A group of bananas bypassed by modern times offers a glimpse of what the ancestors of the export banana might have looked like. A Bioversity project, supported by the Gatsby Charitable Foundation, has been working with partners to understand the banana diversity of the Comoro Islands and to conserve it before it is too late.

A banana time machine on the Comoro Islands

French banana breeder Frederic Bakry pores over a plant portrait photographed by Mohamed Said Mzeouigni. He is searching for visual clues that will allow him to put the plant in its correct place among the known diversity of bananas and plantains. The fruit looks like a plantain but the colour of the male bud is all wrong. The inescapable conclusion is that this plant belongs to a type found only where the photo was taken, the Comoro Islands, a group of islands tucked away off the coast of Africa between Mozambique and Madagascar.

Thanks to the pioneering work done by his colleagues at the French Agricultural Research Centre for International Development (CIRAD), Bakry had known for some time that farmers in the Comoro Islands had been nurturing several unique types of banana. In the 1970s and 1980s French scientists visiting the islands noted the unusually high levels of banana diversity and collected samples for conservation in genebanks. This diversity took on additional significance in 2005, when CIRAD scientists probing the genetic make-up of the Comorian material conserved in the centre's banana collection in Guadeloupe announced that some of the varieties were the closest living relatives of the Cavendish banana that currently dominates the export market and of its predecessor, Gros Michel. It is by no means obvious to the naked eye that these Comorian bananas are of the same stock as the two export bananas, but the discovery of a genetic link has reawakened the dream, thwarted by repeated failures, of one day creating a commercial banana that would taste and perform like Cavendish (or better yet Gros Michel) while also being much more resistant to pests and diseases.

Mohamed Said Mzeouigni

'Padji', a local variety that is resistant to black leaf streak disease (black Sigatoka), might help efforts to breed a better dessert banana.

Bakry and his colleague, Christophe Jenny from the Guadeloupe station, were keen to continue documenting this diversity and securing it against threats such as disease, competition from introduced varieties and agricultural intensification. They approached Bioversity's Commodities for Livelihoods Programme in Montpellier, France, with a project to survey the islands' *Musa* diversity. Richard Markham, the programme director, immediately proposed integrating their survey into a Bioversity project on conserving banana biodiversity for Africa, funded by the Gatsby Charitable Foundation.

One of the objectives of this project, which ended in 2007, was to assess the gaps in existing collections in relation to known or postulated centres of diversity. Collecting missions were targeted on Tanzania and Kenya for East African highland bananas, an indigenous group of dessert and cooking bananas, and the Congo basin of the Democratic Republic of Congo for plantains. The Comoro Islands survey presented a perfect opportunity to check on a third group of distinctly African bananas.

Nobody knows when the ancestors of today's African bananas reached the continent or how they arrived there. Bananas originated in the tropical rainforests of Asia. Recent archaeological evidence suggests that cultivated varieties may have arrived on the east coast of Africa as far back as 4000 years ago, although it is impossible to say whether they included the ancestors of today's highland bananas and African plantains. While Africa was becoming a secondary centre of diversity for these two groups, domestication was also proceeding in Asia, where more productive triploid varieties were replacing the ancestral diploid ones (see box, Wild beginnings).

The Comoro Islands, in contrast, became a refuge for diploid bananas derived from *Musa acuminata*. Bakry and his colleagues speculate that this happened because the islands are small and for most of their history have been off the beaten track of human migration and trade. Nearby Madagascar, for example, is much larger and has more biodiversity—as the theory of island biogeography predicts—but its banana diversity doesn't come close to that of its smaller neighbours (the islands of Pemba and Zanzibar also harbour rare diploids).

Bakry had no difficulty persuading Mohamed Said Mzeouigni, a Master's student at the Université Pierre et Marie Curie in Paris, to survey the banana diversity of the three main Comorian islands. Funding from CIRAD, the French government and Bioversity's Gatsby-funded project allowed Mzeouigni to spend two months in the Comoro Islands. His mission: to describe the plants based on established descriptors and to take photos and leaf samples from every unusual banana plant he was able to find with the help of a local agronomist. (All the information will be included in Bioversity's *Musa* Germplasm Information System.)

So far, some 48 plants have been tentatively classified into almost as many varieties based on Mzeouigni's photos and notes. Most of the leaf samples were analysed using a technology called flow cytometry, which revealed 9 diploids and 28 triploids (the ploidy of some samples could not be determined because they had deteriorated). The triploids tend to belong to groups that are common elsewhere but Bakry points to a few unique specimens. 'Padji' is a dessert banana that CIRAD scientists have shown is resistant to black leaf streak disease, the fungal disease commonly known as black Sigatoka that is forcing most commercial growers to use an increasingly heavy regime of fungicides. Unfortunately, 'Padji' doesn't have the post-harvest qualities that would allow it to break into the export market.

Wild beginnings

Botanists have identified some 70 species of wild bananas. Many bananas trace their origin entirely to *Musa acuminata*, which donated the so-called A genome. However, many cultivars, especially plantains, also include in their lineage *M. balbisiana*, which donated the B genome. Wild bananas are diploid; that is they have two sets of chromosomes, one from each parent. Typically full of seeds, wild bananas became edible when some of their offspring started producing fruits that had more flesh than seeds, prompting farmers to propagate them by using the offshoots (known as suckers) that grow at the base of the plants. But since these edible diploids were still fertile, they could also receive pollen from wild bananas.

Domestication went into high gear when one of the parents 'accidentally' contributed a double set of its chromosomes (instead of a single set, as sexually reproducing organisms normally do). These triploids very seldom set seeds, but what they lost in fertility they made up for in productivity, making them very attractive to farmers. From that point on, cultivated bananas relied entirely on vegetative reproduction; diversity was created by farmers selecting and multiplying any favourable mutations that arose. The most well-known triploid bananas, at least in banana-importing countries, belong to the Cavendish group, which dominates international trade.

T. Lescot/CIRAD

A woman carries a bunch of Cavendish bananas from her plot. The diversity of bananas on the Comoro Islands is threatened by the spread of Cavendish.

The diploids are more unusual. With one exception, Bakry reckons that they belong to a rare group of bananas that French scientists call 'mlali'. Some of those varieties, 'Samba' and 'Chicamé' for instance, are unique to the Comoro Islands while 'Mjenga' is also grown in Tanzania. Another, 'Chimwali kananbobwa', is unusual because it is a diploid that looks like a triploid. The great drawback of these diploids, however, is that they are very susceptible to diseases.

Pests and diseases, especially the black weevil, are one of the reasons why banana yields in the Comoro Islands are low, confirms Thierry Lescot, a banana production specialist at CIRAD. He adds that farmers do not use fertilisers and the scarcity of water on the islands precludes irrigation to make up for the lack of rain during the six-month dry season. Comorians traditionally grow bananas on small plots in low-input, mixed cropping systems. Yields have not been keeping up with growth in the islands' population and as a result farmers are under pressure to use pest- and disease-resistant varieties to boost productivity. Improved hybrids, however, are not popular with the islands' farmers or consumers. Modern varieties are mostly bred to solve disease problems, especially those found on large-scale plantations, and often lack the characteristics that would make them appealing to smallholder farmers with a long tradition of eating a large diversity of bananas.

Comorian bananas have become a traded commodity only in the past 40 years. Before that they were grown communally and belonged to everybody. Bakry thinks that the cultural value associated with bananas might have helped the rarer varieties survive to this day, but he is worried about the future. He thinks the islanders should be helped to conserve their unique banana diversity, and suggests setting up a field collection on each of the islands and even establishing a breeding centre that would help Comorians to create their own varieties. Bakry stresses the urgency. About three-quarters of the bananas produced in the archipelago are already the ubiquitous Cavendish. Time is not on the side of the edible diploids and there is still work to be done before scientists have a comprehensive picture of the islands' unique banana diversity.

The conservation of *Musa* diversity is one of Bioversity's goals, and the Commodities for Livelihoods Programme has developed a strategy for *ex situ* conservation with the Global Crop Diversity Trust. Sorting out diversity—which includes getting names right and establishing relationships among varieties—is a vital prelude to effective conservation. This is a painstaking activity that requires a strong commitment, if only because we have a tendency to appreciate the importance of diversity only after it has disappeared. Making sure that the Comorian bananas escape that fate is a demanding but important activity.

Further information
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DArT targets molecular information

Descriptors for Banana, developed by Bioversity and CIRAD, lists 121 morphological characters that can be used to identify a banana plant. To make the job a little easier it also points to the 30 most discriminating descriptors that are stable across different environments. This reduced set of descriptors is being tested on 718 *Musa* accessions from Bioversity's International Transit Centre (ITC) that are being grown in the field to verify their identity (see *Rejuvenated bananas justify genebank confidence*, Annual Report 2005, p. 26). A reliable set of descriptors eases the process of identifying an unknown banana somewhat, but for more-precise identification at the cultivar level the latest strategy has been to look in detail at the DNA.

Various types of molecular marker have been tested to see if their results agree with those obtained with morphological characterization. The most useful approach for processing a large number of diverse samples at the same time is a recently-developed method known as DArT, for Diversity Arrays Technology. The great benefit of DArT is that it does not require any knowledge of the DNA sequence. It works by taking DNA from a large sample of individuals and from this 'metagenome' identifying fragments that are present in only some of the individuals. These are the so-called DArT markers. Once they have been identified, it is reasonably easy to develop a molecular profile for individual samples based on which of the DArT markers their DNA contains. As with other molecular markers, from these profiles it is possible to assemble a family tree that indicates relationships among the samples.

As part of a Gatsby-funded project studying *Musa* diversity, Bioversity has been working with Andrzej Kilian, the inventor of DArT technology, to investigate the same 718 *Musa* accessions from ITC that are being characterized using morphological descriptors. The results should help to confirm the identity of accessions that the morphological descriptors suggest are mislabelled. They will also be interesting for the light they might shed on the banana's phylogenetic tree and the places of the various African branches.

DArT analysis confirms that some of the Comorian diploid AA bananas are closely related to Cavendish and Gros Michel, which are triploid AAA. The East African highland bananas, on the other hand, cluster among the AA bananas from Papua New Guinea, even though they too are AAA. Finally, as predicted from morphological studies, the African plantains are closely related to the Pacific ones, which together share a common ancestor with AAB bananas from India.