

It Starts With a Seed

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Between now and 2050, nearly every coffee tree on the planet will be replaced. Some new trees will be planted where none exist now, and some will be torn out and replanted with something else. Some farmers' children will take over their parent's farms; many will not. It's staggering to think of the scale of change that will be experienced in the places where coffee now grows. But if all those billions of trees can't thrive, and if the farmers tending to those trees can't thrive, we won't have coffee at all. All of it, everything that we love about coffee, depends on the plant and the farmer succeeding. At the same time, it's thrilling to imagine all the innovations that will undoubtedly happen between now and then.

We are just beginning to glimpse the transformational power of one such innovation—a new class of varieties called F1 hybrids. As with anything genuinely new, the potential of F1 hybrids is hard to understand. Currently, only a few thousand hectares of land in the world are planted in F1 hybrid varieties. But by 2050, these varieties could make up a majority of all the area cultivated in Arabica coffee.¹ The advantages they offer coffee producers and coffee drinkers can't be overstated. They are the single most exciting innovation in coffee in the last decade, but very few people know what they are or why they matter so much. To offer just a glimpse of their potential, we can look at one of the new F1 hybrid varieties: Centroamericano.

ANATOMY OF A VARIETY: CENTROAMERICANO

When Gonzalo Adán Castillo Moreno, a respected coffee producer in Nicaragua's Nueva Segovia region, speaks to his coffee trees, he speaks with both affection and sadness: 'I'm very sorry Caturrita, you have an excellent cup, but you cannot win against the rust.'

This is one of the profound and durable trade-offs experienced by coffee farmers in Central America over the last 50 years—the traditional varieties most prized for their high cup quality—Castillo's Caturra, Pacamara, Bourbon, or Typica—are also most susceptible to the major diseases of arabica coffee. And while superior cup quality may earn farmers a premium price, that price is rarely high enough to offset the considerable risk farmers take when they grow disease-susceptible varieties. No comprehensive figures exist for coffee globally, but it is generally believed that farmers lose 20–40 per cent of their crop annually to disease and pests. The measures to prevent those losses—intensive pruning, fertilizing, applying fungicides or pesticides—frequently end up costing more than farmers ever earn in premiums, if they are able to earn premiums at all.

Enter Centroamericano. This F1 hybrid variety is rust resistant, produces 22–47 per cent more cherry, even under shade, and if cared for and grown in



the right environment, can score over 90 points. F1 hybrids, and not just Centroamericano, are notable because they tend to have significantly higher production than non-hybrids—a result of ‘hybrid vigour’ (more on this below).

Castillo Moreno was one of the first farmers in the world to plant Centroamericano on his farm. It required a significant leap of faith—the variety performed well in trials but was untested on farmer fields. Every square metre of land he planted with baby seedlings of Centroamericano was a square metre not planted in something familiar—or something actively producing cherries that he could sell. But within a few years, his bet paid dividends—his coffee took second place in the Nicaraguan Cup of Excellence in 2017, scoring 90.5 points. His coffees subsequently won first

place in the Fengjen International Coffee Competition in Taiwan.

‘The most exceptional thing is that it is a consistent variety in terms of the quality of the cup,’ Castillo told *El Nuevo Diario*. This combination of exceptionally high cup quality with agronomic traits that reduce risk for farmers has been elusive in the past. F1 hybrids like Centroamericano provide one additional benefit for farmers: they typically begin producing cherry after 18–24 months, generating income a full year before traditional varieties.

Trying a new variety is no small matter for a farmer. Most varieties take three years to produce cherry, and don’t achieve their full production potential for five. If a variety turns out to be a dud, it can take a full decade to make up for it—one reason why it has

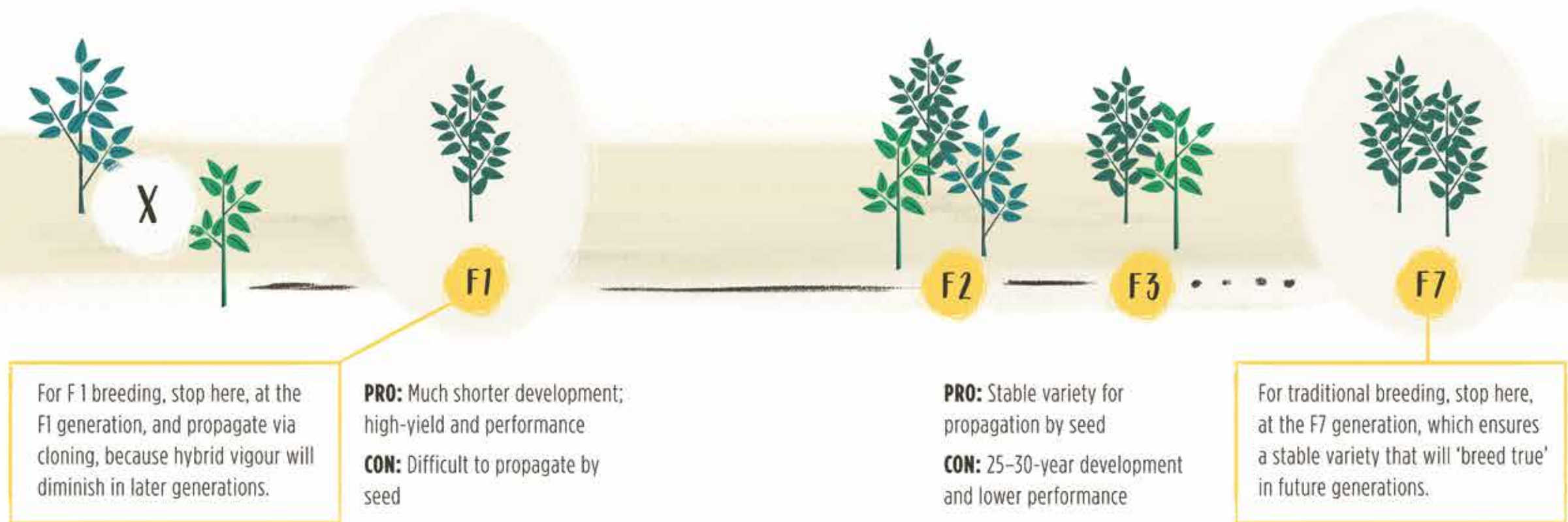
historically taken so long for new varieties to take hold in coffee.

TRADE-OFFS: PART ONE

The development of any new coffee variety—like any process of design—involves trade-offs. The most intensive period of modern coffee breeding happened during the 1970s and ’80s, when a major outbreak of coffee berry disease in Kenya and Tanzania in 1968 led to losses of more than 50 per cent of the year’s harvest, and with the arrival in 1970 of coffee leaf rust to the Americas via Brazil (it had previously only been a threat in Africa and Asia). Public institutions jumped to action, drawing on trees that had been identified as resistant or tolerant to both diseases for breeding new

varieties, and by the 1990s, the first waves of these new varieties were ready for farmers. These were created with farmers’ most pressing needs in mind: battling disease and improving yield. Cup quality was a secondary consideration, in no small part because buyers at the time were not concerned with quality in the way they are now. As a result, a lasting but erroneous impression was formed: disease resistance and high cup quality are mutually exclusive. This is certainly not true of the F1.

The fundamental trade-off for F1 hybrids has to do with how they are mass-produced for farmers. Traditional varieties are all replicated through seed—you know, that same seed we grind and drink. But farmers would be ill-advised to do that with F1 hybrids. To understand why, it’s time to turn to an explanation



of what an F₁ hybrid is, and how it's different from the varieties of the past.

GOOD OLD-FASHIONED PLANT SEX

An F₁ hybrid is created by crossing genetically distinct arabica parents (same species, but genetically far apart) and using the *first-generation* offspring, hence the term 'F₁', meaning 'first filial generation'. Our old friend Centraamericano can help us to understand how it works.

Centraamericano is a cross between the Ethiopian landrace variety Rume Sudan and a rust-resistant Sarchimor-type variety called T5296 (which is used primarily in breeding and is not itself in widespread production). Breeders create the F₁ hybrid variety by collecting pollen from the father tree, T5296, in a little vial and transporting the pollen to the location of the mother tree, Rume Sudan. They dip a small brush into the vial and paint the pollen on to the mother flowers. This, in a nutshell, is human-assisted plant sex. After that, a paper bag is tied around the flower branch to prevent any other pollen from contaminating the cross. Over the next few weeks, the sexual reproduction cycle unfolds on the mother tree. The pollinated flower transforms into a coffee cherry, inside of which is a little coffee baby—the seed (or bean). This is the F₁ hybrid offspring which, when germinated and then planted, grows into an F₁ hybrid plant.

Centraamericano, like most F₁ hybrids, grows to be stronger, more productive, and more tolerant to stressors than a traditional variety. Why? Because of a property of genetics known as 'heterosis' or hybrid vigour. Plant and animal breeders have been exploiting hybrid vigour for a century. Perhaps the most famous F₁ hybrids are maize, or corn, hybrids. Since the advent of maize hybrids, maize production in the United States has increased six-fold over the last 60 years. Crops ranging from tomatoes to broccoli have used an F₁ hybrid breeding approach to create high-performing varieties for decades, but the approach is new in coffee.

Hybrid vigour tends to be strongest when the mother and father plants are further apart genetically.

In order to create F₁ hybrid crosses capable of maximum hybrid vigour, World Coffee Research developed two essential new tools for modern breeders: the 'genetic distance matrix' for arabica, and a collection of genetically diverse wild coffees to use as father plants. First, we genetically analysed 1000 arabicas to determine a subset of 100 that contain nearly all the genetic diversity of the whole group. We named it the WCR Core Collection. Next, we used the matrix to measure the genetic distance of these plants from one another.

When it's time to make a new hybrid cross, our breeders first identify a father with known traits that we want to target. For example, Gesha might be chosen for cup quality potential, or a rust-resistant variety like Obata or Marsellesa might be chosen for coffee leaf rust resistance traits. The father variety is chosen based on locating the plant in the Core Collection that is genetically the furthest apart from the mother plant. We make the crosses and then ... well, we wait and see. Hybrid vigour isn't a guarantee and not all crosses will result in plants that are going to have a good combination of traits for farmers, which is why you make a lot of crosses, then see which ones work best. Currently WCR has 66 F₁ hybrid crosses in evaluation.

TRADE-OFFS: PART TWO

But, as mentioned earlier, there is one big trade-off to F₁ hybrids: reproducing them in large quantities. Hybrid vigour is only maximized in the first generation. If you grow an F₁ hybrid plant successfully on your farm, and then take the seed produced by that plant (the F₂ or second-generation seed) and plant it, that plant will not behave the same as the mother plant from which the seed was taken. In short, seeds taken from F₁ hybrid plants will not have the same characteristics as the parent plants, with potential losses of yield, disease resistance, quality, or other agronomic performance traits.

This means that, as of now, you cannot mass propagate F₁ hybrids from seed—or you would be unwise to do so. The only way to produce a lot of them at once is either manually (by taking pollen from the father and painting it onto the mother flowers—which



is extremely labour intensive and cost-prohibitive), or by cloning—literally making clones of the F1 hybrid plant using biotechnology. The latter has been successful in mass producing F1 hybrids in Central America, but because it requires a tissue culture cloning lab, it is more expensive and currently more limited.

Because of these and other reasons, when the idea of coffee F1 hybrids was first proposed nearly 30 years ago, many believed it was not worth even attempting. But a small group of breeders persisted because it was increasingly clear that while farmers of every other crop in the world were benefiting from improved genetics, coffee was stagnating.

F1 hybrids offer a different vision of a possible future. But despite their great promise for farmers, there is today hardly any infrastructure in coffee-producing countries to mass propagate F1 hybrid. Even where infrastructure exists, the cost of F1s is currently beyond what many farmers can afford—about 2.5

times more expensive than traditional varieties, depending on location. Consequently, the farmers that would most benefit—smallholders growing their coffee in agroforestry systems—are least likely to have access to them.

These concerns are real, and worrisome. But for the first time in decades, coffee farmers have a new tool in their toolkits, and one that has the potential to dramatically reshape coffee farming in the years to come. Coffee F1 hybrids are an example of what can happen when you design not for the world as it is, but the world as we want it to exist—a world where coffee producers have a fair shot at success.

THE FUTURE OF COFFEE

Despite their challenges, World Coffee Research believes F1 hybrids are essential to the future of arabica coffee. As demand for the varieties rises, more nurseries should become interested in propagating them and the cost to produce them should come down.

In our own breeding programme, we are placing a big bet on F1 hybrids. Using tools like the genetic distance matrix mentioned above, we have created 66 F1 hybrids at our research farm in El Salvador in the last three years, with more on the way. wcr is working with multiple countries to establish regional breeding hubs in addition to our current hub for Central America, where country breeders can bring their best varieties to cross with Core Collection plants using the genetic distance matrix. The results will be evaluated locally for adaptation to the local environment and local contexts. Within the next half decade, multiple countries will have their own F1 hybrids in development.

The varieties of the past were not designed to meet today's challenges, and there is urgent concern among coffee breeders that nearly all of today's coffee varieties resistant to coffee leaf rust will no longer be resistant in just a few years' time. These varieties derive their resistance from a common grandparent—

Timor Hybrid. Multiple varieties derived from Timor Hybrid have been overcome by coffee leaf rust in recent years, including most famously the Lempira variety in Honduras. Breeders worry it is just a matter of time before all resistant varieties lose their resistance. However, F1 hybrids, because of their hybrid vigour, are much better able to cope with rust infections. Recent research shows that a susceptible F1 hybrid will maintain superior productivity (20–60 per cent) when attacked by rust, compared with a traditional variety like Catuai.

Within a decade, the barriers of cost and availability of F1 hybrids may evaporate. Within two, it may be possible to mass produce hybrids by seed. Breeding, and research and development more generally, is changing what's possible. The future of coffee has never been grimmer; the future of coffee has never been brighter. ☘

