PLANT GENOMICS

A Bunch of Trouble

The banana is endangered and largely ignored by funding agencies, researchers, and breeders. But things might finally be going its way

2001 was supposed to be the year of the banana. That summer, a handful of researchers gathered in a small room at the U.S. National Science Foundation (NSF) in Arlington, Virginia, to form a consortium to sequence the fruit. Scientists had just deciphered the genome of *Arabidopsis*, with the rice genome close behind, and the banana community desperately wanted to be next. A new strain of soil fungus was threatening the commercial banana, and the community was convinced that a genome project could provide the genetic tools needed to save the crop. "The time was ripe," says Emile Frison, then head of the consortium. He predicted that within 5 years—a time period that would see the launch of major efforts to sequence corn, sorghum, and even green algae—banana buffs would have their genome.

Today, they're still waiting.

That's quite an indignity for one of the world's most popular fruits. Americans consume as many kilograms of bananas as apples and oranges combined, and in many African countries, bananas make up nearly half of all calories consumed. What's more, the banana most of us are familiar with—the Cavendish (*Musa acuminata*)—is in danger of disappearing. The soil fungus Frison fretted about in 2001 causes a nasty blight known as Panama disease that has devastated crops in Malaysia, the Philippines, and China. If the disease makes its way to Latin America, it could wipe out the Cavendish in less than 10 years. African bananas, too, have begun to disappear, victims of globalization and unsustainable farming practices.

Yet the banana continues to sit on the shelf while other crops benefit from research dollars and attention. Some blame the United States for failing to support the fruit as it has other major food crops. Others blame the banana community for being too fragmented to unite behind a single project. And still others blame the banana itself, for a bizarre biology that frustrates breeders and researchers alike.

At last, however, banana researchers may have found a benefactor: A French research agency will announce funding for the long-awaited genome project next week. The community just hopes it's not too late. "If the Cavendish is wiped out, there's nothing to replace it," says Nicolas Roux, Frison's successor as coordinator of the Global *Musa* Genomics Consortium. "We're sitting on a time bomb."

A crop in crisis

Juan Fernando Aguilar Moran has been trying to defuse that bomb for 7 years, not through sequencing but through breeding. As the chief breeder at the Honduran Agricultural Research Foundation (FHIA) in San Pedro Sula, the world's largest banana and plantain breeding center, Aguilar Moran is hoping to produce a variety that's hardier than the Cavendish. But the banana's not making it easy.

Unlike rice, wheat, and corn—the three crops that are eaten in larger quantities than the banana—most bananas are completely sterile. Unusual breeding in the Cavendish's past, for example, has led to a plant with three sets of chromosomes that has no seeds, no pollen, and no sex life. Farmers must hack off a piece of the plant and coax it into putting down roots, meaning a Cavendish eaten in Iowa today is genetically identical to one consumed in Ireland 30 years ago.

Faced with such a prudish plant, breeders like Aguilar Moran must instead turn to its wild relatives to create new varieties, and they, too, produce few viable seeds. Adding to the hassle, the plants grow at about one-fifth of the pace of rice, wheat, and corn, so experiments take years to complete. That may explain why there are only five breeding programs in the world dedicated to the banana versus hundreds for those other crops. "It's a lot of work," says Aguilar Moran.

So why does he persist? Two words: Gros Michel. The Cavendish's predecessor, "Big Mike," used to be the developed world's banana of choice. But an early incarnation of Panama disease known as Race 1 decimated the fruit—and nearly took the banana industry with it—in the mid-1900s. The Cavendish—a lucky, last-minute find originally from China—was resistant, but Aguilar Moran says its days are numbered. The new form of Panama disease that has invaded Asia, known as Race 4, takes no pity on the Cavendish. Because every plant is genetically identical, they're all equally susceptible to the same diseases. Once Race 4 hits the banana heartland in Latin America, says Aguilar Moran, it's game over for our favorite fruit.

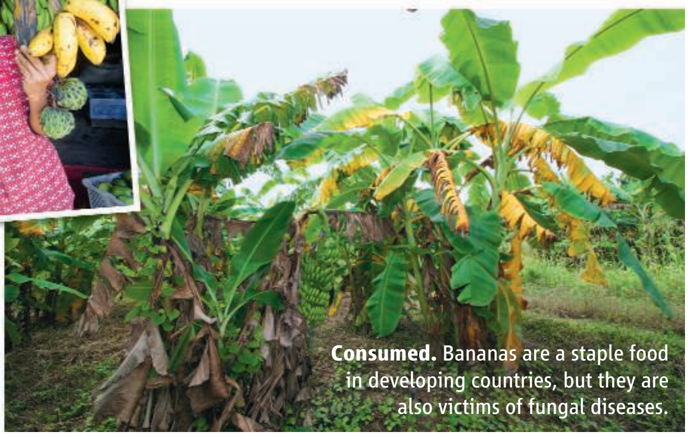
Another dark shadow is black sigatoka, a fungus that turns banana leaves black and blocks photosynthesis. Over the 50 years the

CREDIT: DEVON BOWMAN

pathogen has been on the scene, fungicides have become increasingly ineffective against it. "In Central America, we need to spray once a week," says Aguilar Moran.

Black sigatoka is on the march in Africa, too, but it's just one of many threats to that continent's bananas. Frison, now the director general of Bioversity International, a nonprofit that coordinates research into improving the lot of bananas and other crops, says that in Eastern Africa, farmers have been growing bananas on the same plots for 100 years, which has led to a decline in soil fertility. "They can't grow bananas anymore," he says.

Banana biodiversity is also suffering: Due to globalization, African farmers in-creasingly grow only the varieties they can sell at the market, says Frison. Whereas the average farmer used to cultivate a dozen varieties, now he only grows four or five. Without human-assisted propagation, the rest of the varieties disappear. That means less raw material for breeders like Aguilar Moran.



Consumed. Bananas are a staple food in developing countries, but they are also victims of fungal diseases.

CREDITS (TOP TO BOTTOM): JOSE FUSTE RAGA/CORBIS; JUAN FERNANDO AGUILAR MORAN

The forgotten fruit

Of course, diseases and loss of biodiversity plague many of the world's other major food crops. But they have one distinct advantage over the banana: People care about them. The United States, China, and other countries have spent far more on rice, corn, and wheat than they have on bananas. In 2008, for example, the U.S. Agency for International Development funded about $9 million in rice research but just over $1 million in banana research. "It puzzles us," says Richard Markham, a program director at Bioversity International. Most funding agencies in developed countries don't take the Cavendish seriously, he says, and they don't realize that the vast majority of other bananas are a staple food source for millions. (In Uganda, the word for "banana" and "food" is the same.) "It's hugely neglected and underinvested."

Even the banana industry doesn't seem to care. Banana suppliers Dole Food Co. and Chiquita Brands International have largely stayed out of banana research for the past 20 years, says Markham, although Chiquita has recently begun funding FHIA. Critics say the companies are shortsighted and that they haven't learned the lessons of the Gros Michel disaster. (Representatives for Dole and Chiquita did not return phone calls for this article.) Regardless, the assumption that these companies are looking out for the banana has kept the public sector away, says Markham.

The lack of attention has dealt a huge blow to efforts to sequence the banana. Frison hoped the 2001 meeting at NSF would mobilize a big investment, but nobody jumped on board. "We only found small and scattered money," he says. Roux took over for Frison in 2003, and over the next 4 years the Global *Musa* Genomics Consortium collected members—37 institutions in all, including the J. Craig Venter Institute and the Max Planck Institute for Chemical Ecology—but not much funding.

Hoping for U.S. support, the consortium approached the U.S. Department of Energy's (DOE's) Joint Genome Institute (JGI) in January 2008. JGI has a program to which research communities can apply to have the DNA of their favorite organism deciphered. Roux says JGI seemed enthusiastic about the banana. But this summer, the consortium learned that it didn't make the cut. Duckweed and sea grass did.

JGI's James Bristow says these species fit better into DOE's mission of investigating species for alternative fuels and bioremediation, though he admits to being disappointed by the reviewers' decision. "It's an important and endangered worldwide food crop," he says. "There's no question that this genome should be sequenced."

Jane Silverthorne, who headed NSF's Plant Genome Research Program from 1999 to 2007, says the bigger problem may be that the banana community is just not as well-organized as other crop communities. "It's small and fragmented," she says. Some banana proponents would rather see money put into subsistence farming than sequencing, Markham points out, "and even within molecular biology, some say we don't need the entire sequence—or that we should wait until the cost of sequencing comes down."

Nonetheless, Markham says it would be a "huge boost" for banana researchers to have the sequence. The trick is finding someone who will step up to fund it.

Slipping into the future

That someone might just be France. When members of the banana consortium gathered at the JGI workshop in January to present their sequencing plan, they got an unexpected boost from Francis Quétier, then deputy director of French sequencing giant Genoscope. Quétier announced that his institute would do half the work needed to generate a reliable sequence by covering the genome four times over. It had settled on a close relative of the Cavendish with only two sets of chromosomes. "Everyone cheered wildly," says Markham. But there was a catch: The French National Research Agency (ANR) would fund the project only with help from an international partner. When JGI subsequently passed on the banana, "the whole thing looked like it would unravel," Markham says.

Now Quétier, who recently became a program coordinator in genomics at ANR, says the agency is about to announce that it will fund the project anyway—and that it plans to sequence the entire genome. "We are at the beginning of the story," he says. "I'm very optimistic."

James Dale can't wait. A banana biotechnologist at the Queensland University of Technology in Brisbane, Australia, Dale has been trying to develop a better banana for 12 years through genetic modification. Once the sequence reveals the full range of genes in banana, he says, biotechnologists like him will be a step closer to using the banana's own genes to, say, boost disease-resistance.

That's not all. With the sequence, basic researchers can do comparative genetics with other crops and figure out how bananas got so strange in the first place. Even traditional breeders like Aguilar Moran will benefit: Molecular markers found in the genome will help them home in on traits of interest and better select varieties for crossing. "A tremendous amount of information will come out of this," says Dale.

Frison is also optimistic. As he did in 2001, he's predicting that the banana genome is within reach—and with it a brighter future for the fruit. "We've reached a turning point," he says. Bristow thinks that Frison might be right this time. "Once you've got a little bit of data, it starts to get interesting," he says. "Nothing rallies a community like some progress."

–DAVID GRIMM

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