

## Participatory breeding of superior, mosaic disease-resistant cassava

R8302

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See R6617, *Perspectives on Pests 1996–2000*, p. 10

Cassava is the cheapest starch staple available in Ghana. It is a particularly important food for both rural and urban poor, and a source of food security. The aim of this project was to improve Ghanaian farmers' access to cassava diversity, and to work with them to develop a range of superior, disease-resistant cassava clones appropriate to their needs. For the first time in Africa, a farmer-participatory approach to breeding cassava from the seedling stage was applied. Analysis of clones selected over three generations indicated that this approach enabled farmers and scientists to work together beneficially. Superior clones are selected quickly because validation by farmers, a cassava breeder, and plant pathologists is achieved simultaneously rather than sequentially. The clones selected need to be released officially if they are to benefit from wide dissemination through official means, and the additional trials needed to achieve this have been identified and planted. Surveys have identified the main characteristics of current cassava end-users in Ghana, and potential and expanding uses in non-traditional foods, livestock feed and non-food uses. A side effect of this has been to improve links between the conventional breeding process in Ghana and the end-users. Clones selected through participatory breeding are being trialled on farms owned by two medium-scale food processors, and flour derived from clones selected by the project has been characterised biochemically.

### ISSUES

Cassava is a significant part of the diet of many people in Africa, and contributes about 22% of Ghanaian agricultural gross domestic product. Its production in Ghana is increasing, replacing yam, cocoyam, plantains, grains and other crops. About 80% of the population rely on it as their main starch staple, providing 18% of dietary energy, more than any other crop. About half the production is consumed fresh in local products such as *fufu* (pounded into a thick paste), and the remainder is processed, for example into *gari* or *kokonte*, dried products that may be stored for long periods and are relatively easy to transport to distant markets.

Cassava also provides a significant source of income through both sales of the storage roots and providing employment in small processing units (e.g. for *gari*). A President's Special Initiative has recently launched a cassava-based starch-production industry, targeting mainly export markets. The Government of Ghana's



Farmers showing the high root yield of one of their selected clones

recognition of the importance of this crop is also indicated by the Roots and Tuber Improvement Programme (funded by the International Fund for Agricultural Development and led by the Ministry of Food and Agriculture) which aims to enhance food security and increase the income of resource-poor farmers. One of the key elements in achieving this aim is increasing the availability of improved cassava planting materials.

### SELECTED PUBLICATIONS

MANU-ADUENING, J.A., LAMBOLL, R.I., DANKYI, A.A. and 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. *et al.* (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* (in press).

A number of pests and diseases cause major problems on cassava, including cassava mosaic geminiviruses (CMGs). Although CMGs affect cassava crops throughout Africa, the disease has also been associated with national or regional epidemics flaring up every few decades. Such an epidemic is currently devastating cassava production in East and Central Africa, and is threatening West Africa. Previous work (R7565) in two communities in Ghana suggests that farmers know much about the symptoms and causes of insect pest damage and of the symptoms of various diseases, but have less understanding of what causes diseases, including cassava mosaic disease (CMD).

Breeding work in Africa on cassava has been primarily on-station, although generally with final validation on-farm. A selection derived from an interspecific cross with *Manihot glaziovii* (tropical *Manihot* species, TMS) became the basis for a series of agronomically improved CMD-resistant cassava clones and seed, which have provided the main control strategy in Africa for several decades. More recently, another source of resistance has been identified in some West African landraces, leading to the TME (tropical *M. esculenta*) series of clones.

Only four varieties of cassava had been released in Ghana in the past few decades. A number of new varieties have now been released by the Savannah Agricultural Research Institute, Kwame Nkrumah University of Science and Technology, Kumasi and CRI, but it is too early to assess uptake by farmers. Landraces remain the main means of cassava production in Ghana, as in much of Africa.

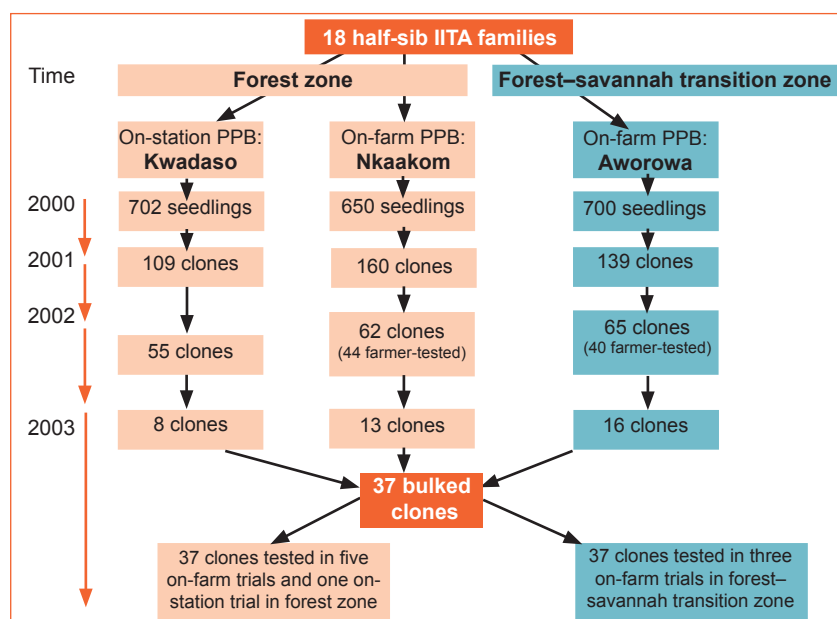
## ACHIEVEMENTS

This project continued the development and validation (begun by R7565) of a process involving the participation of both farmers and scientists for selecting superior disease-, pest- and weed-resistant cassava clones. The aim was to select clones that are more adapted to local conditions and more appropriate to the needs of farmers and other end-users than those selected by the current on-station selection process. This is the first application in Africa of selection by both farmers and scientists from a wide diversity of cassava seedlings, provided by scientists and grown on-farm by farmers. Farmers, a formally trained cassava breeder and plant pathologists from CRI made separate selections over one seedling generation and three subsequent clonal generations, in which genotypes selected by

any one of these three groups were retained (see figure). This process ensured the selections of each group were all retained, with no opportunity for one group to influence the others and coincidentally allowing opportunities to analyse the outcomes of selections by each group.

Participatory plant breeding activities in two communities and at an on-station trial, monitoring the characteristics of selected accessions through several generations, have led to the selection of 37 superior clones that are being tested in further multi-locational community trials in Brong Ahafo and Ashanti regions. The bases for the breeder's and the plant pathologists' choices were predetermined; the basis of the farmers' choices was determined by questionnaires at each harvest. The breeder placed most emphasis on yield; the plant pathologists on absence of foliar diseases; and the farmers on a diversity of storage root characteristics (of which high yield is the main one) and canopy formation.

Farmers, the CRI plant breeder and plant pathologists all tended to make broadly similar selections, as indicated by a considerable degree of overlap between their choices. Despite this, each group of selectors (particularly the farmers) made many unique selections, highlighting the value of their inclusion. Farmers' selections, in particular, were also reasonably consistent from one generation to the next, demonstrating their competence in selection. The project capitalised on unique selections by different groups by ensuring that selections of all groups were retained from one generation to the next. This did not slow the elimination of inferior accessions excessively: the progress of selection of superior accessions occurred at a similar rate to that of conventional plant breeding and benefited from all groups selecting simultaneously, so there is no need for subsequent on-farm testing by farmers. The selection process has identified genotypes that



The participatory breeding scheme



*Clockwise from top right: pounding fufu, Suhum, Eastern Region; large-scale starch processing, bagging of high quality starch, Awutu-Bawjiase, Central Region; medium-scale multi-purpose processing, milling flour, near Amasaman, Greater Accra Region; small, family-run, peri-urban gari processor, Cape Coast, Central Region*

are high-yielding under farmers' conditions, and with a relatively high and well branched canopy intercepting a high percentage of light. The accessions selected appear moderately resistant to diseases, and are likely to shade out weeds. These results validate the participatory selection process adopted – all groups, particularly farmers, made their selections in an effective and individual, yet inclusive manner.

The method will not finally be validated until long-term adoption by farmers is demonstrated. This is being enabled in the communities in which the project works directly, by allowing farmers to take cuttings of their preferred accessions to plant on their own farms. Relying on farmer-to-farmer transfer of superior accessions is expected to be slow. The project is well placed within the official Ghanaian system to release superior genotypes through the Ghanaian Variety Release Committee, enabling official systems to distribute more widely. Analysis of previous release documents demonstrated the lack of a broad enough range of multi-locational trials in specified

agro-ecologies, so additional multi-locational community trials have been planted in Brong Ahafo and Ashanti regions.

A weakness of the project's initial participatory approach (and of conventional cassava breeding at CRI) was a failure to address the needs of cassava end-users other than farmers. This has now been addressed by surveys of non-farmer end-users, current and potential uses of cassava, and the activities of post-harvest researchers in Ghana. The results of these surveys have led to an initial pair of trials of superior accessions selected by the project at farms of medium-scale manufacturers of cassava food products. The surveys were conducted either by, or in close cooperation with, the CRI plant breeder. This activity has achieved a closer working relationship of the CRI cassava breeder with non-farm end-users and scientists at the Food Research Institute in Ghana, resulting in starch characteristics being included in cassava variety release documents for the first time in Ghana (and perhaps in Africa).

This participatory breeding project has provided an approach by which

farmers, a plant breeder and plant pathologists can work together in an effective and inclusive manner in selecting cassava genotypes from seed. It also provided an environment whereby farmers made a significant and consistent contribution to the outcome of selection.

## FURTHER APPLICATION

A project extension (R8405) aims to submit documentation of the requisite characteristics of selected cassava

genotypes to the Ghanaian Variety Release Committee, and as a result to release one or more varieties in Ghana. This would achieve independent, official validation of the participatory breeding approach, and provide a 'worked example' of how to achieve it to other researchers.

The same participatory approach has been transferred to Uganda and Tanzania for selection of farmer-preferred and sweet potato virus disease-resistant varieties of sweet potato (R8243, page 28; extension project R8457). Because sweet potato has a much shorter generation time than cassava, this activity in Uganda has already reached a similar stage and appears to have quickly identified several high-yielding, disease-resistant clones, which farmers are also already multiplying and adopting. These clones also appear to be particularly well adapted to the marginal lands to which this crop is often relegated. Again, the material has been adopted by the national programmes for inclusion in multilocal trials, with the ultimate aim of national release.

# Maximising and promoting the benefits to farmers of cassava mosaic disease-resistant varieties

## R8303

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See R6765, R6614, *Perspectives on  
 Pests 1996–2000*, pp. 13–17

## SELECTED PUBLICATIONS

COLVIN, J., OMONGO, C.A., MARUTHI, M.N., OTIM-NAPE, G.W. and THRESH, J.M. (2004) Dual begomovirus infections and high *Bemisia tabaci* populations: two factors that drive the spread of a cassava mosaic disease pandemic. *Plant Pathology* 53: 587–614.

COLVIN, J., CHOWDA REDDY, R.V., REKHA, A.R. *et al.* (2004) Ecological and reproductive isolation amongst African and Asian *Bemisia tabaci* populations. In: *2nd European Whitefly Symposium*, Cavtat, Croatia, 5–9 October 2004 (abstract).

LEGG, J.P., SSERUWAGI, P. and BROWN, J. (2004) *Bemisia* whiteflies cause physical damage and yield losses to cassava in Africa. p. 65. In: *6th International Scientific Meeting of the Cassava Biotechnology Network* (abstract).

OMONGO, C.A., COLVIN, J., SSERUBOMBWE, W. *et al.* (2004) Host plant resistance to African *Bemisia tabaci* in local landraces and improved cassava mosaic disease resistant genotypes in Uganda. p. 84. In: *6th International Scientific Meeting of the Cassava Biotechnology Network* (abstract).

Cassava is among the most important food crops for the rural poor throughout Africa, both for food and food security. A pandemic of cassava mosaic disease (CMD) associated with very large populations of their whitefly vectors has been devastating the crop in East and Central Africa. This project validated control methods (CMD-resistant varieties; selecting disease-resistant planting material; intercropping with a resistant cassava variety to protect a susceptible one) and means of disseminating knowledge of them to farmers in East Africa. This work has also shown that whiteflies are now a direct pest of cassava in Africa, as well as the vector of its main disease. Major progress has been made towards their control: previously unknown sources of whitefly resistance have been identified not only in African landraces, but also in advanced breeding lines sufficiently superior in yield and CMD resistance to be trialled for national release. If successful, this material will be a major weapon in the fight to control direct damage by whiteflies, and will contribute to protecting the crop against CMD and the spread and evolution of more whitefly-borne viruses.

## ISSUES

Cassava mosaic disease (CMD), the most damaging insect-borne disease of African food crops, is the main constraint to cassava production in Africa, diminishing production by an estimated 15–24% (12–23 million tonnes per year). CMD is caused by

viruses belonging to the genus *Begomovirus*, family Geminiviridae. Cassava mosaic geminiviruses are transmitted in the persistent manner by the whitefly *Bemisia tabaci*. The disease is caused mainly by two viruses – African cassava mosaic virus (ACMV) and East African cassava mosaic virus (EACMV). Previous projects (R6614,

R6765, R7565) have shown that the spread of CMD in East Africa from the late 1980s was associated with unusually large whitefly populations, rapid spread of CMD and very severe disease symptoms. The cause is now known to be a natural recombinant of ACMV and EACMV. This new strain, called EACMV-Ug ('Ugandan variant'), alone or in dual infections with ACMV, was shown experimentally to cause the severe symptoms typical



Severe CMD on a CMD-susceptible variety (foreground) contrasted with a resistant variety in the background



Farmers in Tanzania emerging from a sea of healthy, highly CMD-resistant cassava varieties (photo: James Legg)

of the epidemic. Its arrival in Tanzania in 2000 has resulted in the Department of Research and Development giving highest priority to controlling virus diseases of root crops (principally CMD) in the Lake Zone. As in Uganda, the pandemic has already created much hardship in these newly affected areas to the west of Lake Victoria. The impact looks set to increase dramatically as severe CMD spreads to the south and east of the lake, where farming communities depend even more on cassava for their livelihoods.

Modern resistant varieties provide the main control strategy for the CMD pandemic in Africa, but no single variety is perfect. This project, in partnership with the international Tropical Whitefly IPM Project (R8041), aimed to validate modern resistant varieties and other control technologies, including selection of planting material and mixing susceptible landraces with resistant varieties, in a close working collaboration with farmers in Uganda and the Lake Zone of Tanzania.

## ACHIEVEMENTS

Working with farmer groups in Uganda and Tanzania, the project has tested the use of CMD-resistant varieties, selecting disease-free

planting material and different cultural control practices, notably intercropping with a resistant cassava variety to protect a susceptible one. Field demonstration plots in five farmers' fields in Mukono have demonstrated to farmers (and validated for researchers) the lower incidence of CMD in resistant varieties (00067; TME14; TME204; NASE 10) and in carefully selected disease-free planting material of CMD-susceptible landraces planted among a CMD-resistant variety. The final incidences of CMD in the local varieties (Kabwa and Njule), when grown with a CMD-resistant variety (00067), were 45% for Kabwa and 73% for Njule, in Mukono District, versus 68 and 99% when grown alone. Comparable figures for two other locals (Bao and Nyaraboke) in Apac were 57 and 58%, respectively versus 73 and 83% when grown alone. In the mixed crops, healthy plants remaining at the end of these experiments were sufficient to provide clean cuttings for further plantings. Civil unrest in northern Uganda resulted in the abandonment of work in Lira and its late replacement with work in Soroti.

Resistance was clearly the most effective means of controlling CMD, but the cultural control measures did provide a means by which farmers were able to sustain production of

moderately resistant local landraces despite the pandemic.

A leaflet describing the causes, means of spread and various ways of controlling CMD through the use of high-yielding resistant varieties has been produced by the Uganda team in English, Kiswahili and Luo. A guide in Kiswahili describing the causes, means of spread and ways of controlling both CMD and sweet potato virus disease (which, like CMD, is spread by whiteflies) has been drafted by the Tanzanian team. Members of the Tanzanian team have also visited Uganda to exchange ideas.

Training in how to control CMD has been provided to farmers in the collaborating farmer groups in Uganda. Here, however, the pandemic has long been established and most farmers are already aware of the causes of the disease. In Tanzania this is not the case, and the project has collaborated with other organisations, notably Norwegian People's Aid (NPA), to provide training for extensionists, mostly within the Lake Zone but also further afield in the country. This collaboration with NPA has also extended to providing technical aid in the dissemination of planting material of resistant varieties.

Populations of whiteflies one to two orders of magnitude greater than before the CMD pandemic have been observed, notably in Uganda but also in other countries affected by the pandemic. Sooty mould is often observed blackening middle and lower leaves where whitefly excreta have become infected with fungi. Chlorosis and stunting of middle and upper leaves occurs, caused on the upper leaves by adults feeding, and on middle leaves mainly by nymphs feeding.

A trial repeated in two seasons, and involving eight varieties differing in apparent susceptibility to whiteflies, was conducted in Uganda to assess the effect on yields of using insecticides to control whiteflies. The insecticides controlled the



*Above, whitefly damage (sooty mould) on cassava; right, whiteflies on underside of a cassava leaf*

whiteflies, removing observable signs of whitefly feeding damage, reducing the spread of CMD in susceptible varieties, and generally leading to a higher root yield. The higher yield was seen in both CMD-susceptible and near-immune varieties, so it was not the result of reduced spread of CMD. These results also demonstrate for the first time in Africa how the spread of CMD can be decreased by the use of insecticides to control the vector.

Large numbers (279) of Ugandan landraces have been screened for resistance to whiteflies, leading to the identification of a few resistant ones, such as Njule. Some released varieties also appear to support relatively few whiteflies. Screening of advanced clonal accessions in national advanced and uniform yield trials has also identified potential resistance in these clones. In particular, the clones MM96/4271 and MM96/0686 supported few whiteflies and whitefly nymphs in uniform yield trials, and were also chosen by farmers and scientists using other criteria. Resistance of the identified clones has been confirmed in screenhouse preference tests. It is important that this work is continued so that

future released varieties will be less susceptible to whiteflies than some previous releases.

Project scientists have also identified an outbreak of another whitefly-borne virus, cassava brown



streak, in Uganda (see R8227, page 20). This seems likely to result from the large numbers of whiteflies affecting cassava crops in Uganda, and whitefly resistance may be a key component in its control.

### FURTHER APPLICATION

The sustainability of this approach needs to be tested, and there is also scope for trying intercrops or barrier crops. Such work should be

done in different areas to cover a range of different circumstances and infection pressures.

The cassava mosaic pandemic continues to expand in and from the Lake Zone in Tanzania, with severe effects on the livelihoods of poor rural people there, many of whom are unusually dependent on cassava for food because the dry conditions limit the growth of other crops. It is also affecting many other Central African countries, including Rwanda, Burundi and the Democratic Republic of Congo, and appears to have the potential to spread throughout sub-Saharan Africa. This project plans to disseminate knowledge of and materials for the control of CMD; to train government and NGO extensionists using the protocols and materials developed; and to disseminate resistant materials.

Future work should address the problem of how to improve the current unsatisfactory health status of the many local varieties still being grown, some of which are highly regarded by farmers. A more farmer-participatory approach to cassava breeding (see R8302, page 14) could facilitate the development of resistant varieties with the preferred characteristics of these local varieties. Currently local varieties predominate in a high proportion of all plantings, yet they are almost totally infected and yields are seriously impaired. They are also an important source of inoculum from which there is spread to other varieties, which increases the likelihood of a breakdown of resistance.

The increasing numbers of whiteflies on cassava remain a serious problem in Uganda and other countries affected by the pandemic, in terms of both direct damage and increased risk of whitefly-borne viruses. The project plans to continue work on identifying sources of resistance through an extension of this CPP project and through the Tropical Whitefly IPM Project (R8041).