# Can SCIENCE Save Specialty Coffee?

## World Coffee Research Works Toward the Industry's Long-Term Survival

by Hanna Neuschwander
photos courtesy of World Coffee Research

AS COMMUNICATIONS DIRECTOR for World Coffee Research (WCR), I have weekly conversations with people—from roasters to producers to bankers to everyone in between—about what the organization does. Almost uniformly, people are curious about our work and express a sense of its importance, but few seem to feel as if they truly understand what we do.

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WCR coffee breeder Benoit Bertrand examines baby plants from the Core Collection, a group of the 100 most diverse arabica coffees from the CATIE germplasm collection in Costa Rica. The plants will be used by coffee breeders to develop the next generation of cultivars.

That's normal. Most of us haven't cracked a science textbook in years. To further complicate the matter, we as an organization sometimes have tunnel vision, talking about individual projects at the expense of focusing on the larger mission and research agenda.

When *Roast* asked me to provide an update on our work, I immediately thought of these conversations, so rather than dive into the status of this or that research trial, I thought I'd take this opportunity to explain who we are, what we do—and, perhaps more importantly, why we're doing it.

## What is World Coffee Research?

In 2010, realizing that coffee was becoming increasingly vulnerable because of a lack of research and development, a group of coffee industry leaders came together to address this emerging concern. They formed WCR as a global nonprofit, with a mission to "grow, protect and enhance supplies of quality coffee while improving the livelihoods of those who produce it."

Unique among the entities doing research on coffee, WCR is directed and funded by the coffee industry. Our priorities are your priorities. The most important fact about our work is that it is being done for the benefit of all—no one company and no one country benefits to the exclusion of others. The dollars that enable our research come primarily from roasters, some big and some tiny, but also from importers, traders, equipment manufacturers and others. Anyone can become a WCR member and support the organization's work. (Visit *worldcoffeeresearch.org* to learn more.) This is essential, because the problems we are trying to solve are vast and global—not issues that can be tackled by one company, one nation or, for that matter, one organization alone.

So, what exactly do we research? We focus most of our efforts on the coffee plant itself, looking at ways to make it more profitable and sustainable for the people who grow it. We have scientific trials located in many coffee growing countries, most conducted in collaboration with local government, research or private sector partners. We are headquartered at Texas A&M University in College Station, Texas, one of the United States' top institutions for agricultural research. Our research staff includes experts on coffee genetics, plant physiology, coffee diseases, molecular biology, coffee breeding and sensory science.

Given that we are a small organization, it's essential that we partner with other researchers—including faculty members at Texas A&M, as well as researchers from around the world. Our research partners include academic institutions like the Tropical Agricultural Research and Higher Education Center (CATIE, by its Spanish acronym) in Costa Rica, the International Center for Tropical

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Agriculture (CIAT) and the National Coffee Research Center (Cenicafé) in Colombia, Agricultural Research for Development (CIRAD) in France, and Kew Gardens in the United Kingdom, as well as national and regional coffee organizations in producing countries, such as PROMECAFE in Guatemala.

Since launching in 2011, we have established more than 20 ongoing research projects, with trial sites in 23 countries. We also work closely with industry organizations such as the Specialty Coffee Association of America (a key partner in the founding of WCR), the Coffee Quality Institute, and the International Coffee Organization, among others.

## Why Coffee Needs Research

Historically, most coffee related research has happened in the countries where coffee is grown, usually funded by universities or government agricultural ministries. The applied research scientists conduct in these centers is critical—they create or select new coffee varieties with resistance to important diseases, work to understand how to help the plant adapt to climate change and experiment with better ways to manage coffee farms—and they do all of it taking into account the local context and environment in their country. (Great examples are Cenicafé in Colombia, and Embrapa and University of Lavras in Brazil.)

But research funding has been declining, sometimes precipitously, since the 1980s. CATIE, an important center for coffee breeding in Central America famous for possessing the most important collection of arabica plants outside of Ethiopia, lost nearly 250 plants in the mid-1990s because of the age of the trees (most planted in the 1960s) and a lack of funding to support the collection. In recent years, funding has eroded further. At the Agronomic Institute in Brazil, another important coffee research center, a lack of funding has led to the loss of a number of trees; the budget no longer supports staff to water

At a meeting of the World Coffee Research technical advisory team in 2012, a group of coffee scientists from around the world help plan the organization's research agenda for the next five years.


WCR board member Lindsey Bolger, director of sourcing for Keurig Green Mountain (left), visits the International Multi-Location Variety Trial site in Laos, one of 19 countries participating in the trial. Plants will be transplanted from the nursery into research fields in 2016.

and prune them. Many institutions worldwide have had to lay off researchers or cut back on programming because of a lack of funding.

Worse, in some coffee growing countries, especially smaller, poorer ones, literally no research is conducted that would help farmers. In countries where research *is* conducted, sometimes it isn't shared with others. This leaves farmers in these poorer countries especially vulnerable. Coffee isn't alone—less than 30 percent of the world's total budget for agricultural research is spent in developing countries, despite the fact that they're home to 80 percent of the world's population.

Additional research occurs at centers in former colonial powers, such as Portugal and France, but after the global economic crisis, funding there also has declined. In Portugal, the Coffee Rust Research Center was the only place in the world where coffee scientists could test coffee plants to see if they were resistant to coffee leaf rust. After years of progressive budget cuts, the center closed in 2014, at the height of the rust epidemic.

Coffee farmers in this century face challenges serious enough to undermine the entire global business of coffee. Among these are increased disease and pest outbreaks, aging coffee trees and significant land pressures, all of which are making it increasingly difficult for farmers to support a sustainable livelihood by growing coffee.

One of the most critical challenges is climate change. According to research conducted by WCR in 2015, climate change is expected to decrease by half the land area suitable for growing coffee by 2050, and associated increases in severe or unseasonable weather already are affecting coffee and farmers. Most of the world's coffee farmers are relatively poor smallholders, which means they don't have the resources necessary to face these challenges.

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Seedlings from the Core Collection being established at the J. Hill Nursery in El Salvador. In 2016, they will be planted at the WCR research farm nearby.

It is well documented that research and development can lead to significant gains. The USDA estimates that for every $1 invested in agricultural research, $20 is generated for the economy. In coffee, the rate of return may be much higher. An analysis of a program led by PROMECAFE to develop rust resistant coffee varieties in Central America in the 1980s and 1990s showed that for every $1 million spent on the program, $48 million in value was created. Corn yields have tripled over the past 50 years due to the use of hybrids created by breeders; rice yields are expected to increase by 15 to 20 percent by applying the same technology. Agricultural crops including bananas have been saved from complete collapse more than once by investments in research. If coffee yields could increase by just 10 percent without losing quality, it would represent a huge leap forward in profitability for coffee producers.

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# What Is an F1 Hybrid?

An experimental F1 hybrid developed by WCR. The plant shown is the mother plant (Geisha La Luisa), which was crossed with pollen from another variety (Marsellesa). The cherries pictured here are the offspring, and will be harvested, germinated and planted in 2016 to see if the new plant is able to retain the best characteristics of its parents.

One of the most important techniques in coffee breeding is something farmers always have done on their own: selecting the best plants for a given desirable trait. A farmer (or breeder) might desire a plant that produces a high yield of fruit, for example. Perhaps this farmer notices a particular plant on his or her field that seems to be producing more fruit than other plants (possibly because a natural mutation has occurred). The farmer selects seeds from the plant, then plants the seeds and waits for the trees to grow. When these trees reach maturity and produce fruit, the farmer again identifies the highest-producing plants and selects seeds from them, repeating the process over many generations, each time selecting seeds from the plants that bear the most fruit.

In the first few generations, it is likely that some of the offspring plants will have high yields while others won't, but after careful selection over many generations (often at least six or seven) the high yield should be observed uniformly in the offspring. Once achieved, this uniform plant is called a "pure line."

Because coffee takes three to four years to mature, getting to the sixth or seventh generation can take 20 years or more. One example is the tekisic cultivar, a selection of bourbon created by the Salvadoran Institute for Coffee Research (ISIC, by its Spanish acronym) in El Salvador, beginning in 1949. It was not released until 1977—28 years after selection began. By contrast, F1 hybrids—which are typically crosses between two different pure lines—can get from the experimental phase into farmer fields in as little as five to 10 years.

Let's say a coffee breeder observes vigorous growth in one coffee, but no resistance to coffee leaf rust. In another coffee, there is disease resistance but lower yield. Pure lines of each of the two plants are cross-pollinated. The seed resulting from this cross is called an F1 hybrid. Plants grown from this seed should have the best traits of each parent—in this case, good vigor and leaf rust resistance.

There are many advantages to this approach. F1 hybrids tend to have significantly higher production than non-hybrids (frequently producing 30 to 50 percent more fruit), grow more uniformly and produce their first fruit in year two instead of year three. They cannot, however, be reproduced through seeds, because the children of F1 hybrids will not have the same characteristics as the parents—they will perform differently and have less productivity. Because they generally must be produced by nurseries using advanced technologies (including somatic embrogenesis and microcutting), they tend to be more expensive; plants can cost up to twice as much, typically 50 to 70 cents per plant. (The cost, however, is already nearly half what it was 10 years ago.) Even so, because coffee is not an annual crop like corn or wheat, coffee growers do not need to purchase more expensive plants every year—most farmers renovate every 10 years or more—so the resulting increases in yield and uniformity vastly offset the higher initial cost. ■

## Starting With the Coffee Plant

Coffee farms are diverse and complex, so there are many ways to approach the challenges that face them. However, as the leaf rust crisis has shown, we are already behind where we need to be. The fastest, most sustainable way to meet the challenges of the 21st century for coffee is to start where coffee starts—with the plant itself.

The genes available to any living organism determine how it can respond to a given challenge. "Good genes" are like tools in a toolbox: The more you have, the more likely you are to be able to overcome the problem at hand. By understanding—and making use of—the genetics of coffee, we can begin to devise ways of helping the plant become more productive, more resilient and better tasting.

In light of this, WCR focuses most of its efforts on coffee genetics. "Genetics" in this case covers many things—from lab science focused on understanding what individual genes do and in-the-field testing of new coffee cultivars to working with nurseries to make those plants available to farmers and helping farmers learn how to optimize those coffees to produce the best possible cup.

It's important to note that "genetics" does not mean genetically modifying coffee—transferring genes within and across species boundaries to produce new organisms. Instead, we use the latest technologies in molecular genetics to understand which genes in coffee perform important functions, allowing us to selectively breed for those traits using traditional breeding methods.

## Understanding Varieties

The International Multi Location Variety Trial was the first trial WCR launched after forming in 2011. It is in some sense the organization's signature effort, and it will continue for the next two decades at least, hopefully longer. It is a first-of-its-kind undertaking to understand how 35 of the world's best coffees perform under different conditions, and to facilitate the global exchange of these varieties.

Setting up this trial was not an easy task. After two years of planning, WCR was able to negotiate with 11 countries and suppliers to collect 35 top-performing varieties from around the world, including some known for quality, like geisha from Panama and SL28 from Kenya; some known for disease resistance, like Lempira from Honduras and Marsellesa from Nicaragua; and others known for high yields, like CR95 from Costa Rica. The collection is being planted on more than 60 research plots in 19 countries.

In 2015, more than 12,000 baby coffee plants were grown in a phytosanitary lab in Florida to ensure they were disease-free, then were sent in sterile containers to research sites in 16 of the 19 participating

countries. In summer and fall 2015, they were grown to mature seedlings in nurseries, and in many countries have now been planted in the field. In 2016, the remaining plants will be shipped to the final three countries. We also expect the number of participating countries to grow to include new locations, such as Cameroon and Zimbabwe. Over the course of the next decade, an exhaustive list of variables about the performance of the plants will be measured. In 2016, early data about some agronomic traits will be gathered, traits like how vigorously the plants grow.

Crucially, the trial opens the door for the exchange of planting material between countries. In many countries, coffee producers have only a handful of varieties available to them, and those may not be optimal for an individual producer's situation. The trial will allow countries to observe how coffees perform locally and, if they discover something desirable, will allow them to negotiate with the donor country to bring the coffee into production in their area.

But the ultimate goal is much bigger—to build a comprehensive understanding of how coffee genetics are impacted by different environments, what scientists call the genotype x environment, or GxE, interaction. How is gene expression influenced by climate factors, altitude or weather patterns? What are the conditions under which a given variety performs best? This is crucial information for coffee breeders as they work to develop new coffees that are able to meet the challenges that lie ahead.

## Arabica Genetic Diversity

If you want to develop new coffee varieties to meet complex challenges, you have to understand coffee's genetics. The total amount of genetic diversity in a plant species determines the size of the toolbox available to meet specific challenges. More diversity means a bigger toolbox. Unfortunately, arabica is not genetically diverse. A study of 846 arabica coffees completed by WCR in 2015, including many wild coffees from Ethiopia, showed only 1.2 percent diversity among the samples. (While this does not include every arabica in existence, it can be used as a broad estimate of the species' overall genetic diversity.) Compare that to roughly 20 to 30 percent diversity in crops such as corn, rice and soy, and it looks as if arabica coffee is one of the least genetically diverse major crop species in the world.

But there is an upside to the study. Understanding the limits of arabica genetic diversity allows us to develop an informed, rigorous strategy for breeding programs to introduce more diversity—and therefore more resilience—into the arabica species. Our research determined that 100 of the 846 arabicas tested captured nearly all (about 90 percent) of the total genetic diversity available

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in the collection. This group of the 100 most diverse arabica varieties, called the WCR Core Collection, will be the basis for multiple future breeding efforts.

Currently, these 100 varieties are being planted in research fields on three sites: in Santa Ana, El Salvador, at the WCR research farm, and in Costa Rica at the Aquiares farm outside Cartago and the Starbucks research farm on the slopes of the Barva Volcano. They will be a living resource for coffee researchers and breeders for decades to come.

## The Next Generation of Coffees

Because coffee is a tree crop that takes three to four years to mature, breeding new coffees traditionally has been a slow process. It can take 20 years or longer to bring a new cultivar to market. But using new tools and the groundwork laid by

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A farmer in Yepocapa, Guatemala, shows how badly his farm was damaged by leaf rust in the 2012–2014 outbreak. Epidemics like this one are expected to become more frequent with climate change.

The first plants for the International Multi-Location Variety Trial went into the ground in El Salvador in 2015. WCR will begin collecting data on the performance of these plants at sites across the globe in 2016.









WCR's coffee genetics research, we can accelerate the creation of high-performing coffees for farmers.

At the end of 2015, the Core Collection and the genetic diversity study were put to use for the first time to create a new group of experimental F1 hybrids. F1 (which stands for filial generation 1) hybrids are the offspring of distinctly different parental types that are crossed to produce a new, uniform plant with a combination of characteristics from the parents. (See "What Is an F1 Hybrid?" on pg. 29 for more details.)

The hybrids make use of pollen from the genetically diverse Core Collection plants, which are crossed with "mother" plants that have known desirable traits. For example, one mother is

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A stone marker designates the place where a coffee tree once stood in the CATIE field gene bank, a collection of nearly 10,000 arabica trees that contain critical genetic diversity. Research stations like CATIE have struggled to maintain funding in recent years.

WCR researchers Trish Klein, Fabian Echaverria Beirute and Leo Lombardini.


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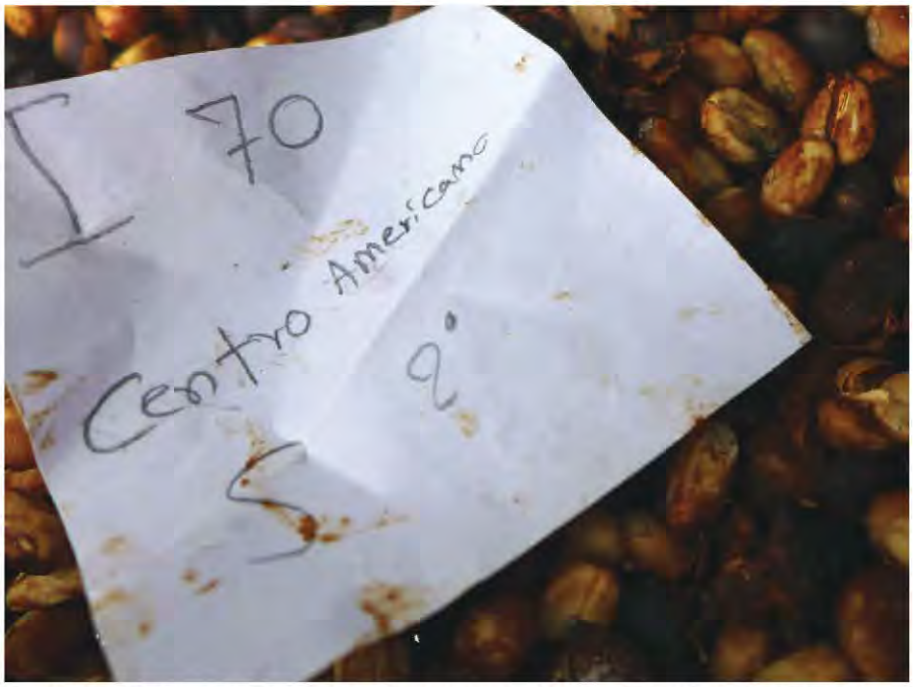


A research project in Costa Rica is evaluating whether reducing the fruit load of a coffee plant—thinning its fruit, for example—increases cup quality and tolerance to leaf rust. Pictured: Seeds from the Centro Americano cultivar.

geisha, known for quality. Another is obata, a cultivar developed in Brazil that is known for good cup quality and tolerance to coffee leaf rust. Hybrids like these, with genetically distant parents, are frequently more productive and uniform than either parent, so the hybrids are expected to produce more fruit—up to 30 to 50 percent more in some cases.

After meeting with coffee breeders from around Central America, WCR has created 50 experimental crosses. In 2016, the offspring will be germinated, transplanted and observed for performance, including rust resistance and drought tolerance. WCR plans to launch F1 breeding programs in Africa, Asia and Brazil this year. It will take a few years to evaluate the plants, but it's possible they could become available to coffee producers in as few as five years, instead of the 20 years it used to take.

## Into Farmer Fields

Having the best coffees in the world doesn't matter if farmers can't see for themselves how they perform. Starting in 2016, WCR aims to install dozens (and eventually hundreds) of on farm demonstration trials throughout Africa and Central America, where farmers can observe firsthand how new technologies—specifically, high-performing cultivars and targeted soil treatments—can make farming more profitable. The demonstration trial plots also will evaluate climate-smart technologies, such as grafting quality F1 hybrids onto drought-stable robusta rootstock.

Instead of traditional research plots, which are typically small, the demonstration trial plots will be large enough that a farmer can experience the monetary gain derived from having high quality, high yielding varieties combined with appropriate composting or fertilization treatments adapted for climate

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In October 2015, WCR held a breeding and genetics workshop with researchers from across Africa. WCR plans to bring the Core Collection to Africa and launch a collaborative F1 hybrid breeding program for the region in 2016.

WCR Data Manager Daniel Dubon interviews a member of the ECA Montellano farmers co-op in Guatemala. The data from this survey will contribute to a study on how improved coffee varieties impact farmer profitability.

Farmers in Yepocopa, Guatemala, whose farms were badly affected by coffee leaf rust are receiving improved F1 hybrids for renovating their fields. The project is funded by the Starbucks Foundation. WCR will work with the farmers to study the impact on farm profit of these improved varieties.

change. Demonstration days, when neighboring farmers can observe the improved performance, will be held to help spread awareness about how these simple investments can yield big returns for farmers. Because the plots will have common designs, WCR will be able to aggregate results over hundreds of global locations and many years to recommend more effective, climate-smart technologies for extension applications and inform future research.

By using advanced technologies—many of which are cheaper now than ever before—WCR is aiming to leapfrog over many years of disinvestment in coffee research and make up for lost time. Why does it matter? Conducting scientific research on coffee and the coffee plant is fundamental to the long-term survival of the industry. The future of coffee literally depends on it.

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