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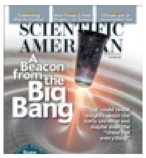

See Inside

Can Science Avert a Coffee Crisis?

Researchers are racing to breed beneficial new traits into the dangerously homogeneous coffee crop before it succumbs to disease or other threats

Sep 16, 2014 | By Hillary Rosner |

LEVI BROWN *Trunk Archive*

The coffee that the caterer had set down alongside some guava-filled pastries was tepid and bitter, with top notes of chlorine. Several of the guests would not touch it, no matter how much they craved caffeine. Standing on a narrow balcony, facing the scrubby hills of Turrialba, Costa Rica, they sipped water or pineapple juice instead. They were entitled to a little coffee snobbery. The roughly 20 people gathered this past March at CATIE, an agricultural university, to discuss the uncertain future of Central American coffee included leading experts on humanity's most beloved beverage.

They had convened to discuss a serious threat: coffee rust, or *roya*, as it is known in Spanish. The rust is a fungus that infects the plants' leaves, making them unable to absorb the sunlight they need to survive. It has ravaged the region's crop over the past few years, afflicting approximately half of the one million acres planted across Central America and slashing production by about 20 percent in 2012 compared with 2011.

The outbreak, which is still spreading, is just one crisis looming over coffee in our era of global warming. "Most coffee varieties today aren't likely to be able to tolerate disease and insect pressures, as well as increased heat and other environmental threats from climate change," Benoît Bertrand, a geneticist and coffee breeder at CIRAD, a French center focused on agriculture and development, told the group in Costa Rica after the coffee break. If crops fail, coffee farmers lose their livelihoods. They may tear out the trees and plant other crops or sell their land to developers—leaving a trail of unemployed laborers and environmental destruction.

Bertrand, who wore a blue sweater tossed over his shoulders and has the debonair look of a French filmmaker rather than someone who spends his days hunched over a petri dish, is justifiably concerned. Coffee, it turns out, cannot adapt to heat or fend off disease, because it lacks crucial genetic diversity. Although the selection of coffees on tap in your local café may read like a guidebook to exotic travel destinations—an acidic brew from Aceh, Indonesia, a velvety roast from Vietnam, a mellow cup from Madagascar—all that variety hides a surprising fact: cultivated coffee is incredibly homogeneous. In fact, 70 percent of it comes from a single species, *Coffea arabica*. The strain, growing region and roasting method make for a remarkable range of tastes, but they also mask the plant's genetic history. Nearly all of the coffee that has been cultivated over the past few centuries originated with just a handful of wild plants from Ethiopia, and today the coffee growing on plantations around the world contains less than 1 percent of the diversity contained in the wild in Ethiopia alone.

Despite coffee's importance on a global scale—for economic, political and environmental stability, not to mention its roles as a centerpiece of cultural life and an essential caffeine-delivery system—it is an “orphan crop,” largely abandoned by modern research. There is no Monsanto of coffee, no agribusiness behemoth that stands to make a fortune selling patented seeds. That orphan status allows small farmers in poor countries to make a decent living growing coffee for export. But it also means there has been little investment in science, leaving the crop highly vulnerable to whatever nature throws its way. Now, faced with mounting threats against cultivated coffee, researchers are racing to advance the science and save our joe—before it is too late.

Harnessing Diversity

Tim Schilling, a geneticist who resides in the French Alps and is best known for helping to revamp Rwanda's coffee industry in the early 2000s, has made it his mission to bring some much needed science to the business of making java. Today he oversees World Coffee Research, a new nonprofit funded by the coffee industry—30 companies big and small, including Peet's, Allegro and Counter Culture. He has been called the Indiana Jones of coffee, but presiding over the meeting in Turrialba, in jeans and a long-sleeved white shirt, with black owl-frame glasses and thick locks, Schilling bore a closer resemblance to Andy Warhol. He asked the group how much research was currently available on climate change and coffee rust. A coffee breeder in the room held up his thumb and index finger about half an inch apart, the international sign for “peanuts.”

Experts worry the impact could be huge. The coffee rust fungus thrives in warm weather, and as temperatures rise, the fungus could spread to higher altitudes. Changes in rainfall—too much rain or even too little—might also give the fungus a boost. Fungicide sprays can combat *roya*, but the chemicals are expensive and may not work against emerging strains of the disease.

To Schilling, the only real long-term solution is harnessing genetics. As a first step, he wants to exploit the adaptations that already exist in the gene pools of *C. arabica* and the other cultivated coffee species, *Coffea canephora*. Known in the industry as robusta, *C. canephora* is easier to grow and higher-yielding, but it tastes bitter and is used mainly as a filler in lower-quality coffees—like the kind on tap at the CATIE meeting. Although cultivated coffee is homogeneous in that it belongs to just these two species, the many strains of each do offer some regional genetic variation, just as human populations differ despite all belonging to *Homo sapiens*. Schilling's grand plan includes a relatively simple project, currently under way, to swap coffee strains between regions and countries—sending plants from Congo to Brazil, say, or from Colombia to Honduras, to see if they will grow better than the strains local farmers are already growing. In three to four years, farmers will be able to say, “Hey, this coffee from India produces way more beans,” and they can then opt to plant more of the Indian seeds. Scientists identified 30 of the highest-yielding coffee strains from 10 countries for the study.

Taking advantage of the genetic variation within cultivated coffee may help in the short term. But it almost certainly will not be enough to save the crop. Commercially grown strains contain only a tiny portion of the total genetic diversity in *C. arabica* and *C. canephora*. Their wild counterparts, however, are incredibly varied. Recent advances in coffee genome sequencing have revealed what Bertrand calls “a vast catalogue of genes” in these untamed cousins of the farmed beans, many of which reside in gene banks around the world. He hopes to exploit that rich genetic soup to make coffee crops more resilient, productive and delicious.

Evidence of that genetic diversity abounds at CATIE. Across campus from the meeting and down a dirt road, a wooden sign with painted yellow letters reads “Café Coleccion de Etiopia (FAO).” Here nearly 10,000 *arabica* coffee trees grow, row after row of them stretching across roughly 21 acres. Established in the 1940s, the assortment includes coffee plants collected during several different expeditions to Ethiopia, first by the British during World War II and more recently, in the 1960s, by the United Nations Food and Agriculture Organization and a French research team. The repository also includes coffee plants from Madagascar and elsewhere in Africa, as well as from Yemen. Unlike the seeds of many other crop plants, such as corn, coffee seeds cannot survive in jars stored in refrigerated vaults. Instead they must be continually grown in the field or else cryopreserved. So at CATIE, one of the world's most important gene banks for coffee DNA is “stored” as one big, scruffy coffee garden.

Bertrand is building new hybrid strains of coffee using promising plants from living coffee gene banks akin to the one at CATIE. A variety he created more than a decade ago by crossing *C. arabica* with some of its wild cousins boosted yields by more than 40 percent.

Now he and Schilling have selected 800 plants from CATIE, as well as another 200 from coffee gene banks around the world, and sent them to a laboratory in Ithaca, N.Y., to have their DNA sequenced. That information will help him evaluate what traits each plant could offer up.

The researchers are looking for genes that might make a plant strong in all kinds of ways: resistant to rust, less thirsty, able to thrive in heat. To find them, Bertrand and Schilling are screening for plants that are "pumped up with incredible amounts of genetic diversity," as Schilling puts it. They want the biggest possible range of traits in the smallest number of plants. "Then we'll be crossing that material with stuff that we all love—great-tasting, high-yielding, disease-resistant material we know of already."

Into the Wild

Schilling is certain that those breeding efforts will yield far better varieties for coffee farmers to grow—and for roasters to sell and consumers to drink. But he and his collaborators have another ambition, too: to one-up Mother Nature by producing a new, synthetic version of *C. arabica*. In essence, they want to develop a plant that has the flavor of *C. arabica* and the temperament and yield of *C. canephora*. The plan is to redo the original cross that created *C. arabica* (that of *C. canephora* and another species, *Coffea eugenioides*), only with a far more diverse group of parents this time. To manage this feat, they need to look beyond what exists in gene banks. They need to go back to the wild.

There are roughly 125 known species of coffee on the earth, each of which contains much more genetic variation than can possibly be represented in a gene bank's small sample. And other species surely remain to be discovered—assuming researchers can find them before they vanish.

When Aaron Davis began hunting for wild coffee plants in 1997, he did not expect to find anything new. The then recent Ph.D. graduate was having tea one day at the Royal Botanic Gardens in Kew, England, when a renowned coffee taxonomist happened to sit nearby. Davis asked her how many species of coffee there were, where coffee grew and what its natural range was. The answer to all his questions, she replied, was that "nobody knows." In short order, she sent him off to find out. Davis spent the next 15 years traipsing around Madagascar—a country known for coffee diversity—where he found a vast range of species, some already catalogued but a lot completely unknown to anybody apart from some local villagers.

In Madagascar, he found the plant with the world's largest coffee cherry, or fruit—about three times the standard size—and the world's smallest, about half the diameter of a pushpin. He found two species whose seeds are dispersed via water, rather than animals, and bear winged fruits that look like folded ribbons. He discovered a species called *Coffea ambongensis*, whose beans resemble brains. Davis's expeditions showed that wild coffee grows across a wide swath of the tropics, from Africa to Asia and even as far as Australia. In Ethiopia, *C. arabica*'s main territory today, some forests are packed with arabica plants, as many as 8,000 per acre. Those plants, Davis believes, have huge potential for breeding.

But these wild plants, like their cultivated counterparts, are in trouble. Up to 70 percent of them are in danger of extinction. And 10 percent could be gone within a decade. Land conversion poses the biggest threat. By the late 1990s more than 80 percent of Ethiopia's forests had already been cleared. In 2007 in Madagascar, where people continue to clear forests at an alarming rate, Davis's team came across a new species growing in a patch of forest no bigger than a baseball diamond. Where wild coffee plants are concerned, he says, in many cases, "climate change is not going to have a chance to have an impact." The plants will simply disappear, along with their habitat.

Davis worries that researchers are placing too much emphasis on what is already in gene banks while potentially vital genetic material is languishing in the wild—or being bulldozed. "There's this feeling, 'Yeah, we've got everything, we're fine,'" he says. "But that's your storehouse of genetic resources, those wild populations."

Ethiopia itself poses another problem. The country where coffee originated curates a large collection of coffee plants that exist nowhere else in the world. But the government keeps them under lock and key and will not allow foreign researchers access. "There's been a lot of bad blood between Ethiopia and the coffee industry," Davis explains. "It's no wonder they're guarded about their genetic resources." A few years ago, for instance, Ethiopia got into a heated dispute with Starbucks over whether the country had the right to trademark the names of Ethiopian coffee cultivars.

Access to the Ethiopian germplasm—the organic material stored in gene banks—could give Schilling's coffee-breeding projects a huge boost. Perhaps it contains crucial genes for adapting to higher temperatures or for growing more beans on less land. Schilling hopes the country will relent. In the meantime, scientists are working with what they have.

Digging in the archives at Kew, Davis discovered records showing that local people in Uganda and elsewhere have long made coffee from wild varieties growing nearby. Some of it may taste awful, but all of it produces a recognizable coffeelike aroma if you roast the beans. And, Davis says, “some that were used 100 years ago are reputed to be excellent. We're going back and reinvestigating some of those early cultivated species that could have potential in their own right or in breeding programs.”

Racing the Clock

Shortly after Schilling formed World Coffee Research—with the help of an industry group that represents high-quality and boutique coffee companies (the Specialty Coffee Association of America) and with initial funding from Green Mountain Coffee and Coffee Bean International—the rust outbreak hit Central America. So Schilling convened a small meeting in Guatemala to discuss what the organization could do. Almost immediately, he started getting requests from people who had heard about the meeting and wanted to attend it. “It turned into about 200 people,” recalls Ric Rhinehart, executive director of the Specialty Coffee Association of America and one of Schilling's chief collaborators. “We couldn't hold them all.”

Among the interested players was the U.S. Agency for International Development, which invited Schilling to apply for a grant for coffee rust research. If Central America's coffee industry were to collapse, it could spark a wave of migration to the U.S.—so the government has an interest in it. World Coffee Research estimates that the 2012 rust outbreak cost coffee farmers $548 million and cut workers' pay by 15 to 20 percent. Roughly 441,000 jobs disappeared. If nothing is done, Central America's coffee industry could be wiped out by 2050.

Although short-term, “emergency” responses to the rust crisis were under way in 2012—supplying farmers with fungicides and credit, for instance—Schilling believed a much more coordinated, long-term effort was needed. usaid ultimately funded Schilling's plan, which will help build a high-tech breeding program to provide new climate- and pest-resistant coffee varieties to farmers.

The rust epidemic is, in many ways, a preview of what might befall coffee worldwide, as new diseases hit defenseless plants that are weakened by heat or extreme weather. At the CATIE meeting, Carlos Mario Rodriguez, director of global agronomy for Starbucks, mentioned that Chinese farmers were reporting as many as five new strains of rust on their plants. “At high elevations, farmers didn't know about rust—and now they do,” Rodriguez said.

For coffee to survive, it must become far more resilient. Brett Smith, president of North Carolina–based Counter Culture Coffee, likens the DNA problem to “a stock portfolio with very few stocks.” He is confident, though, that Schilling and his band of collaborators are up to the task of safeguarding coffee.

The only question is whether they can do it in time. “If we'd done this research 10 years ago, we wouldn't be facing these problems now,” Rhinehart says. “If we don't start today, every day that we wait is more time. And we could be facing an existential threat.”

This article was originally published with the title "Saving Coffee."

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