TAILORING BIOTECHNOLOGIES
Vol. 3, Issue 1, Winter 2007, pp: 107-130

Who needs GM bananas?
And will they have the chance to choose?

Anne Vézina and Richard Markham

Abstract

In this article we present a case for genetically engineering bananas and plantains (Musa spp.), both the staple and the export crops, in order to shift the focus of the debate on GM crops out of the political and ideological arena and refocus it on technical and economic arguments. We argue that GM bananas do not pose a threat to the environment, human health and smallholder farmers who grow 85% of the global production. We fear that unless consumers in industrialized countries overcome their reticence, the people with the most to gain will be denied the benefits of this technology.

Introduction

The controversy over genetically modified (GM) crops is exacerbated by the tendency on both sides of the debate to stick to their respective position and defend it with evangelical fervor. In what has become a battle for people's hearts and minds, the general public and policy-makers are asked to take sides for or against GM crops in general. With supporters giving the impression that they would back any kind of modification and opponents refusing to consider that certain GM crops might do more good than harm and advocating banning genetic modification altogether, rather than certain types, there seems to be little room for deciding on a case-by-case basis.

The debate over the relevance of GM crops to developing countries is similarly bogged down in issues that are not easily resolved by scientific debate. It is perhaps understandable that concerns about GM technology have become entwined in broader concerns about who provides and controls technological innovation and for whose benefit. However, we feel that the best way to move the debate forward is to discuss individual cases on their respective merits.

We present a case for genetically engineering bananas and plantains-the varieties grown by small-farmers, which represent a staple for millions of people in the tropics and account for about 85% of the global production, as well as the export dessert banana that makes up the rest. As the world's most popular fruit, the banana offers the opportunity of reaching out to the well-fed populations of rich countries for whom the benefits of genetic modification are viewed as being so marginal as to not be worth the supposed risk, but whose reticence is denying the benefits of this technology to people who have more to gain from it.

Why bananas?

The main motivation for using transgenic approaches is that most domesticated varieties of bananas and plantains (Musa spp.) are for all practical purposes sterile-farmers traditionally replant their fields with shoots produced by the mother plant while commercial companies use plantlets derived from tissue culture. The problem is that the slow rate at which genetic diversity is generated in these crops (by occasional, naturally-occurring mutation) gives the advantage to the natural enemies of bananas and reduces the ability of the plants to adapt to changes in the environment.

Breeding bananas by conventional means is feasible, but only because some varieties retain some fertility. However, a low seed set combined with the relatively long time (12-18 months) required to grow a plant to maturity, when its performance can be evaluated, make progress slow. This is especially the case because agronomically useful varieties are rarely if ever inter-fertile and, after crossing them to a more fertile, nearer-to-wild-type relative, numerous further generations of crosses may be needed before an acceptable hybrid is obtained.

For instance, the first breeding efforts targeted a variant of the Gros Michel banana, the variety that dominated the international trade until the 1950s, when a soil-borne fungus made its cultivation on large plantations no longer possible. Unlike the completely sterile Cavendish varieties that have replaced it, Gros Michel can be stimulated to produce some seeds when fertilized with the pollen of wild-type bananas. But because breeding disrupts desirable agronomic or fruit characteristics, many of them complex traits under the control of multiple genes, none of the hybrids derived from Gros Michel, and from the other dessert varieties that have also been tried, have met the exacting standards of the industry.

The few breeders working on bananas have since redirected their efforts mainly to addressing the needs of small-scale farmers; however, consumers in areas where bananas have been part of the diet for hundreds, if not thousands of years, also have exacting standards. It has taken several decades to come up with more productive, disease-resistant varieties that stood a chance of being adopted by farmers. But even these improved hybrids do not readily substitute for local varieties in traditional dishes and so far the record on adoption of improved hybrids among small-scale farmers is at best mixed. As a result, most of the varieties grown for local consumption are still farmer selections of naturally occurring mutants.

The appeal of genetic engineering is that it holds the prospect of preserving the characteristics of a plant to which farmers and consumers are attached, while complementing them with useful traits such as resistance to certain pests and diseases and tolerance to abiotic stresses, which are on the rise as a result of a shrinking and degraded land base and a changing climate.

As with breeding, the first to try their hand at genetically modifying bananas were the large-scale commercial producers. The industry initially explored transgenic solutions to the problems caused by nematodes, which attack roots, and the fungal disease black leaf streak, better known as black Sigatoka. Spraying against the fungus, which attacks the leaves, is said to represent about 30% of production costs in dessert banana plantations (Stover and Simmonds, 1987) while nematicides are hazardous both to the workers applying them and to the environment. These efforts appear to have reached the stage of producing dessert bananas with useful levels of resistance to nematodes; they used cystatin genes from other food plants, which should have presented no risk to consumers, while getting rid of the health and environmental hazards of nematicide use. It is hard to know exactly what happened, but word along the scientific 'grapevine' suggests that companies stopped short of completing registration and commercialization of the new varieties mainly from fear of an adverse consumer reaction.

Although most of the work on transgenics was carried out mainly by public sector entities, such as universities, rather than by the companies themselves, much of the intellectual property associated with the research remained proprietary, delaying the possible redirecting of this technology to the effort of breeding better GM bananas for smallholders. Now, however, the public use of key technologies has either been negotiated with the owners or open-use alternatives have been developed and the way is open for a renewed public sector effort.

Yes, we have GM bananas

Efforts to develop public-sector GM bananas draw on the earlier private-sector initiative on bananas, on more advanced work on GM cultivars of other crops, such as rice, and, most recently, on more fundamental research to understand the banana genome itself. Among the front-runners in the field, researchers in Belgium have engineered both Cavendish and plantain varieties using anti-fungal proteins, that have reached the stage of field-testing in Cuba but, given the costs and uncertainties of registration procedures, are unlikely to advance through biosafety testing into commercial production. Meanwhile, in Colombia and South Africa, scientists are developing and evaluating transgenic resistance to black leaf streak disease, banana weevils and nematodes. Australian scientists are working on resistance to banana bunchy top babuvirus and banana bract mosaic potyvirus, while others are trying to introduce genes to enhance the nutritional quality of some varieties by introducing genes involved in the synthesis of carotenoids, precursors of Vitamin A.

In Uganda, home to a group of mainly cooking bananas that are unique to the highlands of East Africa and are eaten at almost every meal, a biotechnology centre was established at the National Agricultural Research Organization (NARO) with the specific task of making some of the most popular varieties resistant to the main diseases small-scale farmers wrestle with. The centre was set up at the request and with the support of the Ugandan government in collaboration with an international consortium of research organizations.

The Ugandan scientists sent abroad to do their studies have since returned home to continue their search for sources of genetic resistance and refining the techniques for introducing them into the local varieties. Drawing on the technologies already developed in Europe and Australia, these researchers have already demonstrated their capacity to make their own transformations in-country. However, progress on setting up the biosafety and legal framework for testing and planting genetically modified crops has been slow and for the moment the GM plants remain firmly behind closed door in the laboratory.

But should we plant them now?

While anxious to see these efforts bear fruit, we feel that a recent call to expedite the process, in order to fight an emerging disease on the grounds that the transgenic approach is 'the most effective way' to combat it (Wamboga-Mugirya, 2006), has confused the situation, by misrepresenting the role GM bananas can play and creating an unnecessary rivalry with viable management options.

The disease in question is banana Xanthomonas wilt (BXW), which is caused by the bacterium *Xanthomonas campestris* pv. *musacearum*. Previously observed only in Ethiopia, the disease was first observed in Uganda in 2001 (Tushemereirwe et al., 2004) and has since spread to neighboring countries (Ndungo et al., 2005; Reeder et al., 2007). In the three years that followed its discovery, BXW developed into a full-blown epidemic in central Uganda, where the most affected variety is Kayinja, a type of banana used to make juice, beer and alcohol, which provide a much needed income to poor farmers

In propounding the case for engineering bananas to make them resistant to BXW, it was said that all the banana varieties tested so far eventually succumb to the disease (Wamboga-Mugirya, 2006). However, these results were obtained by injecting the bacteria directly into the plant. In farmers' fields, the conditions for the bacteria to enter the plant naturally are not always met, making it possible for some varieties to escape infection.

The main agents of transmission are flying insects and farm tools. The insects pick up the bacteria when they visit the inflorescence of sick plants, which exude bacteria-laden ooze through the openings made by the fallen bracts. Snapping off the male flower bud as soon as the fruits have set prevents insects from transmitting the bacteria to healthy plants and has been shown to reduce the incidence of new infections almost to zero. In southwestern Uganda, where farmers have been routinely removing the male bud for other reasons (mainly because they believe that better fruit are formed), the disease has not reached epidemic proportions. When the disease appears, farmers have been advised to sterilize cutting tools and uproot the diseased plants to avoid further transmission.

Urgency has been added to the GM argument by claims that BXW could cost Uganda US$6-8 billion over the next 5-10 years (Wamboga-Mugirya, 2006), but this estimate is based on a worst-case scenario of 90% of all bananas in Uganda being eliminated by the disease, an unlikely scenario given the options available to farmers to combat the disease.

There is no denying that engineering Kayinja plants to make them resistant to BXW would benefit farmers, but we think that, given the time needed to develop and evaluate the modified material, it is best seen as part of a long-term strategy to manage the disease, rather than a quick-fix solution. We don't think, in the current climate of suspicion over GM crops (and over the motives of scientists promoting them), that the best strategy is to scare people into accepting them. Biosafety regulations are intended to reassure consumers and farmers that their interests are being considered and the Ugandan government has almost completed the process of putting in place its own regulations and infrastructure. Using partisan arguments to influence the process will only reduce confidence in it and, in the long run, will undermine the value of any short-term gains.

Should we be scared of GM bananas?

Nothing suggests that, in the context of the small-scale subsistence systems that characterize much of banana farming in developing countries, the modifications currently worked on by public-sector scientists would pose a threat to the environment, nor would they increase the dependence of farmers on commercial suppliers of herbicides in the way that the herbicide-resistant versions of major crops so popular in the Americas have done. Moreover, the banana's vegetative mode of reproduction should allay fears that farmers would be cut off from their source of planting materials were they to grow GM bananas. The chances of introduced genes escaping into related wild species are also negligible if GM technology is applied to the least fertile cultivated varieties where transgenic approaches are most needed.

Concerns over health risks are harder to ease as they mainly rest on inchoate fears about the consequences of moving genes around. These include not only the desired genes that are meant to impart the new character-which may be derived from distantly related organisms, such as the 'Bt toxin', derived from a soil bacterium; they also include (depending on the method used) the sequences, often of bacterial or viral origins, that regulate the expression of genes, serve as markers to check that the plant has been genetically modified or are used to carry the new material into the plant's genome.

Research is offering alternatives to these pioneer and somewhat crude technologies. For example, it is no longer necessary to introduce genes for antibiotic resistance that were needed when antibiotic treatments were used to separate the newly transformed plant material (carrying the agronomically desirable along with the antibiotic resistance) from the non-transformed. One trend is towards using sequences of DNA that are automatically eliminated in subsequent cell division, leaving only the desired gene.

It should also be borne in mind that many genes being used for transformation are also simply moved from one familiar food crop to another. Among the genes being tried out against both weevils and nematodes in banana are plant-defense compounds called cystatins, that disrupt the digestion of insects but not mammals; the genes are derived from food crops such as rice and papaya,

are already widely consumed and thus, rationally, should not provoke a consumer reaction.

Progress in banana genomics is also uncovering candidate genes for resistance to pests and pathogens in wild bananas and in some of their domesticated relatives (Wiame et al. 2000, Coemans et al. 2005) and the ecology of various wild species suggests that they harbor sources of tolerance to abiotic stresses, such as mechanisms for tolerance to cold, water-logging and drought, that could be brought into cultivated bananas by GM techniques. Logically, consumers should be less concerned about these so-called cis-genic bananas than about GM bananas transformed with genes from more 'exotic' sources.

Bananas are also being mined for promoter genes, which regulate gene expression. Tissue-specific promoters would provide an extra level of insurance by limiting the expression of the introduced genes to certain tissues. The major pests and diseases attack the leaves or roots of the plant, rather than the fruit, and most responses to abiotic stresses similarly target the vegetative parts of the plant. Current research on tissue-specific promoters, for instance, suggests that bananas could be engineered so that compounds targeted to provide resistance against nematodes could be produced only in the active roots or even in the surface cells of the root that protect its growing tip.

Do GM bananas have a future?

Currently, the market for GM crops is dominated by those that are either not eaten by humans or that end up mainly as ingredients in processed foods. In 2006 the majority of GM crops were soybean, maize, canola and cotton modified to be tolerant to herbicides, resistant to insect pests (Bt crops), or both (James, 2006). As a result, most Americans are largely unaware that they are eating GM foods, as a recent survey of U.S. consumer attitudes indicates (Pew Initiative on Food and Biotechnology 2006). Even though more than half of the processed products at American grocery stores are produced using some form of biotechnology, according to the survey, only 26% of the respondents think that they have ever eaten GM foods. The result is very similar to the percentage (27%) who support GM foods, a figure that has remained stable since the survey started in 2001, whereas opposition has declined from 58% to 46% over the same time period.

These results suggest that the attitude of Americans, reputed to be pro-GM, is not that different from that of supposedly anti-GM Europeans. But attitudes are not necessarily good predictors of behavior, especially in the context of a survey in which participants tend to react as citizens making judgments from the point of view of society as a whole and give what they think is the socially desired response (Spence and Townsend, 2006). Such surveys are also criticized for being biased in favor of opponents of GM foods, since the latter are more motivated to respond. Experimental studies testing the willingness of participants to taste GM food or to purchase them have found far less resistance (Spence and Townsend, 2006; Townsend and Campbell, 2004).

The possibility that opposition to GM foods is not as entrenched as generally believed is good news for GM bananas, which, unlike the other GM crops on the market, would never be allowed to enter the diet by stealth. Modifying fruits and vegetables that are directly consumed represents the ultimate test for the acceptance of GM foods, but it cannot be realized until more countries adopt labeling to identify them as such.

Such a situation would certainly require investing in education on GM crops. In the case of the export banana, consumers could be sensitized to the issue of pesticides, which would give them a more balanced view of potential benefits of genetic modification, both from their own point of view and from the point of view of the environment and plantation workers. Most consumers do not realize that, despite efforts to reduce pesticide application, many crops are still sprayed weekly during the growth cycle, some residues do remain in the fruit (Veneziano et al. 2004) and certainly workers and the environment in producing countries are affected by heavy spray regimes (Castillo Pinzon et al., 2000; Astorga, 1998; Wesseling et al., 1996). In Costa Rica, the agricultural activity that consumes the most pesticides is the banana industry, which uses 16 times more pesticides than the level estimated for intensive agriculture systems in industrialized countries (Astorga, 1998).

Large-scale commercial banana plantations are generally located in the humid tropics where pests and diseases proliferate easily and where organic cultivation methods are hard to implement (organic bananas are mostly produced in the drier areas where fungal diseases are less of a problem). If they understood more about pesticide use in conventional export bananas, consumers would be better placed to make a rational choice about GM (or organic) alternatives.

The case of the 'world's favorite fruit' provides an opportunity to shift the focus of the debate on GM out of the political and ideological arena and refocus it on technical and economic arguments. In our view, this would help to marginalize the extreme proponents and opponents, leaving those nearer the centre ground to work together to design policies that exclude the unnecessary

and inappropriate applications of GM technology and leave us with the ecologically responsible and cost-effective ones.

The views in this article represent the opinions of the authors and not necessarily those of Bioversity International.

References

Astorga, Y. (1998), The Environmental Impact of the Banana Industry: A Case Study of Costa Rica. First International Banana Conference, Brussels, Belgium.

Castillo Pinzon, L.E., Ruepert, C. and Solis, E. (2000), Pesticide residues in the aquatic environment of banana plantation areas in the North Atlantic zone of Costa Rica. Environmental Toxicology and Chemistry 19(8):1942-1950.

Coemans, B., Matsumura, H., Terauchi R., Remy, S., Swennen, R. and Sagi L. (2005), SuperSAGE combined with PCR walking allows global gene expression profiling of banana (*Musa acuminata*), a non-model organism. Theoretical and Applied Genetics 111:1118-1126

James, C. (2006), Global Status of Commercialized Biotech/GM Crops: 2006. ISAAA Brief No. 34. International Service for the Acquisition of Agri-Biotech Applications, USA.

Ndowora, T., Dahat, G., LaFleur, D., Harper, G., Hull, R., Olszewski, N.E. and Lockhart B. (1999), Evidence that badnavirus infection in *Musa* can originate from integrated pararetroviral sequences. Virology 255: 214-220.

Ndungo V., Eden-Green S., Blomme G., Crozier J. and Smith J. (2005), Presence of banana xanthomonas wilt (*Xanthomonas campestris* pv. *musacearum*) in the Democratic Republic of Congo (DRC). New Disease Reports Volume 11: February 2005 - July 2005. British Society for Plant Pathology, UK. http://www.bspp.org.uk/ndr/july2005/2005-29.asp

Pew Initiative on Food and Biotechnology. (2006), Public sentiment about genetically modified food http://pewagbiotech.org/research/2006update/2006summary.pdf

Reeder, R H., Opolot, O., Muhinyuza, J. B., Aritua, V. and Crozier, J. (2007), Presence of banana bacterial wilt (*Xanthomonas campestris* pv. *musacearum*) in Rwanda. New Disease Reports Volume August 2006- January 2007. British Society for Plant Pathology, UK. http://www.bspp.org.uk/ndr/jan2007/2007-01.asp

Spence, A. and Townsend, E. (2006), Examining consumer behavior toward genetically modified (GM) food in Britain. Risk Analysis 26(3):657-670.

Stover, R.H. and Simmons, N.W. (1987), Bananas. 3rd edition. Longman Scientific & Technical. Essex, England.

Townsend, E. and Campbell, S. (2004), Psychological determinants of willingness to taste and purchase genetically modified food. Risk Analysis 24(5):1385-1393.

Tushemereirwe, W., Kangire, A., Ssekiwoko, F., Offord, L.C., Crozier, J., Boa, E., Rutherford, M. and Smith, J.J. (2004), First report of *Xanthomonas campestris* pv. *musacearum* on banana in Uganda. Plant Pathology 53:802.

Veneziano, A., Vacca, G., Arana, S., De Simone, F. and Rastrelli, L. (2004), Determination of carbendazim, thiabendazole and thiophanate-methyl in banana (*Musa acuminata*) samples imported to Italy. Food Chemistry 87(3):383-386.

Wamboga-Mugirya, P. (2006), Uganda needs biotech law to save banana sector. SciDevNet. 11 October 2006. http://www.scidev.net/News/index.cfm?fuseaction=readnews&itemid=3149&language=1

Wesseling, C., Anlbom, A., Antich, D., Rodriguex, A.C. and Castro, R. (1996), Cancer in banana plantation workers in Costa Rica. International Journal of Epidemiology 25(6):1125-1131

Wiame, I., Swennen, R., and Sági, L. (2000), PCR-based cloning of candidate disease resistance genes from banana (*Musa acuminata*). Pp. 51-57 *in* Application of biotechnology and molecular biology and breeding - gene expression and molecular breeding, genome analysis (Plas, L.H.W. van der, Dons, J.J.M., Vanderleyden, J. and De Loose, M., eds). XXV International Horticultural Congress, 02-07 August 1998. Acta Horticulturae, International Society for Horticultural Science, Leuven, Belgium