian Variety Release Committee

1.1 Conduct final multi-locational field trials in an appropriate range of agroecologies
1.2 Collate data for variety release documents for 1 or more cassava accessions selected by a participatory process

The nine multi-location trials planted by the previous phase of the project in the Forest and the Forest Savannah Transition Zones in Ghana, testing 35 cassava clones selected in Aworowa, Nkaakom or Kwadaso, were harvested in May – June 2006. Disease incidences and yields are shown in Tables 1 and 2. A further four trials of the 15 clones selected as superior from the outcomes of the previous trials were planted across the two zones inJune/July. These will be ready for harvest in late 2006 and will provide the final data for a first presentation to the Variety Release Committee. The top three selected to be front runners for variety release on the bases of compromises between yield, virus resistance and farmer preferences have been planted at CRI [Kumasi] and Aworowa in blocks each approximately 8 x 25m [about 200 plants][Plate 2] to provide inspection blocks for the Committee and initial sources of planting material variety once release is accepted. They are expected to be ready for inspection in April/May 2006.

Plate 2. Part of the inspection plot at Aworowa showing one of the selected ‘front runners’ (left) versus the landrace Bensere

Table 1. Yields of cassava accessions tested at nine locations within the forest and forest-savannah zones of Ghana

Clone	Yield (Kg/2plants) per location									Across locations	
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***Mean***	***SD***
AW 1*	12.6	7.4	13.5	13.6	12.4	15.8	-	23.5	10	**13.6**	**4.73**
AW 2	8.5	7.5	6.8	9	6.6	10.4	-	7.5	5.8	**7.76**	**1.49**
AW 9	9.7	10.2	6	2	7.9	12.1	6.5	15.5	12.5	**9.16**	**4.05**
AW 17	6.8	6.5	6.5	7.6	9.9	9.3	-	5.9	13.8	**8.29**	**2.64**
AW 18*	10.5	7.8	19	3.2	12.3	10.2	14	18.9	10.5	**11.82**	**5.04**
AW 34	8.8	13.9	24.5	15	11.8	16	5.5	10.6	12	**13.12**	**5.34**
AW 46	11.6	12.2	20.6	4	8.7	13.1	-	16	5	**11.4**	**5.51**
AW 48	9.4	7.1	10	-	9.1	8.5	-	12.5	15.2	**10.26**	**2.73**
AW 49	10.6	14.5	14	4	11.6	13.7	9	14.5	25.6	**13.06**	**5.80**
AW 57	7.8	-	10.2	-	7.9	-	2.9	11.5	-	**8.06**	**3.28**
AW 58	-	-	15.8	-	-	-	-	3.6	-	**9.7**	**8.63**
AW 63	9.2	13	16.4	6.5	8.8	11	6.5	27.4	11	**12.2**	**6.49**
AW 64	8.9	10.7	16.8	10.5	11.5	9	-	17.3	-	**11.23**	**2.91**
AW 65	-	2.5	18	8.5	9.1	10.5	10	7	8	**10.49**	**5.06**
NK 6	9.5	3.2	7	14.8	6.6	8.7	7.5	10	17	**9.37**	**4.23**
NK 7	6.4	8.5	9.5	12.5	10.2	8	4.2	5.4	10	**8.3**	**2.61**
NK 8	11.6	22.8	8.5	3	7.4	14.9	3	16	8	**10.58**	**6.47**
NK 10	12.1	9.1	7.5	18	10.6	10.2	3.5	24	11.5	**11.83**	**5.98**
NK 36	10.8	15.6	21.3	-	14.6	-	-	-	11.5	**14.83**	**4,80**
NK 37	9.9	9.5	20	7.5	13.1	11.6	12.5	9.8	-	**11.74**	**3.79**
NK 43	12.1	2.7	14.1	-	8.6	5.8	-	25.4	-	**11.45**	**7.98**
NK 55	9.8	12	10	11.2	-	12.7	-	16.7	29	**14.49**	**6.80**
NK 57	6.4	17.8	16.3	5.6	8.9	12	1.5	22.5	17	**12**	**6.89**
NK 69	9.7	6.5	11.2	18	7.5	9.1	5.5	21.8	12.8	**11.34**	**5.43**
NK 70	6.1	10.1	15.5	15.1	6.9	8.9	2.5	7	16.8	**9.88**	**4.92**
NK 76	8.4	3	6.4	-	5.6	9.9	2.5	16.2	9.5	**7.69**	**4.41**
NK 77	6.9	2.8	9.1	12	8.5	8	2.5	3.1	10.2	**7.01**	**3.46**
K 7	9.1	6.8	11	7	5.8	8.5	1.5	4.3	10	**7.11**	**2.97**
K 17	10.6	13	15.8	2.6	7.9	8.6	-	3.3	11.5	**9.16**	**4.56**
K 25*	15.6	5.8	26.4	8	13.2	10.1	12	16.9	9.5	**13.06**	**6.12**
K 34	8.4	5.5	9.5	15.5	7.8	11.6	2.5	15.2	-	**9.5**	**4.50**
K 35	12.1	9.5	25.3	-	13.9	7.8	4	15.5	14	**12.76**	**6.32**
K 40	7.5	4.4	6.1	13.6	6.4	14.6	5	16.8	6.2	**8.96**	**4.69**
K 48	10.2	13	8.5	8.5	9.2	8.7	9.8	6.8	11	**9.52**	**1.77**
K 60	6.1	8.6	8.7	5	6.6	6.9	7	9.5	11	**7.71**	**1.88**
Afisiafi	10.6	3.8	26	6.6	13.2	12.2	9.5	11.1	11.5	**11.61**	**6.14**
Abasafi	8.9	4.4	14.2	19	8.4	8.8	3	20.9	13.1	**11.19**	**6.12**
Land-race-1	12.6	24.5	9	18	9	4.5	2.9	2.9	7	**10.04**	**7.27**
Land-race-2	7.9	5.2	5.5	3	7.2	10.6	3.5	12.7	23	**8.73**	**6.21**
Land-race-3	6.4	3.8	-	5.6	7.8	-	5.8	3.3	7.5	**5.74**	**1.71**
Land-race-4	-	-	-	2	-	-	8	-	19	**9.67**	**8.62**
Mean	**9.48**	**9.08**	**13.35**	**8.31**	**9.28**	**10.32**	**5.08**	**13.05**	**12.48**		

- Locations: 1- Afrisipakrom, 2 – Akosomo, 3 – Aworowa, 4 – Seneso, 5 – Watro, 6 – Fumesua, 7 Ntotroso, 8 – Nkaakom, 9 - Mpatasee.

*Clones in red are the three front runners for release

Table 2. Percentage of cassava accessions infected with CMD at different locations within the forest and forest – savannah transition zones of Ghana. Mean severities are in brackets.

Clones	% incidence (severity) per location								
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
AW 1*	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	25 (2)	-	0 (1)	0 (1)
AW 2	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	14 (2)	-	0 (1)	0 (1)
AW 9	25 (4)	100 (2)	20 (2)	0 (1)	67 (3)	0 (1)	100 (4)	100 (4)	50 (2)
AW 17	100 (4)	100 (3)	0 (1)	0 (1)	25 (2)	14 (2)	-	22 (3)	25 (3)
AW 18*	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
AW 34	33 (3)	0 (1)	0 (1)	0 (1)	10 (2)	100 (4)	0 (1)	0 (1)	0 (1)
AW 46	50 (3)	20 (3)	0 (1)	100 (3)	100 (3)	0 (1)	-	70 (4)	100 (3)
AW 48	0 (1)	0 (1)	0 (1)	-	0 (1)	0 (1)	-	0 (1)	0 (1)
AW 49	0 (1)	0 (1)	100 (4)	0 (1)	25 (2)	0 (1)	0 (1)	0 (1)	0 (1)
AW 57	0 (1)	-	25 (2)	-	100 (3)	-	0 (1)	0 (1)	-
AW 58	-	-	0 (1)	-	-	-	-	0 (1)	-
AW 63	0 (1)	0 (1)	10 (2)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
AW 64	63 (4)	0 (1)	0 (1)	0 (1)	0 (1)	86 (3)	-	0 (1)	-
AW 65	-	100 (2)	50 (2)	10 (2)	50 (2)	20 (2)	0 (1)	0 (1)	0 (1)
NK 6	25 (3)	0 (1)	0 (1)	100 (2)	50 (3)	0 (1)	10 (2)	10 (2)	0 (1)
NK 7	0 (1)	0 (1)	0 (1)	0 (1)	10 (2)	0 (1)	0 (1)	0 (1)	0 (1)
NK 8	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
NK 10	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
NK 36	0 (1)	0 (1)	0 (1)	-	0 (1)	-	-	-	13 (2)
NK 37	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	17 (2)	10 (3)	0 (1)	-
NK 43	0 (1)	0 (1)	0 (1)	-	0 (1)	0 (1)	-	0 (1)	-
NK 55	0 (1)	0 (1)	15 (2)	0 (1)	-	67 (3)	-	0 (1)	0 (1)
NK 57	0 (1)	0 (1)	25 (2)	0 (1)	10 (2)	0 (1)	0 (1)	0 (1)	10 (2)
NK 69	0 (1)	0 (1)	0 (1)	100 (2)	67 (3)	0 (1)	33 (3)	25 (2)	0 (1)
NK 70	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	100 (4)	0 (1)	0 (1)	13 (3)
NK 76	0 (1)	0 (1)	0 (1)	-	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
NK 77	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	10 (2)
K 7	20 (3)	10 (2)	0 (1)	0 (1)	10 (2)	50 (2)	-	13 (2)	100 (3)
K 17	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	56 (3)	0 (1)	0 (1)	0 (1)
K 25*	0 (1)	0 (1)	100 (4)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
K 34	10 (2)	30 (2)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	-
K 35	0 (1)	0 (1)	0 (1)	-	87 (3)	11 (2)	10 (2)	0 (1)	100 (4)
K 40	0 (1)	0 (1)	100 (4)	0 (1)	10 (2)	0 (1)	0 (1)	0 (1)	0 (1)
K 48	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)
K 60	0 (1)	0 (1)	0 (1)	0 (1)	33 (2)	67 (2)	0 (1)	38 (2)	25 (3)
Afisiafi	20 (3)	67 (3)	0 (1)	0 (1)	25 (2)	60 (2)	20 (3)	16 (2)	21 (3)
Abasafit	20 (3)	100 (2)	0 (1)	0 (1)	10 (2)	0 (1)	25 (3)	0 (1)	0 (1)
Land-race-1	27 (3)	0 (1)	0 (1)	100 (3)	67 (3)	0 (1)	100 (4)	0 (1)	100 (2)
Land-race-2	100 (4)	100 (3)	0 (1)	100 (4)	100 (4)	0 (1)	100 (4)	0 (1)	100 (4)
Land-race-3	100 (4)	100 (4)	-	100 (3)	85 (3)	-	0 (1)	-	0 (1)
Land-race-4	-	-	-	80 (3)	-	-	0 (1)	-	75 (3)

- Locations: 1- Afrisipakrom, 2 – Akosomo, 3 – Aworowa, 4 – Seneso, 5 – Watro, 6 – Fumesua, 7 Ntotroso, 8 – Nkaakom, 9 - Mpatasee

*Clones in red are the three front runners for release

2. Wider uptake of participatory breeding process, particularly in Ghana

2.1 Develop a crossing block in Ghana incorporating superior exotic and local cassava germplasm

Crossing blocks incorporating a mixture of exotic (IITA-derived) and Ghanaian landraces have been planted in the Forest Zone at CRI [Fumesua] (Plate 3) and in the Forest Savannah Transition Zone at Wenchi.

Plate 3. Dr Joe Manu-Aduening, Head of the Cassava Programme, standing in front of his new cassava crossing block at CRI

2.2 Facilitate others to initiate communal trial of seedlings of another crop such as sweet potato or yams for participatory breeding.

Based on the outcomes of the participatory breeding with cassava in Ghana, similar breeding programmes have been initiated for sweet potato with three communities in both Uganda and Tanzania, again linking with plant breeders in national research institutes. The programme has been transferred directly to sweet potato breeders in Uganda by the leader of this project initiating a similar project in Uganda and Tanzania (See FTR for R8457) in collaboration with national programmes (Plate 4). The programme in Tanzania was constrained by various natural disasters but the programme in Uganda has now reached a similar stage as the cassava breeding programme in Ghana. Thus, a few superior clones have been identified from several thousand seedlings and these are being tested by the Ugandan National Potato Programme in multilocational trials prior to variety release. The National Programme has also achieved funding from the McKnight Foundation to initiate their own participatory breeding programme part of which includes funding for PhD and MSc studies into the advantages and disadvantages of the approach. Early access to project experiences and publications and to literature identified by the project has been provided to these colleagues.

Plate 4. The Ugandan National Potato Programme leader [centre] plus some of the farmers at Luwero evalutating a sweet potato participatory breeding trial together

2.3 Prepare a guide on participatory breeding appropriate for the Ghanaian context.
2.4 Review the issues associated with participatory plant breeding, focusing on an evaluation of the process.

Strategy planning meetings amongst the project team identified that the main target group for disseminating the process of participatory plant breeding were fellow scientists, particularly national programme plant breeders throughout the developing world. The meetings also identified that a main way of validating and disseminating the approach was through publication in a peer-reviewed and widely respected international journal. A paper [See Appendix 1] was therefore prepared and subsequently accepted by the international refereed journal *Euphytica* entitled:

MANU-ADUENING, J.A., LAMBOLL, R.I., AMPONG MENSAH, G., LAMPTEY, J.N., MOSES, E., DANKYI, A.A. & GIBSON, R.W. 2006. Development of superior cassava cultivars in Ghana by farmers and scientists: the process adopted, outcomes and contributions and changed roles of different stakeholders. *Euphytica* (Accepted)

This paper describes how, for both cassava and sweet potato, production throughout Africa is predominantly using landraces. Details of how these landraces developed have recently been reported for cassava in Ghana in another paper recently published by the Project also in Euphytica [Manu-Aduening, J. A., Lamboll, R. I., Dankyi, A. A. & Gibson, R. W. 2005. Cassava diversity and evolution in Ghanaian farming systems. *Euphytica* **144:** 331-340]. This latter established, for cassava, the basis for collaboration between farmers and scientists. The continued success of landraces implies that farmer selection, whether conscious or subconscious, has much to offer cassava breeding. Despite that, our recently-gained knowledge of the process identified sources of inefficiency. These include that farmers ignore [or even hoe up] most seedlings and that farmers can also only access diversity already within their local germplasm. Such factors have probably contributed to the relatively slow evolution of superior disease-resistant landraces yet can easily be corrected by scientists. This complementarity provided the basis for this project, throughout which the underlying philosophy has been to combine the different strengths of the farmer and scientist partners.

The paper provides detail of the method the project used, starting with developing knowledge of the two communities we worked with, focusing particularly on the cassava cropping system and the systems within the community with which we might work. This led to the identification and/or development of farmer groups, briefing the farmers of the aim of the work and the general development of good working relationships. It also includes how the scientists contributed access to large numbers of diverse seedlings through Dr A Dixon [International Institute of Tropical Agriculture (IITA)] from his crossing block in Ibadan, Nigeria and their contribution to the selection process. The farmers selected separately from the scientists; each selector was asked why s/he retained or rejected a particular genotype. Rather than attempting to reach a consensus amongst the farmers and scientists as to which plants to retain [as would normally occur for the plant pathologists and plant breeder selecting on-station], all selections by all actors were replanted in a new trial.

These reports are the first for farmer participatory breeding from seed of vegetatively propagated crops in Africa, although the benefits of farmer participation in breeding seed-propagated crops such as beans has been achieved for more than a decade. The paper concluded that, although farmers were unused to handling seedlings of cassava and sweet potato, this seemed to present few problems. The main problem vegetative propagation presented was that clonal propagation was slow, particularly for cassava; the main advantage seemed to be that clonal propagation simplified selection by preventing further genetic variation.

The paper also reviewed the advantages and disadvantages of the approach [Activity 2.4]. A main advantage of the process was its speed. For both cassava and sweet potato, a few genotypes were selected from an original population of several hundreds or thousands within 4 - 5 generations, a similar timescale to that for conventional on-station breeding. However, since farmers and scientists selected simultaneously rather than, as in more formal plant breeding, sequentially with farmers validating scientists' initial selection, the net result is a much faster selection process. Saving time is important because it means the benefits of better varieties are attained earlier. Farmers also contributed unique selections and analysis of the results indicated that their selection of genotypes was consistent with their claimed criteria. Farmers both had some different criteria to those of the scientists and, even for criteria they shared, farmers often had a different approach from scientists – farmers generally selected for positive features such as healthy-looking leaves whereas scientists generally selected by rejecting diseased plants. Selecting under farmer conditions also appears to have led to different genotypes being selected than may have been selected on-station and led to genotypes being selected that had high yields relative to controls [particularly landraces] and were also relatively disease-resistant.

The approach has potential to make good use of limited resources. The main saving is that, because farmers are involved from the beginning, it is unlikely that effort will ultimately be wasted because farmers reject released varieties. It is true that considerable resources were utilised visiting the communal trials. However, the main need for scientists to visit the trials was for the evaluation of the genotypes at maturity and then re-planting the selected ones – and these operations were often combined since it is ideal for both crops if the cuttings are soon after they have been harvested. There was a need to 'pop over' to see the farmers and the trials occasionally but this could generally be combined with other duties. Also, it is generally appreciated now that even with on-station breeding it is necessary to bring farmers on-station at some stage – and bringing an adequate range of farmers on-station may be more expensive than bringing scientists to the field.

One difficulty that became highlighted during the progress of the projects was that of assessing postharvest attributes of the sweet potato and cassava roots. Even simple boiling the roots was impractical until the number of genotypes remaining was reduced to double figures and cassava in particular is processed into large numbers of different products both for traditional foods and the expanding diversity of new products on the market now. This meant that many genotypes were discarded without even sampling their postharvest qualities. No easy solution seems available; the problem equally afflicts conventional on-station selection. Another area that wasn't fully addressed was that farmer participation can be seen as a broad decentralisation of activities; and whilst it was relatively easy to decentralise the activities, we did not address how to decentralise resources.

We learnt of the acceptance of this paper by Euphytica in early January. Further discussions on the use of this paper as a means of disseminating the project approach to participatory breeding identified concerns that only a limited number of African national programme breeders might normally become aware of the paper unless other means were employed to facilitate this. Two approaches have been made to address this. The first is review of popular journals and newsletters in Africa identified the wide distribution throughout Africa of 'African Farming' and of the newsletters 'Roots' particularly in East and southern Africa and 'Coraf Action' in West Africa. More popular articles have therefore been written for each of these newsletters [Appendices 2, 3 & 4], making mention that the approach has been tested on both cassava and sweet potato and referring to the Euphytica paper. The second approach planned is to use funds earmarked for a dissemination tool to enable colour figures to be present in the Euphytica paper and for the paper to be downloaded freely from the journal website. The latter will be done once proofs have been approved.

3. Communication between end users and other stakeholders in variety development in Ghana enhanced

3.1 Collaboratively assess performance with post-harvest researchers and end-users of advanced cassava clones selected through a participatory process and/ or seed in trials.
3.2 Prepare a communication tool promoting the opportunities offered by cassava varietal development.

Two sets of trials were planted at farms located close to factories belonging to two cassava processors: Amasa Agro-processing Company Ltd (Motherwell Farms) which is based in the Coastal Zone near Accra and Mubasmus Ventures, starch processors in the Forest Zone near Cape Coast. The trials comprise three replicates each of 15 cassava clones selected through participatory breeding, along with released varieties and advanced clones from another CRI breeding programme. At each, one set was established towards the end of the 2004 rains and one was established midway during the 2005 rains.

Plate 5. The owner of Mubasmus Venture, Mr Musa Ali, standing amongst a cassava variety trial based on his farm, flanked on either side by cassava breeders and project members from CRI

The first set of these trials will be ready for harvest in May 2006 and the second are expected to be ready around November. The owner of Mubasmus Venture, Mr Musa Ali (Plate 5), won the award of 'The best national cassava farmer for 2005' in Ghana. This is a prestigious award which will indirectly help validate selections made on his farm and enable these trials to be an even more effective tool to disseminate knowledge of our project approach through visits by farmers, scientists and officials, this added benefit confirming the appropriateness of our selection of this farmer/processor as our collaborator.

4. Additional activity: assess the impact of breeding activities on the participatory communities in Ghana.

Farmers in both Aworowa and Nkaakom had received planting material of cassava accessions selected in their communities either directly from the project community trials or by exchange between farmers. In a survey in 2004 previously unreported, 23 such farmers had been identified in the two communities. This rather limited number of farmers indicated that the clones selected by collaborative breeding did possess various attributes which were superior to those of their current landraces (Table 3), in particular indicating that they considered the accessions to have a better yield, earlier maturity and to be less affected by pests, diseases and weeds - though with some countervailing disadvantages.

Table 3. A comparison of the different proportions of farmers considering clones selected by collaborative breeding were better, for different attributes, than landraces currently-available to them

Attribute	% of farmers considering clones selected by collaborative breeding to be better than landraces currently-available
Yield	87
Early maturity	96
Poundable into fufu	30
Taste	52
Disease tolerance	91
Pest tolerance	83
Control of weeds	83
Intercropping	22
In-ground storage	26
In-house storage	22

A follow-up survey was conducted in September 2006 in Nkaakom and Aworowa and this time a total of 67 farmers who had received planting material of clones selected by collaborative breeding were identified, some obtaining their material from farmers rather than directly from the project communal field.

Table 4. How the project clones were used initially by 67 recipients

		% of farmers			
	Number of farmers	Planted	Gave to others	*Did not plant	Not known
Nkaakom	31	65	3	3	29
Aworowa	36	67	8	19	6
All	67	66	6	12	16

* Recipients did not plant and survey team unable to determine what happened to the material

A continuing problem was that most farmers (80%) were no longer able to identify the accession numbers of even one of the clones they had received and none could identify all five. Encouragingly, though, more than half the farmers who had planted a first crop of the accessions replanted them (Tables 4 & 5). Most farmers seemed to be planting just small quantities, perhaps therefore continuing to experiment with them.

Table 5. How the project clones were used by 43 farmers who had planted and were surveyed.

Village	Number of respondents	How clones were used (% of respondents)		
		Harvested	Replanted	Clones currently grown
Nkaakom	21	43	29	14
Aworowa	22	95	50	45
All	43	70	40	30

Tables 6 and 7 list the main reasons elicited in this survey why farmers continued to grow project-derived clones or didn't consider they were worth replanting. Ability to be pounded into *fufu* and high yield were major reasons for continuing to grow the project-derived clones and also apparent resemblance to their own landraces. It seems significant that one of the three clones [coded No 24] selected as front runners for variety release closely resembles the landrace *Bensere*. As well as having a higher yield and greater disease resistance to *Bensere*, its similar canopy may enable it to fit easily into the current cultivation practices of farmers and may explain why it in particular seems to be being adopted rapidly by farmers.

Table 6. Reasons why project clones are currently being grown.

		Reasons why clones are grown (% of responses)				
	Number of responses	Poundable	High yield	Expect researchers to visit	Resembles local landrace	Other
Nkaakom	8	38	25	13	25	0
Aworowa	17	35	18	12	12	24
All	25	36	20	12	16	16

The reasons why farmers were not continuing to grow the clones often seemed to involve temporary circumstances such as a poor market for cassava or personal situation.

Table 7. Reasons why project clones are not currently being grown.

Villages		Reasons why clones are not grown (% of responses)					
	Number of responses	Poor market	Absence of material	Other	Landrace available	Personal situation	Not poundable
Nkaakom	24	4	25	25	8	17	21
Aworowa	16	44	38	19	0	0	0
All	40	20	30	23	5	10	13

Overall, the survey was encouraging because it suggests that at least some farmers remain interested in exploring the potential of the project clones, including by individual as well as communal activities. This suggests that this approach may be feasible on a wider scale as part of a process of decentralization of varietal development. On-going monitoring could hugely increase the costs of such an approach if large numbers of farmers operating individually were involved. However, a main reason for close monitoring in such circumstances may be to attribute success to specific research organizations or individual plant breeders in such organizations. Our experiences seem to suggest that farmers are unlikely to maintain such records without close supervision but alternative methods such as the use of genetic markers may be cost effective if only the few plants which are eventually selected by farmers are tested to identify their origin. This would be a complimentary approach to varietal development for specific market uses.

Seven individual case studies were also made. These tended to support the concept that farmers were currently still experimenting with the different clones and the diversity of attributes being considered. They also highlighted how personal circumstances were often involved in their loss, sometimes one family or community member causing the loss of material apparently inadvertently by not consulting with others.

Plate 5. Mr. Gyasi, a native of Aworowa, holding the stem of the project-derived cassava plant No 24 and with a plant of the landrace *Bensere* on his left. Note the similar phenotypes of the two and the severe CMD symptoms in the *Bensere*.

Contribution of Outputs to developmental impact

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 foods available and is increasingly being turned to as population pressures increase on the land. Thus, the project's focus on cassava contributes to DFID's development goal of alleviating poverty by boosting the sustainable production of food for poor people. However, cassava is also a cash crop and is increasingly being processed both into various traditional foods and used as a primary source of starch in various non-traditional but primarily food markets. By these means, cassava contributes broadly to sustaining livelihoods of poor people, providing food and cash sales to farmers, cheap high-energy food to urban dwellers and also employment for those involved in growing and processing it.

The project contributes to these roles by working with farmers to develop new varieties appropriate to their needs and the needs of different markets. 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. Earlier phases of the project commissioned studies of end-uses, end-users and researchers working on end-uses of cassava in Ghana. The project has built on links these established between cassava breeders and processors to develop shared variety trial sites.

The main aim of the project is to use collaborative approaches between scientists and farmers to develop new cassava cultivars which are adopted by Ghanaian farmers to an extent that they beneficially impact 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 project has continued its collaboration between farmers and scientists firstly to select 15 superior clones from 35 clones selected over previous phases of the project. All 35 clones have now been grown in multilocational trials and a preliminary analysis made of yield and disease incidence and severity data. The15 clones are also part of as yet unharvested trials on processors' farms. Three 'front runners' have been identified and inspection plots have been prepared both for inspection by the Ghanaian Variety Release Committee but also as future sources of planting material in anticipation of release.

Part of the process of achieving impact of the collaborative approach to plant breeding is validation of the process. Impacts of project activities and project cassava clones have been evaluated by farmers, with broadly encouraging outcomes. The project's breeding approach has also been validated by achieving similarly encouraging outcomes with sweet potato breeding in Uganda. A scientific paper describing and analyzing the project approach has been accepted by an international journal following scientific review. The paper was also written with the aim of disseminating the approach to other breeders in other countries and organizations and of other crops. Since the approach is particularly beneficial in developing countries and particularly for subsistence crops where scientists' situations on station differs markedly from farmers' situations, such a dissemination is likely to be pro-poor in outcome. Popular scientific articles have also been written for regional newsletters to ensure a wider range of dissemination. A system, however, still needs to be developed whereby strong farmer-orientation of breeding is established more permanently in developing countries 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.

Disseminations

Scientific Papers

Manu-Aduening, J. A., Lamboll, R. I., Dankyi, A. A. & Gibson, R. W. 2005. Cassava diversity and evolution in Ghanaian farming systems. *Euphytica* **144:** 331-340.

Manu-Aduening, J.A., Lamboll, R.I., Ampong Mensah, G., Lamptey, J.N., Moses, E., Dankyi, A.A. & Gibson, R.W. 2006. Development of superior cassava cultivars in Ghana by farmers and scientists: the process adopted, outcomes and contributions and changed roles of different stakeholders. *Euphytica* (Accepted)

Popular articles

Farmer participatory breeding for root crops *submitted to* African Farming

R Gibson, J Manu-Aduening, E Byamukama, R Lamboll, G Ampong Mensah, R Mwanga, I Mpembe and J Kayongo 2006. Farmer Participatory Breeding of Cassava and Sweet Potato in Africa *submitted to* Roots Newsletter

Getting the best of both worlds in cassava breeding *submitted to* Coraf Action

Completed PhD Thesis

Manu-Aduening, J. A. 2005. Participatory breeding for superior mosaic-resistant cassava in Ghana. A thesis accepted in partial fulfillment for the award of the degree of PhD by the University of Greenwich; 346pp.

Internal Reports:

1. Quarterly reports to CPP and PSRP
2. Follow-up survey of farmers receiving cassava clones in Nkaakom and Aworowa villages.

Conference presentation:

Gibson, RW, Manu-Aduening, JA, Lamboll, RI, Lyimo, NG & Acola, G. 2005. Some farming practices may delay the development of virus-resistant landraces. Presentation at the IX International Plant Virus Epidemiology Symposium, April 4 – 7, 2005. Lima, Peru

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

Signature:
Name (typed):
Position:
Date:

Appendices

Appendix 1: Paper accepted by Euphytica

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

Subtitle: Cassava participatory breeding

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

Key words: Participatory plant breeding, farmer selection criteria, markets, variety release

INTRODUCTION

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

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

MATERIALS AND METHODS

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

Situation analysis

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

Participation of farmers

The scientists described to farmers in each village what was involved in cassava breeding and the potential benefits new cultivars could bring to the communities. An invitation was given to all cassava farmers in both communities to collaborate as a group with us. A maize/cassava farmers' association identified at Nkaakom during the situation analysis provided a focus there but no similar group was identified at Aworowa. In both communities, group membership exceeded forty. Most members were men (60 – 70%); in Nkaakom, most members were under 30 yrs old whereas at Aorowa, most were 30 – 50 yrs old.

Seedling trials

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

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

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

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

Scientists' evaluation: Two groups of scientists evaluated: (1) the cassava breeder at CRI and (2) two plant pathologists at CRI. The evaluations were done at *ca* 3, 6, 9 and 12 months after planting for each cycle of participatory breeding, though always on different days to the farmers, so avoiding either influencing the other. Farmers evaluated in several small groups to limit domination by a few opinion-leaders. The scientists evaluated the accessions as he/they would during FPB at CRI: the pathologists selected accessions for retention using data on disease incidence and severity from evaluations throughout the growing season; the breeder selected solely on the evaluation at harvest.

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

Clonal trials

In August 2001, 12 stem cuttings of each selected seedling were planted in separate plots measuring 3 x 4m at a communal site in the village where they were selected. In addition to the selected accessions, plots of 12 cuttings of two released varieties (Afisiafi [IITA Tropical Manihot species (TMS) 30572] and Abasafitaa [TMS 4(2)1425]), five landraces (coded DA 002, NK 009, NK 015, WCH 009, & WCH 037) selected by Prof S. Kantanka [Kwame Nkrumah University of Science and Technology, Kumasi, Ghana] from amongst germplasm from the Brong Ahafo Region (Forest-Savannah Transition Zone) of Ghana for evaluation for official release to farmers and three landraces selected by farmers in each village were included as checks. Each plot was clearly labeled. Formal evaluations of the genotypes by farmers were restricted to the harvest day. Roots of accessions selected by farmers or scientists were cooked in individual labelled polyethylene bags for farmers and the breeder to evaluate for palatability and poundability [Poundability refers to the ability of freshly cooked cassava to be pounded in a large pestle and mortar into the traditional food, *fufu*. Poundability was assessed by kneading the cooked cassava by hand]. After harvest at 12mths, further cuttings of selected clones were made from each clone, selections of the farmers, plant pathologists and the breeder were combined and a further communal trial was planted as before in August 2002.

Farmers also selected accessions s/he would like to plant in his/her own farm. Based on this, each farmer was given six cuttings of her/his top five clones. Each farmer taking cuttings back to his own farm was expected to plant these accessions together with one released variety and one local landrace of his choice. The scientists then visited each farmer individually during the growing season to evaluate crop vigour and health status and at harvest. Accessions selected from clonal generation 2 in each community were combined and planted together for a third clonal generation in both of the communities and also in multilocational trial sites in the Forest and Forest Savannah Transition zones (Fig. 1).

Surveys of end-users and current and potential markets

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

Requirements for variety release

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

RESULTS

Situation analysis

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

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

- marketability

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

Farmers' criteria

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

Scientists' criteria

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

Outcome of selections

Generally, both the farmers and the breeder selected a large proportion of the accessions with large storage root yields and with large canopies (Table 3). By contrast, the pathologists selected the greatest proportion of plants bearing no symptoms of CMD (and other diseases – data not shown), the main disease affecting plants in the trials. These results are consistent with the different priorities given to these attributes by the different selectors. There was a trend for the farmers' selection to be slightly better for pounding than the scientists', supporting the farmers' claim to be able to determine this from uncooked tubers. Although none of the accessions has yet been widely adopted by farmers, the breeder in our team is convinced that several offer major advantages over currently released varieties and all accessions have therefore been taken into multi-locational trials as a final step before submission to the Ghanaian Variety Release Committee (VRC).

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

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

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

Surveys of current and potential markets
Table 5 lists the current end-users consulted and important current uses to which cassava is put. Most uses involve processing it in different ways into human food to achieve different tastes, convenience, prolonged storage or other benefits. The survey investigating potential uses for cassava identified opportunities for its increased use as sweeteners in human foods, fillers for various industrial purposes and different preserved livestock feeds (Table 6). Most of these uses require cassava cultivars with a high yield of starch, preferably from roots with a relatively low water content to facilitate transport and drying. Year-round availability is also important for industries. These requirements are all consistent with current breeder and farmer selections. Some of the current and potential uses (Table 6) have defined physicochemical properties (Table 7) but no research into how the physicochemical properties of starch affect the suitability of different cassava cultivars for each use was identified.

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

Requirements for variety release

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

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

Requirements 1 and 2 are already documented in this manuscript. Additional trials of the selected 29 clones have been planted with more communities and on-station across the Forest and the Forest Savannah Transition zones in order to satisfy requirements 3 and 4: these will also be used to select further amongst accessions. Requirement 5 requires on-station laboratory work that is part of the normal practice of CRI for its conventional breeding programme; the scientist component of our collaboration can easily provide this. Our inclusion of different end-user requirements and field trials on processors' farms should also be valuable in meeting this. Table 8 checks for key attributes mentioned by farmers and other end-users in release documents for three sets of cassava varieties submitted to the VCR. Most attributes were mentioned though not always in all documents and sometimes associated with a particular use envisaged or zone targeted. Attributes not mentioned - such as the thickness of the skin, ease of peeling, and suitability for preparation of local foods such as *fufu* and *gari* - generally involved end-use(r)s.

DISCUSSION

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

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

No major problems were experienced in maintaining the experiments on-farm in the villages. A few scientists visiting the farmers' villages some 3 – 4 times each crop generation was easy and cheap, probably more so than bringing many farmers once or twice on-station, now a common final step in FPB in Africa. Genotype x environment interactions affect several aspects of cassava yield in Ghana (Sagoe *et al*., 1998) and perhaps also other key attributes, making selection on-station less inappropriate (Ceccarelli *et al*., 2003; Witcombe *et al*., 2003) by generating cassava varieties which have mostly been poorly adopted by farmers (Nweke *et al*., 1999). '*Evaluation and selection at seedling and clonal generations*' by both farmers and scientists enabled the scientists to know better the attributes required by farmers (Table 1) and their perceptions (for example, that farmers associate stem thickness with high yield). Several of the farmers' selection criteria such as weed suppression and suitability for inter-cropping were not mention in release documents examined (Table 8) suggesting they have received little previous attention from cassava breeders in Ghana. The strategy that a genotype was retained as long as it was selected by at least one of the groups of selectors ensured the opinion of each carried an equal weight [and also provided quantitative information for analysis of their different choices]. By contrast, seeking a consensus would have provided opportunity for one group to dominate. The farmers usually selected positively for plants with good attributes whilst both the breeder and pathologists operated mainly by rejecting poor plants. These differences in approach are consistent with the inclusion of farmers adding to the selection process (Baidu-Forson, 1997). Farmers were relatively consistent in their selection (Figs 3 & 4), re-selecting more than half of their selection in year 2 from their own previous selections and nearly two thirds of the final 29 selected genotypes (Table 4). This consistency was also reported by Sperling *et al*., (1993) and Kitch *et al*., (1998); the farmers may have been assisted by being used to observing crops growing in non-uniform fields. The farmers were also making informed choices: the outcomes of their selections (Table 3) fitted their claimed criteria (Table 1), confirming the effectiveness (Ceccarelli *et al*., 2003) and counteracting doubts (Thiele *et al.,* 1997) of farmers' ability to select amongst large populations of diverse seedlings.

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

An underlying feature of participatory breeding is decentralization (Maurya *et al*., 1988; Berg, 1997). The production of seeds being decentralised to Ghana is one example and selection being done on-farm rather than on-station is another. Concomitant requirements of decentralisation are increased influence and resources of the local actors (Table 10). The participatory breeding approach has increased the influence of farmers within the breeding process but their influence and that of other end-users of cultivars (consumers, processors etc) so far remains unchanged at higher levels, for example, the VRC. Decentralisation of resources has also not yet occurred; how best to recompense farmers for their resources and extra work was an unresolved discussion point within the project team. Downward transfer of influence and resources does not appear to have been resolved by other studies, perhaps an indication of the difficulties involved.

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

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

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

- Not ranked in top ten

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

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

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

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

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

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

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

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

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

Table 6. Current and potential uses for cassava in Ghana

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

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

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

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

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

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

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

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

	farmer groups in other areas of Ghana has so far not been achieved because of lack of resources	scaled out within a crop
Policy and regulations	• Official varietal release can be compatible with participatory breeding	• Changes are needed to give farmers and other end-users a greater official voice
Organisation, incentives and equity	• Participatory breeding involved decentralisation of activities along the IARC's, national agricultural research systems [NARS] to farmers chain • Farmers need some form of recompense for their time and resources • Members of the VRC are experts in the breeding process	• Decentralising roles and responsibilities require rewards, incentives and capacity building to be decentralised too. • VRC membership should encompass all stakeholders, particularly those who will use the released varieties

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

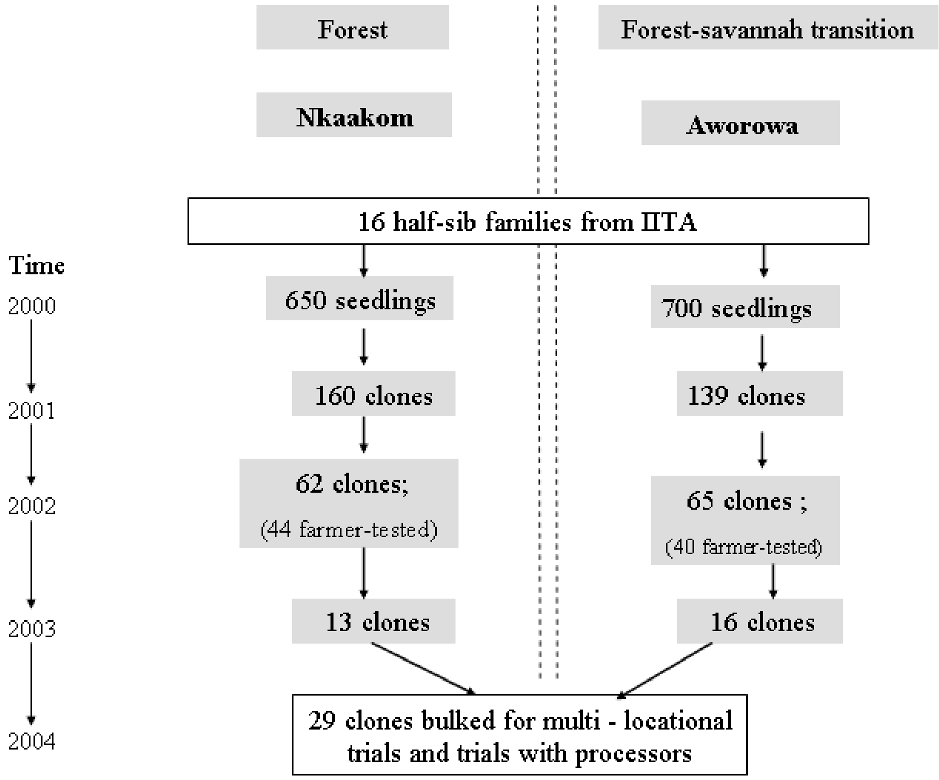


Figure 2. Summary of selection of accessions by farmers, breeder and pathologists over 3 years

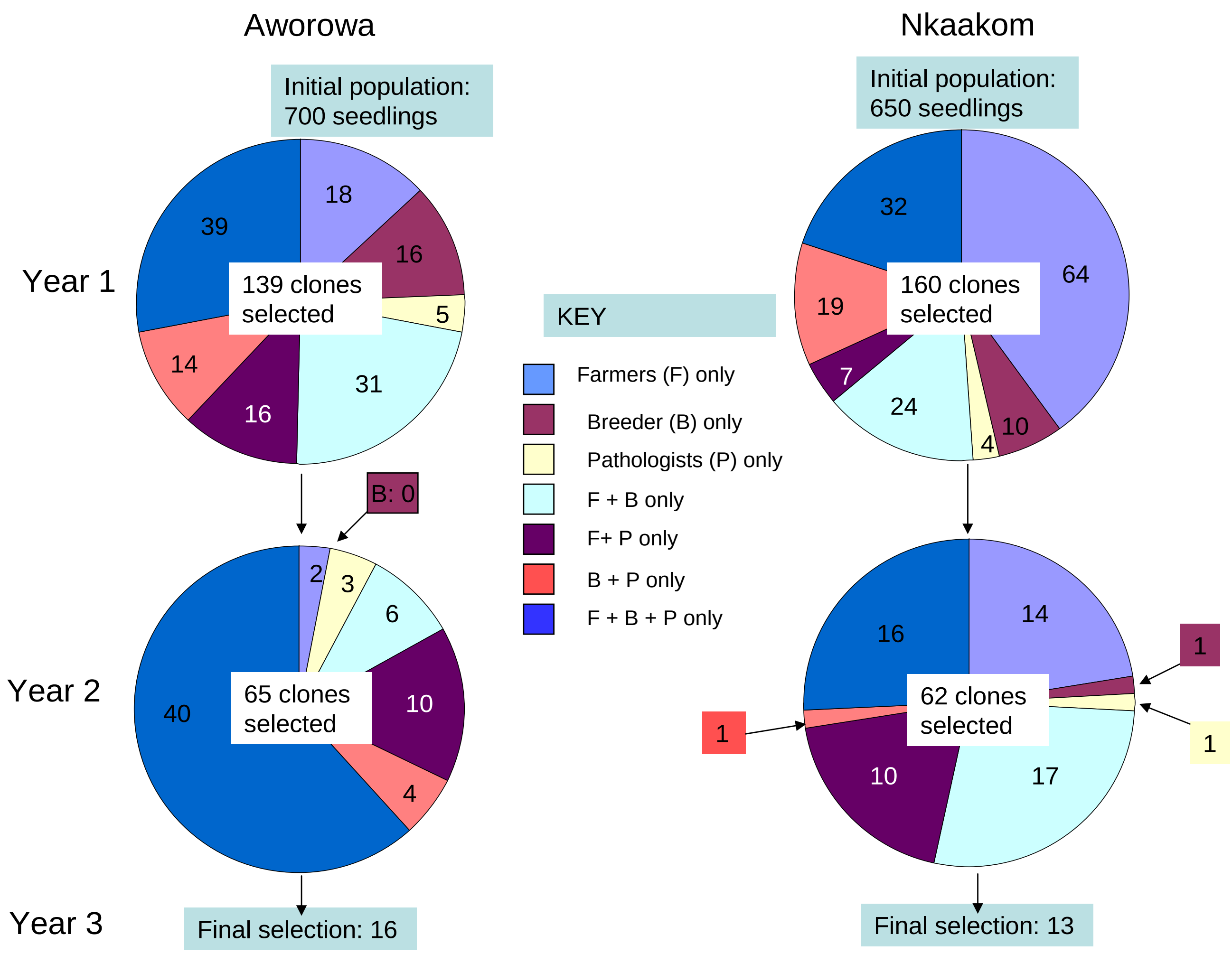
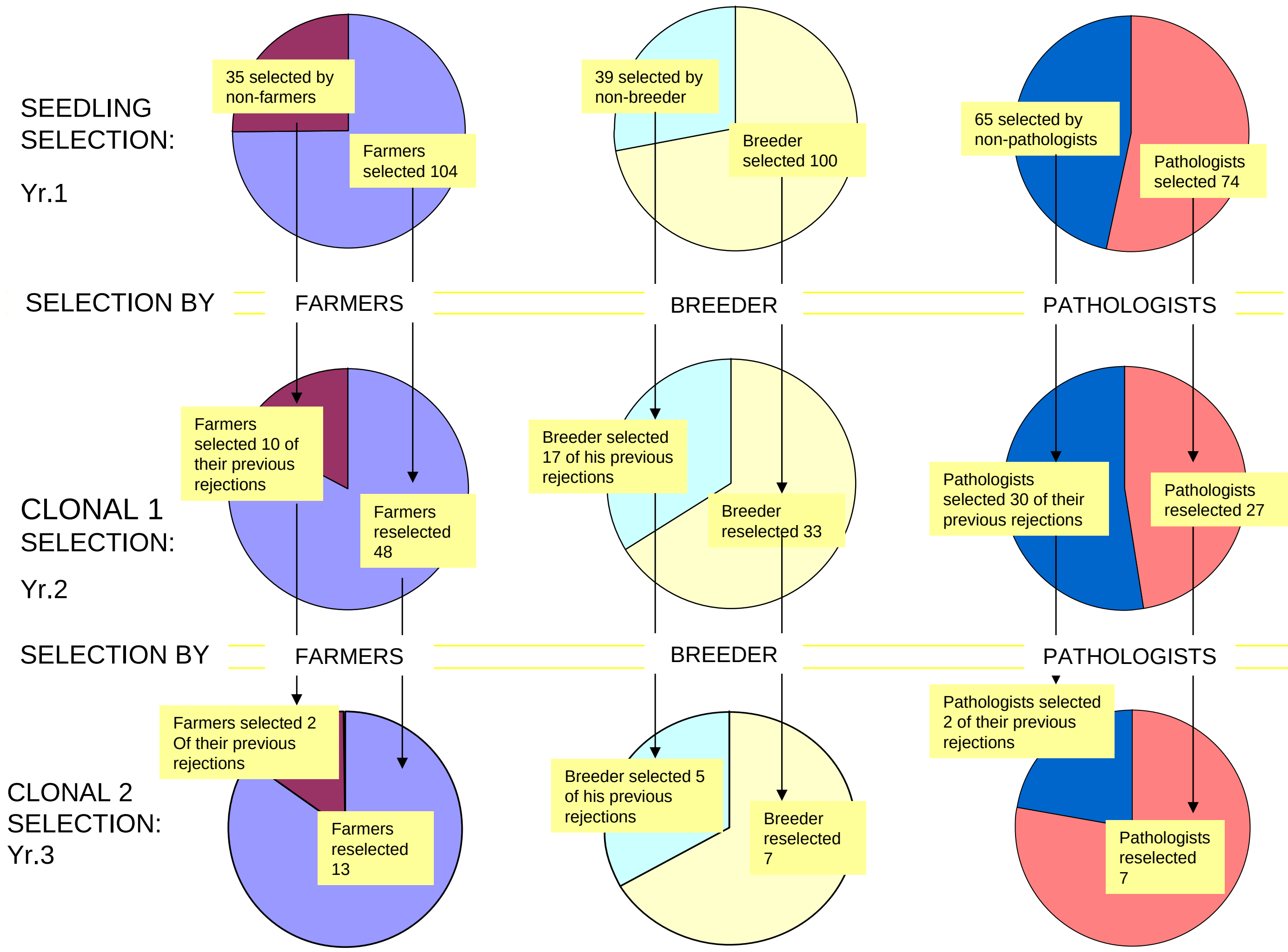
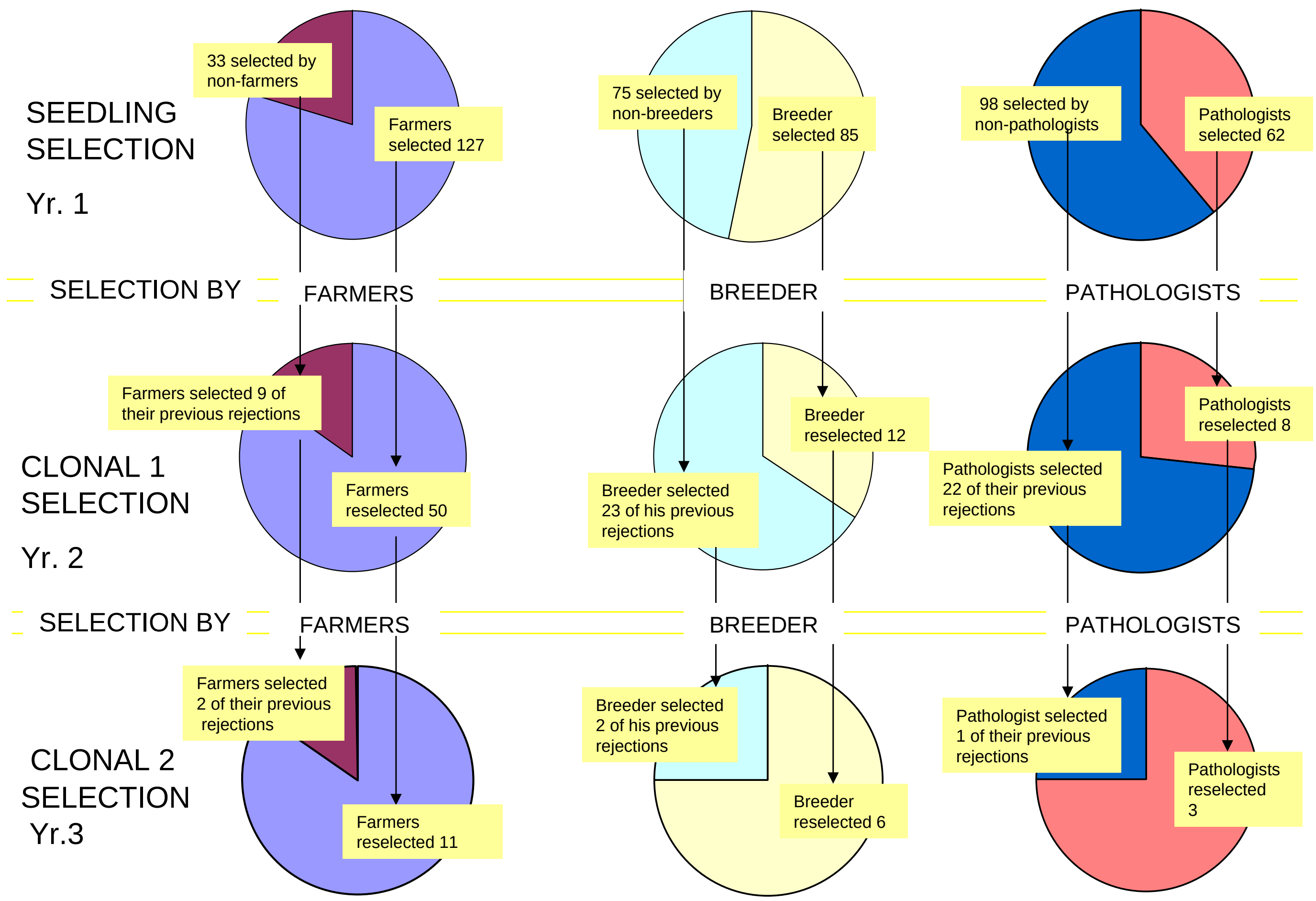


Figure 3. Summary of selection profile of farmers and scientists over three years

a) At Aworowa

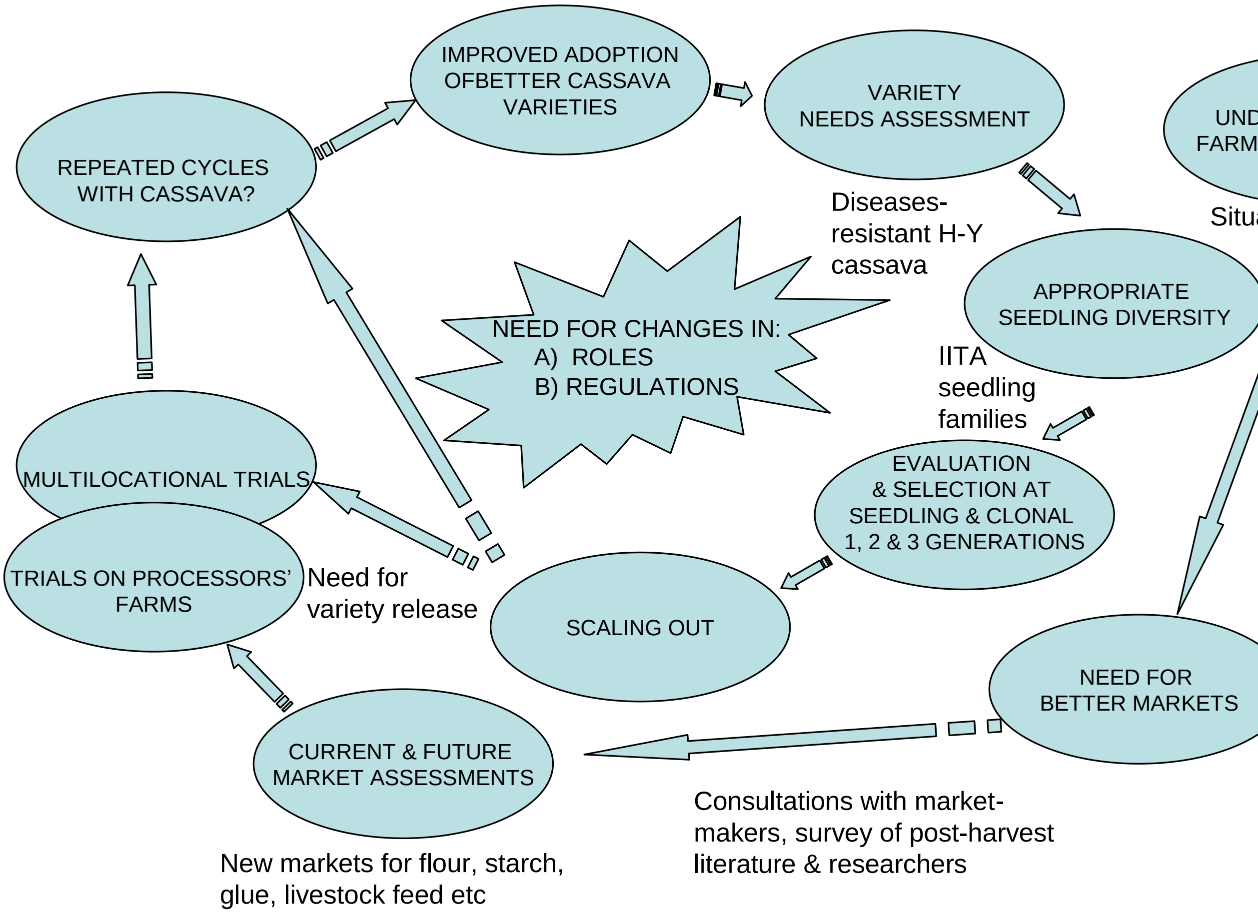


b) At Nkaakom



SEEDLING SELECTION
Yr. 1
33 selected by non-farmers
Farmers selected 127
75 selected by non-breeders
Breeder selected 85
98 selected by non-pathologists
Pathologists selected 62
SELECTION BY
FARMERS
BREEDER
PATHOLOGISTS
CLONAL 1 SELECTION
Yr. 2
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
SELECTION BY
FARMERS
BREEDER
PATHOLOGISTS
CLONAL 2 SELECTION
Yr.3
Farmers selected 2 of their previous rejections
Farmers reselected 11
Breeder selected 2 of his previous rejections
Breeder reselected 6
Pathologist selected 1 of their previous rejections
Pathologists reselected 3

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



Appendix 2: Article submitted to African Farming

Farmer participatory breeding for root crops

Dr Richard Gibson [NRI; UK] describes how researchers in partnership with African farmers have developed an effective method for breeding and promoting cassava and sweet potato

Root crops are especially important foods in sub-Saharan Africa, providing about 20% of the total food calories [FAOstats]. Indeed, in Ghana, this proportion of calories in the national diet is provided by the mean annual *per capita* production of just cassava [465 kg], far ahead of the contribution of any other single crop or animal source. Sweet potato is particularly important in eastern and central Africa and Uganda has the second greatest production the World [after China]. However, these statistics still vastly underrate their importance for poverty alleviation and food security in Africa. Both crops can yield in relatively infertile marginal lands to which poor people are so often restricted, both crops can cope well with erratic rainfall and sweet potato is amongst the most productive and early maturing crops available to African farmers. Sweet potato is also ideal for providing daily family food because individual tubers can be piecemeal harvested and women often grow a small patch of it around their homes for this purpose. However, it would also be wrong to think of these crops just as subsistence crops; cassava probably has the greatest potential of any African crop to supply starch-based industries and intensive livestock production, and orange-fleshed sweet potato, with its high pro-vitamin A content, is increasingly viewed as a health food.

Getting the best of both worlds

Despite the importance of these crops, the production of all root crops in Africa is predominantly by landraces developed over the centuries by African farmers. Many of these have very good taste qualities but their productivity may be only moderate and often held back by infection with diseases such as cassava mosaic disease and sweet potato virus disease. That said, it is often impressive how good some of these landraces are and clearly the traditional method of breeding has a lot to offer. Even so, the traditional method also has major weaknesses. Landraces appear develop only slowly, partly because farmers generally ignore seedlings – which represent the opportunity for new landraces - preferring the safer option of taking cuttings from the landraces whose performance they already know. They do this partly because they do not realise the potential value these seedlings represent. Also, farmers can only access seedlings developing from seed shed by their own varieties. Unlike for example maize, they cannot go along to a shop and buy cassava or sweet potato seed, perhaps generated by commercial breeders in another country or even continent. So they cannot access seedlings with novel characters, say high disease resistance, not found in their own varieties [Contrast this with the speed with which grey leaf spot resistant hybrid maize has become available throughout Africa and how this resistance has quickly spread into maize landraces]. Scientists know why seedlings are important in varietal improvement and can access seeds with particular attributes from colleagues anywhere in the world and partnerships between farmers and scientists can get the best of both worlds. With funding from the Crop Protection and the Plant Sciences Research Programmes of the UK Department for International Development, such breeding programmes in which farmers have a high degree of participation right from the start have now been tested for the first time for both these crops: for cassava in Ghana with scientists from the Crops Research Institute [CRI]; for sweet potato in Uganda with scientists based at Namulonge Agricultural and Animal Production Research Institute [NAARI] and in Tanzania with scientists based at Maruku Agricultural Research Institute [ARI-Maruku].

In all three countries, the work started with an initial study of the farmers' circumstances and what their requirements were. This also got everyone to know each other and included an explanation to the farmers of the concept of participatory breeding and their expected role in it. Cassava seeds of a diversity of half-sib families were obtained by Dr Joe Manu from Dr Alfred Dixon at the International Institute of Tropical Agriculture. Sweet potato seeds were provided by Dr Robert Mwanga from his international crossing block at NAARI. For both crops, the seeds were planted on communal land belonging to the farmers. Some of the Ghanaian farmers were so surprised to see how well many of the cassava seedlings yielded they wondered if the scientists had a subsidiary aim of persuading them to change from using cuttings to using seed as propagation material! For the sweet potato farmers, this was often the first time they realised sweet potato could grow from seed.

At the end of the first growing season, the crops were harvested and the scientists and the farmers, each as a separate group because we wanted each to make independent choices, selected which plants they wanted to keep for planting in the next season. Farmers, by examining clusters of plants and selecting the best in each, managed to cope with the many hundreds of seedlings available despite never having done this job consciously before. Throughout both the cassava and the sweet potato breeding work, the underlying philosophy was to use the different strengths of the farmer and scientist partners to compensate for weaknesses of the other rather than to seek a compromise. For this reason, both the plants chosen by the farmers and those chosen by the scientists were kept. Cuttings of the chosen seedlings were then replanted for another growing season; at maturity, those which the farmers and the scientists wanted to keep were again replanted. This cycle has now occurred for a total of some 4 – 5 generations and the number of genotypes retained has shrunk from many hundreds (or even a few thousand for the sweet potato) of plants to around 10 - but these few are often now outyielding the landrace and released variety controls and are highly disease resistant. They also seem to have characters that the farmers really appreciate in their local varieties: ability to survive drought, some yielding sequentially so they can be piecemeal harvested and yielding well in poor soil [Indeed, after one trial, the team member who owned the land confided in me that he had carefully selected some of his worst land for our trial because he wanted to really test them!]. As the number of cuttings available has increased, farmers took planting material home, partly so they could tell us how they tasted etc. Farmers have been so impressed by them that several are now multiplying them themselves with the aim of selling planting material to other farmers. Planting material of both crops has also been taken by the national programme scientists to incorporate in formal multi-location trials so the best can eventually be released.

The approach seems to bring several advantages. Involvement of farmers and working on-farm in the communities certainly added something extra to the process. Of course farmers and scientists sometimes chose the same plants but this often wasn't the case:

farmers had some different criteria [and their selection of genotypes was consistent with their claimed criteria]. Even for criteria they shared, farmers often had a different approach from scientists – farmers generally selected for positive features such as healthy-looking leaves whereas scientists generally selected by rejecting diseased plants. Consequently, farmers contributed unique selections and a high proportion of these have gone right through to the final selections. Selecting under farmer conditions also appears to have led to different genotypes being selected than may have been selected on-station. For sweet potato, it was evident that the fields chosen by the farmers for the trials were relatively infertile, and drought and diseases were also very important factors in the differential survival and productivity of different genotypes. Whether it is because or despite the above, it is reassuring that genotypes selected had high yields relative to controls [landraces as well as released varieties] and were also relatively disease-resistant.

Another advantage of farmer participatory breeding is that it was fast. For both cassava and sweet potato, a few genotypes were selected from an original population of several hundreds or thousands within 4 - 5 generations, a similar timescale to that for conventional on-station breeding. However, since farmers and scientists selected simultaneously rather than, as in more formal plant breeding, sequentially with farmers validating scientists' initial selection, the net result is a much faster selection process. Saving time is important because it means the benefits of better varieties are gained that much earlier. Our farmers are already multiplying and exchanging their stocks of their preferred clones so stocks are being built up and the new genotypes are already contributing to improved food supply and income generation.

The approach also has potential to make good use of limited resources. The main saving is that, because farmers are involved from the beginning, it is unlikely that all the effort is wasted because, in the end, farmers do not adopt released varieties. It is true that considerable resources were utilised visiting the communal trials. However, the main need for scientists to visit the trials was for the evaluation of the genotypes at maturity and then re-planting the selected ones – and these operations were often combined since it is ideal for both crops if the cuttings are soon after they have been harvested. There was a need to 'pop over' to see the farmers and the trials occasionally but this could generally be combined with other duties. Also, it is generally appreciated now that even on-station breeding generally involves the expense of bringing farmers on-station to validate potential new varieties – and bringing an adequate range of farmers on-station may be more expensive than bringing scientists to the field.

So where next? Clearly, there is a need to extend such breeding programmes to other countries in Africa. Furthermore, one advantage of farmer participatory breeding is that there is the potential to select in all the agroecologies in which the crop is grown in a country [rather than in the more limited number of agroecologies official institutions occupy] and for the different end-uses different communities may have. There is therefore potential to generate a greater diversity of varieties but to achieve this we need to develop a scheme whereby such breeding programmes can develop at a more grass roots level. The other obvious challenge is provided by that other major root crop in Africa, yams. Here, scientists certainly have a lot to offer in the provision of seeds because many yam varieties seldom set seed under normal farming practice. However, yams can also be very important culturally, so community involvement is also very important and farmer participatory breeding would again seem to have a lot to offer.

For further information contact: Richard Gibson at r.w.gibson@gre.ac.uk and Joe Manu-Aduening at jmaduening@yahoo.co.uk . A more detailed analysis of participatory breeding will be published in Euphytica.

Appendix 3: Manuscript prepared for Coraf Action

Getting the best of both worlds in cassava breeding

Root crops are especially important foods in West Africa: in Ghana, >20 % of calories in the national diet is provided by cassava alone [465 kg/person], far ahead of any other single crop or animal source. With rising populations, cassava is increasing its dominance as a food source and it also has perhaps the greatest potential of any African crop to supply starch-based industries and intensive livestock production. Production remains dominated by landraces, particularly for traditional foods like *fufu*, implying that traditional breeding by African farmers still has a lot to offer. Researchers have recently discovered that new landraces develop only slowly, partly because farmers generally ignore seedlings – which represent the opportunity for new landraces - preferring the safer option of taking cuttings from the landraces whose performance they already know and not consciously realising the potential value these seedlings represent. Also, farmers can only access seedlings developing from seed shed by their own varieties and cannot access novel characters, say high disease resistance. Consequently, the productivity of landraces may be only moderate, often held back by infection with diseases such as cassava mosaic. Scientists, on the other hand, know why seedlings are important in varietal improvement and can access seeds from colleagues anywhere in the world. This led to the concept that a partnership between farmers and scientists could get the best of both worlds. With funding from the Crop Protection and the Plant Sciences Research Programmes of the UK Department for International Development, a breeding programme involving farmers right from the seedling stage has now been tested for the first time for cassava by scientists from the Ghanaian Crops Research Institute (CRI) and the UK Natural Resources Institute (NRI).

The work started with an initial study of the farmers' circumstances and what their requirements were. This also got everyone to know each other and included an explanation to the farmers of the concept of participatory breeding and their expected role in it. Cassava seeds of a diversity of half-sib families were obtained by Dr Joe Manu (CRI) from Dr Alfred Dixon at the International Institute of Tropical Agriculture and were planted on communal land belonging to the farmers. At the end of the first growing season, the crops were harvested and the scientists and the farmers, each as a separate group because we wanted each to make independent choices, selected which plants they wanted to keep for planting in the next season. Farmers, by examining clusters of plants and selecting the best in each, managed to cope with the many hundreds of seedlings available despite never having done this job consciously before. Since the underlying philosophy was to use the different strengths of the farmer and scientist partners to compensate for weaknesses of the other rather than to compromise each other's strengths, both the plants chosen by the farmers and those chosen by the scientists were kept. Cuttings of the chosen seedlings were then replanted for another growing season; at maturity, those which the farmers and the scientists wanted to keep were again replanted. As the number of cuttings available has increased, farmers took planting material home, partly so they could find out how they tasted etc. This process has now occurred for some 5 generations and the number of genotypes retained has shrunk from many hundreds of plants to 15 - but with three front runners. These few are high-yielding, highly disease resistant and also to have characters that the farmers really appreciate in their local varieties. Farmers have been so impressed by one that several are now multiplying it themselves. The new genotypes have also been incorporated by CRI scientists in formal multi-location trials so the best can eventually be released.

The approach seems to bring several advantages. Involvement of farmers and working on-farm in the communities certainly added something extra to the process. Farmers and scientists sometimes chose the same plants but this often wasn't the case: farmers had some different criteria and often had a different approach from scientists – farmers generally selected for positive features such as healthy-looking leaves whereas scientists generally selected by rejecting inferior plants. Consequently, farmers contributed unique selections and a high proportion of these have gone right through to the final selections. Selecting under farmer conditions may also have led to different genotypes being selected than would have been selected on-station. Another advantage of collaborative breeding is that it was fast. A few genotypes were selected from an original population of several hundreds within 5 generations, a similar timescale to that for conventional on-station breeding. However, with on-station breeding, farmers then have to validate the scientists' initial selections whereas, when farmers and scientists selected simultaneously, this has already been achieved. Saving time is important because it means the benefits of better varieties are gained that much earlier. Our farmers are already multiplying and exchanging preferred clones so stocks are being built up and the new genotypes are already contributing to improved food supply and income generation.

So where next? One interesting advantage of decentralized collaborative breeding is that there is the potential to select in all the agroecologies in which the crop is grown in a country rather than in the more limited number of agroecologies official institutions occupy and for the different end-uses different communities may have. There is therefore potential to generate a greater diversity of varieties but to achieve this we need to extend the scheme at the grass roots level. The other obvious challenge is provided by that other major root crop in Africa, yams. Here, scientists certainly have a lot to offer because many yam varieties seldom set seed under normal farming practice. Yams are also very important in some cultures, so community involvement is likely to be even more important.

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A more detailed description will be published in *Euphytica* this year.

Photos
1. Ghanaian women with HY Cassava.JPG
A group of a Ghanaian cassava breeding team proudly showing the root yield of a cassava clone they have selected
2. Ghanaian farmers evaluating cassava.JPG
A group of Ghanaian farmers evaluating individual cassava clones in the field

Appendix 4: Manuscript prepared for *Roots*

Collaborative Breeding of Cassava and Sweet Potato in Africa

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Landraces dominate production of both cassava and sweet potato in Africa. Some of these landraces have proved widely useful: the Tanzanian landrace SPN/0 has spread internationally, for example, to Uganda, Kenya and Zambia; the cassava mosaic disease (CMD) near-immunity in TME cassava lines derives from landraces; and the well-adapted orange-fleshed sweet potato varieties such as Kakamega and Kala are Kenyan and Ugandan landraces respectively. Details of how these landraces developed have recently been reported: for sweet potato in Tanzania and Uganda (Gibson *et al*., 2000) and for cassava in Tanzania (de Waals *et al*., 1997) and Ghana (Manu-Aduening *et al*., 2005). It was generally impossible to trace a particular landrace back to the actions of a particular farmer or group of farmers and most farmers ignored seedlings of both crops most of the time, presumably preferring the reliability of taking cuttings from known cultivars. At least for cassava, farmers may occasionally select planting material from natural seedlings because of some attribute they spot but may also use cuttings from seedlings when they have insufficient of their current landraces. New genotypes may also become incorporated in a landrace when seedlings grow within crop, especially if they grow where a cutting was planted and especially if the cutting fails. After that, any genotypes which are superior to the old landrace are presumably planted preferentially and gradually dominate.

The continued success of cassava and sweet potato landraces implies that farmer selection, whether conscious or subconscious, has much to offer breeding programmes. Despite that, our recently-gained knowledge of the process identified sources of inefficiency in the traditional process. These include, for at least sweet potato, the rarity of seedlings and, for both crops, that farmers ignore [or even hoe up] most seedlings. Farmers can also only access diversity already within their local germplasm. Such factors have probably contributed to the relatively slow evolution of superior disease-resistant landraces and contributed to the continuing damage caused by the pathogens, e.g., CMD and sweet potato virus disease (SPVD). Scientists, by contrast, can access a wide diversity of germplasm, understand the underlying mechanisms of genetics and can produce large amounts of seedlings to order. It is appreciated that insufficient resources constrain most African national root crop breeding programmes. So-called farmer participatory plant breeding has been adopted in the developing world for many seed crops, at least in part because normal farmer production circumstances and uses are difficult to simulate on-station. These factors provided the basis for The Crop Protection and the Plant Sciences Research Programmes of the UK Department for International Development funding a project in Ghana in which farmers and scientists collaborated together within local communities to develop superior cassava cultivars from, apparently for the first time ever, seedlings grown on-farm (Manu-Aduening et al., 2006); a similar approach [incorporating lessons learnt] has also been utilised in Uganda [and Tanzania although only the work in Uganda is described here partly to avoid repetition and partly because it has advanced faster] for developing new sweet potato cultivars. Throughout both projects, the underlying philosophy was to develop a collaboration amongst farmers and scientists, each contributing through their different strengths. The purpose of this note is root crop scientists in Africa more widely aware of this approach, including advantages and disadvantages.

The Process

Both cassava and sweet potato, the collaborative breeding programme started with developing knowledge of the requirements of the farmers for new cultivars. For cassava, this was done through a formal situation analysis in the two communities we worked with, focusing particularly on the cassava cropping system and the systems within the community with which we might work. For sweet potato, this knowledge was gained over a long period of working with the communities in participatory varietal selection. Both mechanisms led to the identification and/or development of farmer groups, briefing the farmers of the aim of the work and the general development of good working relationships.

A major benefit scientists can bring to breeding both crops is access to large numbers of diverse seedlings. The cassava seeds were provided by Dr A Dixon [International Institute of Tropical Agriculture (IITA)] from his crossing block in Ibadan, Nigeria and were of 16 half-sib families in which the mother plants were chosen on the basis of high yield, CMD resistance and a predominantly West African origin. The sweet potato seeds were provided from a crossing block at Namulonge Agricultural and Animal Production Research Institute (NAARI) and were of 3 half-sib families in which the mother plants and surrounding pollinators were predominantly East African landraces chosen on the basis of their high yield and/or SPVD resistance. The sweet potato seeds were pre-treated with concentrated H_2SO_4 by the scientists to break dormancy.

The communities offered for the breeding work the land they decided, often for a mixture of social and practical reasons, was appropriate for the task. Seeds were planted in these fields: for cassava, seeds were planted directly into the position the plants were intended to grow; for sweet potato, seeds were initially planted in furrows in seed beds close to the fields and a single cutting was taken from each surviving seedling. Some of the Ghanaian farmers were so surprised to see how well many of the cassava seedlings yielded they wondered if the scientists had a subsidiary aim of persuading them to change from using cuttings to using seed as propagation material!

For the Ugandan farmers, it was the first time they had ever been aware of sweet potato seedlings.

For the cassava trials in Ghana, scientists made 1 – 3 routine visits to each trial site during the growing season, with the main aim of monitoring the plants [mainly for diseases] but also to check on routine jobs like weeding and, perhaps most important, to maintain contact with the farmers. During these visits, the plant pathologists determined which cassava genotypes they considered should be retained for replanting. At maturity of the seedling generation, each plant was uprooted with the foliage attached. The cassava breeder selected those genotypes he would wish to retain for replanting. The farmers also selected separately, in this instance working in small groups, each group selecting plants only within a single family so that each farmer group only dealt with a relatively small group of plants. Each selector was asked why s/he retained or rejected a particular genotype. Rather than attempting to reach a consensus amongst the farmers and scientists as to which accessions to retain [as would normally occur for the plant pathologists and plant breeder selecting on-station], all accessions selected each (group of) selector(s) were replanted in a new trial, this time using conventional cuttings and all cuttings from one genotype being planted in one unreplicated plot. For the sweet potato trials, a similar approach was utilised except that there was no separate selection by plant pathologists and the regional breeder for the International Potato Center (CIP) participated as well as the national breeder. A further difference in outcome in the sweet potato trials was that the farmers' selection included all bar one or two of the genotypes selected by the breeders plus many more so that effectively the farmers drove the selection process; for the cassava trials, both the pathologists and the breeder also made many unique selections and so had a greater role.

At each subsequent clonal generation, the same process of selection occurred; as the number of genotypes retained became fewer, so the size and numbers of cutting planted in each plot increased and replica plots were included. Similarly, as the number of cuttings increased, farmers were encouraged to take home a few preferred cuttings, partly so they could take early advantage of the materials and also so they could tell us how they tasted etc when cooked in local meals. As the accessions retained reached just 10 – 20, cuttings of superior clones were exchanged between farmer groups [along with farmer exchange visits]. Planting material of both crops has also been taken by the national programme scientists to incorporate in formal national multilocational trials to test for broad adaptability and hopefully national release.

Outcomes

These reports are the first for farmer participatory breeding from seed of vegetatively propagated crops in Africa, although the benefits of farmer participation in breeding seed-propagated crops such as beans has been achieved for more than a decade. Unlike these crops, farmers were unused to handling seedlings of cassava and sweet potato but this seemed to present few problems. The main problem vegetative propagation presented was that clonal propagation was slow, particularly for cassava; the main advantage seemed to be that clonal propagation simplified selection by preventing further genetic variation.

The process was fast. For both cassava and sweet potato, a few genotypes were selected from an original population of several hundreds or thousands within 4 - 5 generations, a similar timescale to that for conventional on-station breeding. However, since farmers and scientists selected simultaneously rather than sequentially as in more formal plant breeding - with farmers mainly validating scientists' initial selection - the net result is a much faster selection process. Saving time is important because it means the benefits of better varieties are attained that much earlier. Our farmers are already multiplying and exchanging stocks of their preferred clones so stocks are being built up and the genotypes are already contributing to improved food supply and income generation.

Farmers both had some different criteria to those of the scientists and, even for criteria they shared, farmers often had a different approach from scientists – farmers generally selected for positive features such as healthy-looking leaves whereas scientists generally selected by rejecting diseased plants. Analysis of the results indicated that their selection of genotypes was consistent with their claimed criteria and farmers consequently contributed unique selections. Selecting under farmer conditions also appears to have led to different genotypes being selected than may have been selected on-station. For sweet potato, it was very evident that the fields chosen by the farmers for the trials were relatively infertile, and drought and diseases were very important factors in the differential survival and productivity of different genotypes. The genotypes selected had high yields relative to check cultivars and were also relatively disease-resistant.

The approach has potential to make good use of limited resources. The main saving is that, because farmers are involved from the beginning, it is unlikely that all the effort will ultimately be wasted because farmers reject released varieties. It is true that considerable resources were utilised visiting the communal trials. However, the main need for scientists to visit the trials was for the evaluation of the genotypes at maturity and then re-planting the selected ones – and these operations were often combined since it is ideal for both crops if the cuttings are soon after they have been harvested. There was a need to 'pop over' to see the farmers and the trials occasionally but this could generally be combined with other duties. Also, with on-station breeding it is generally considered necessary to bring farmers on-station in the later stages – and bringing an adequate range of farmers on-station can also be expensive.

One difficulty that became highlighted during the projects was that of assessing postharvest attributes of the sweet potato and cassava roots. Even simple boiling the roots was impractical until the number of genotypes remaining was reduced to double figures and cassava in particular is processed into large numbers of different products both for traditional foods and the expanding diversity of new products on the market now. This meant that many genotypes were discarded without even sampling their postharvest qualities. No easy solution seems available; the problem equally afflicts conventional on-station selection. Another thorny area that wasn't fully addressed was that farmer participation can be seen as a broad decentralisation of activities; and whilst it was relatively easy to decentralise the activities, we did not address how to decentralise resources.

Participatory plant breeding has sometimes been seen as a rival to conventional on-station breeding. However, our projects originated from perceived weaknesses in traditional breeding systems and sprang from a collaboration with the national agricultural research system and national breeders in all activities aiming partly to address these weaknesses. A very positive outcome of this emphasis on collaboration is that the national breeders have incorporated collaboratively-selected genotypes into their system of multilocational trials, with official release seen as the target. Once this is achieved, distribution can then be supported officially, enabling rapid long-distance dissemination within-country, complimenting the mostly local exchange of cultivars amongst farmers.

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