July issue of the National Geographic magazine takes a look at how seed banks around the world are cataloging heritage breeds,

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A crisis is looming: To feed our growing population, we'll need to double food production. Yet crop yields aren't increasing fast enough, and climate change and new diseases threaten the limited varieties we've come to depend on for food. Luckily we still have the seeds and breeds to ensure our future food supply—but we must take steps to save them.

By Charles Siebert
Photograph by Jim Richardson

Six miles outside the town of Decorah, Iowa, an 890-acre stretch of rolling fields and woods called Heritage Farm is letting its crops go to seed. It seems counterintuitive, but then everything about this farm stands in stark contrast to the surrounding acres of neatly rowed corn and soybean fields that typify modern agriculture. Heritage Farm is devoted to collecting rather than growing seeds. It is home to the Seed Savers Exchange, one of the largest nongovernment-owned seed banks in the United States.

In 1975 Diane Ott Whealy was bequeathed the seedlings of two heirloom plant varieties that her great grandfather had brought to America from Bavaria in 1870: Grandpa Ott's morning glory and his German Pink tomato. Wanting to preserve such unique varieties, Diane and her husband, Kent, decided to establish a place where people could store and trade the seeds of their own past. The exchange now has more than 13,000 members and keeps in its walk-in coolers, freezers, and root cellars the seeds of many thousands of heirloom varieties. The farm grows a glorious profusion of select vegetables, herbs, and flowers around an old red barn that is covered in Grandpa Ott's stunningly deep purple morning glory blossoms.

"Each year our members list their seeds in this," Diane Ott Whealy says, handing over a copy of the *Seed Savers Exchange 2010 Yearbook*. It is as thick as a big-city telephone directory, with page after page of exotic beans, garlic, potatoes, peppers, apples, pears, and plums—each with its own name, personal history, and distinct essence. There's an apple known as Beautiful Arcade, a "yellow fruit splashed with red"; one named Prairie Spy, described as "precocious"; another dubbed Sops of Wine that dates back to the Middle Ages. There's an Estonian Yellow Cherry tomato obtained from "an elderly Russian lady" in Tallinn, a bean found by archaeologists searching for pygmy elephant fossils in New Mexico, a Persian Star garlic from "a bazaar in Samarkand."

Heirloom vegetables have become fashionable in the United States and Europe over the past decade, prized by a food movement that emphasizes eating locally and preserving the flavor and uniqueness of heirloom varieties. Found mostly in farmers markets and boutique groceries, heirloom varieties have been squeezed out of supermarkets in favor of modern single-variety fruits and vegetables bred to ship well and have a uniform appearance, not to enhance flavor. But the movement to preserve heirloom varieties goes way beyond America's renewed romance with tasty, locally grown food and countless varieties of tomatoes. It's also a campaign to protect the world's future food supply.

Most of us in the well-fed world give little thought to where our food comes from or how it's grown. We steer our shopping carts down supermarket aisles without realizing that the apparent bounty is a shiny stage set held up by increasingly shaky scaffolding. We've been hearing for some time about the loss of flora and fauna in our rain forests. Very little, by contrast, is being said or done about the parallel erosion in the genetic diversity of the foods we eat.

Food varieties extinction is happening all over the world—and it's happening fast. In the United States an estimated 90 percent of our historic fruit and vegetable varieties have vanished. Of the 7,000 apple varieties that were grown in the 1800s, fewer than a hundred remain. In the Philippines thousands of varieties of rice once thrived; now only up to a hundred are grown there. In China 90 percent of the wheat varieties cultivated just a century ago have disappeared. Experts estimate that we have lost more than half of the world's food varieties over the past century. As for the 8,000 known livestock breeds, 1,600 are endangered or already extinct.

Why is this a problem? Because if disease or future climate change decimates one of the handful of plants and animals we've come to depend on to feed our growing planet, we might desperately need one of those varieties we've let go extinct. The precipitous loss of the world's wheat diversity is a particular cause for concern. One of wheat's oldest adversaries, *Puccinia graminis,* a fungus known as stem rust, is spreading across the globe. The pestilence's current incarnation is a virulent and fast-mutating strain dubbed Ug99 because it was first identified in Uganda in 1999. It then spread to Kenya, Ethiopia, Sudan, and Yemen. By 2007 it had jumped the Persian Gulf into Iran. Scientists predict that Ug99 will soon make its way into the breadbaskets of India and Pakistan, then infiltrate Russia, China, and—with a mere hitch of a spore on an airplane passenger's shoe—our hemisphere as well.

Roughly 90 percent of the world's wheat is defenseless against Ug99. Were the fungus to come to the U.S., an estimated one billion dollars' worth of wheat would be at risk. Scientists project that in Asia and Africa alone the portion of wheat in imminent danger would leave one billion people without their primary food source. A significant humanitarian crisis is inevitable, according to Rick Ward of the Durable Rust Resistance in Wheat project at Cornell University.

The world's population is expected to reach seven billion people this year. By 2045 it could grow to nine billion. Some experts say we'll need to double our food production to keep up with demand as emerging economies consume more meat and dairy. Given the added challenges posed by climate change and constantly mutating diseases like Ug99, it is becoming ever more urgent to find ways to increase food yield without exacerbating the genetic anemia coursing through industrialized agriculture's ostensible abundance. The world has become increasingly dependent upon technology-driven, one-size-fits-all solutions to its problems. Yet the best hope for securing food's future may depend on our ability to preserve the locally cultivated foods of the past.

It took more than 10,000 years of domestication for humans to create the vast biodiversity in our food supply that we're now watching ebb away. Selectively breeding a wild plant or animal species for certain desirable traits began as a fitful process of trial and error motivated by that age-old imperative: hunger. Wild wheat, for example, drops its ripened kernels to the ground, or shatters, so that the plant can reseed itself. Early farmers selected out wheat that, due to a random genetic mutation, didn't shatter and was thus ideal for harvesting.

Farmers and breeders painstakingly developed livestock breeds and food crops well suited to the peculiarities of their local climate and environment. Each domesticated seed or breed was an answer to some very specific problem—such as drought or disease—in a very specific place. The North American Gulf Coast Native sheep, for example, thrives in high heat and humidity and has broad parasite resistance. On the remote Orkney Islands, North Ronaldsay sheep can live on nothing but seaweed. Zebu cattle are more resistant to ticks than other cattle. In Ethiopia a small, humpless, short-horned cattle breed called the Sheko is a good milk producer that withstands harsh conditions and has resistance to sleeping sickness.

Such adaptive traits are invaluable not only to local farmers but also to commercial breeders elsewhere in the world. Finnsheep, for example, long raised only by a small group of Finnish peasants, have become vital to the sheep industry because of their ability to produce large litters. The Fayoumi chicken, an indigenous Egyptian species dating back to the reign of the pharaohs, is in great demand as a prodigious egg layer with high heat tolerance and resistance to numerous diseases. Similarly, the rare Taihu pig of

China is coveted by the world's pig breeders for its ability to thrive on cheap forage foods and its unusual fertility, regularly producing litters of 16 piglets as opposed to an average of 10 for Western breeds.

The irony is that the dangerous dwindling of diversity in our food supply is the unanticipated result of an agricultural triumph. The story is well-known. A 30-year-old plant pathologist named Norman Borlaug traveled to Mexico in 1944 to help fight a stem rust epidemic that had caused widespread famine. Crossing different wheat varieties from all over the world, he arrived at a rust-resistant, high-yield hybrid that helped India and Pakistan nearly double their wheat production—and saved a billion people from starvation. This so-called green revolution helped introduce modern industrialized agriculture to the developing world.

But the green revolution was a mixed blessing. Over time farmers came to rely heavily on broadly adapted, high-yield crops to the exclusion of varieties adapted to local conditions. Monocropping vast fields with the same genetically uniform seeds helps boost yield and meet immediate hunger needs. Yet high-yield varieties are also genetically weaker crops that require expensive chemical fertilizers and toxic pesticides. The same holds true for high-yield livestock breeds, which often require expensive feed and medicinal care to survive in foreign climates. The drive to increase production is pushing out local varieties, diluting livestock's genetic diversity in the process. As a result, the world's food supply has become largely dependent on a shrinking list of breeds designed for maximum yield: the Rhode Island Red chicken, the Large White pig, the Holstein cow. In short, in our focus on increasing the amount of food we produce today, we have accidentally put ourselves at risk for food shortages in the future.

One cautionary tale about the perils of relying on a homogenous food source revolves around the humble potato. High in the Peruvian Andes, where the potato was first domesticated, farmers still grow thousands of otherworldly looking varieties. Spanish ships in the late 16th century first brought the tuber to Europe, where by the early 1800s it had become a reliable backup to cereal crops, particularly in the cold, rain-soaked soils of Ireland. The Irish were soon almost wholly dependent on the potato as their food staple. And they were planting primarily one prodigious variety, the Lumper potato, whose genetic frailty would be cruelly exposed by *Phytophthora infestans,* as fearsome a foe of potatoes as stem rust is of wheat. In 1845 spores of the deadly fungus began spreading across the country, destroying nearly all the Lumpers in its path. The resulting famine killed or displaced millions.

Current efforts to increase food production in the developing world—especially in Africa, largely bypassed by the green revolution—may only accelerate the pace at which livestock breeds and crop species disappear in the years to come. In pockets of Africa where high-yield seeds and breeds have been introduced, the results have been mixed at best. Countries like Zimbabwe, Zambia, and Malawi ended up sacrificing much of their crop diversity to the monocropping of imported, high-yield varieties subsidized by government programs and provided by aid organizations. Small farmers and pastoralists have gone deep into debt to pay for the "inputs"—the fertilizers, pesticides, high-protein feeds, and medication—required to grow these new plants and livestock in different climate conditions. They are like addicts, hooked on a habit they can ill afford in either economic and ecological terms.

One response to the rapidly dwindling biodiversity in our fields has been to gather and safely store the seeds of as many different crop varieties as we can before they disappear forever. It's an idea first conceived by Russian botanist Nikolay Vavilov, who in 1926 had perhaps the least heralded scientific epiphany of the modern era. The son of a Moscow merchant who'd grown up in a poor rural village plagued by recurring crop failures and food rationing, Vavilov was obsessed from an early age with ending famine in both his native Russia and the world. In the 1920s and '30s he devoted himself to gathering seeds on five continents from the wild relatives and unknown varieties of the crops we eat, in order to preserve genes that confer such essential characteristics as disease and pest resistance and the ability to withstand extreme climate conditions. He also headed an institute (now called the Research Institute of Plant Industry, in St. Petersburg) tasked with preserving his burgeoning collection—what amounted to the first global seed bank.

It was on one expedition to Abyssinia (now Ethiopia) in 1926 that Vavilov had a vision in which he attained a vantage point high enough above the planet to see the handful of locations across the Earth where

the wild relatives of our food crops had first been domesticated. Afterward he mapped out seven "centers of origin of cultivated plants," which he described as the ancient birthing grounds of agriculture. "It is possible to witness there," Vavilov wrote, "the great role played by man in the selection of the cultivated forms best suited to each area."

Vavilov's life story did not end happily. In 1943 one of the world's foremost authorities on the potential cures for famine died of starvation in a prison camp on the Volga River, a victim of Stalin, who had deemed Vavilov's seed-gathering efforts bourgeois science. By this time, Hitler's army had already closed in on St. Petersburg (then Leningrad)—a desperate city that had lost more than 700,000 people to hunger and disease. The Soviets had ordered the evacuation of art from the Hermitage, convinced that Hitler had his sights set on the museum. They had done nothing, however, to safeguard the 400,000 seeds, roots, and fruits stored in the world's largest seed bank. So a group of scientists at the Vavilov Institute boxed up a cross section of seeds, moved them to the basement, and took shifts protecting them. Historical documents later revealed that Hitler had, in fact, established a commando unit to seize the seed bank, perhaps hoping to one day control the world's food supply.

Although suffering from hunger, the seeds' caretakers refused to eat what they saw as their country's future. Indeed, by the end of the siege in the spring of 1944, nine of the institute's self-appointed seed guardians had died of starvation.

Vavilov's ideas have been modified in the years since. Today's scientists consider the regions he mapped to be centers of diversity rather than of origin, because it isn't clear whether the earliest domestication occurred there first. Yet Vavilov's vision of these regions as the repositories of the genetic diversity upon which the future of our food depends is proving more prescient than ever.

Today there are some 1,400 seed banks around the world. The most ambitious is the new Svalbard Global Seed Vault, set inside the permafrost of a sandstone mountain on the Norwegian island of Spitsbergen just 700 miles from the North Pole. Started by Cary Fowler in conjunction with the Consultative Group on International Agricultural Research, the so-called doomsday vault is a backup for all the world's other seed banks. Copies of their collections are stored in a permanently chilled, earthquake-free zone 400 feet above sea level, ensuring that the seeds will remain high and dry even if the polar ice caps melt.

Fowler's Global Crop Diversity Trust recently announced what amounts to a recapitulation of Vavilov's worldwide seed-gathering expeditions: a ten-year initiative to scour the Earth for the last remaining wild relatives of wheat, rice, barley, lentils, and chickpeas in order to "arm agriculture against climate change." The hope is that this mad-dash scramble will allow scientists to pass along the vital traits of these rugged relatives, such as drought and flood tolerance, to our vulnerable crop varieties.

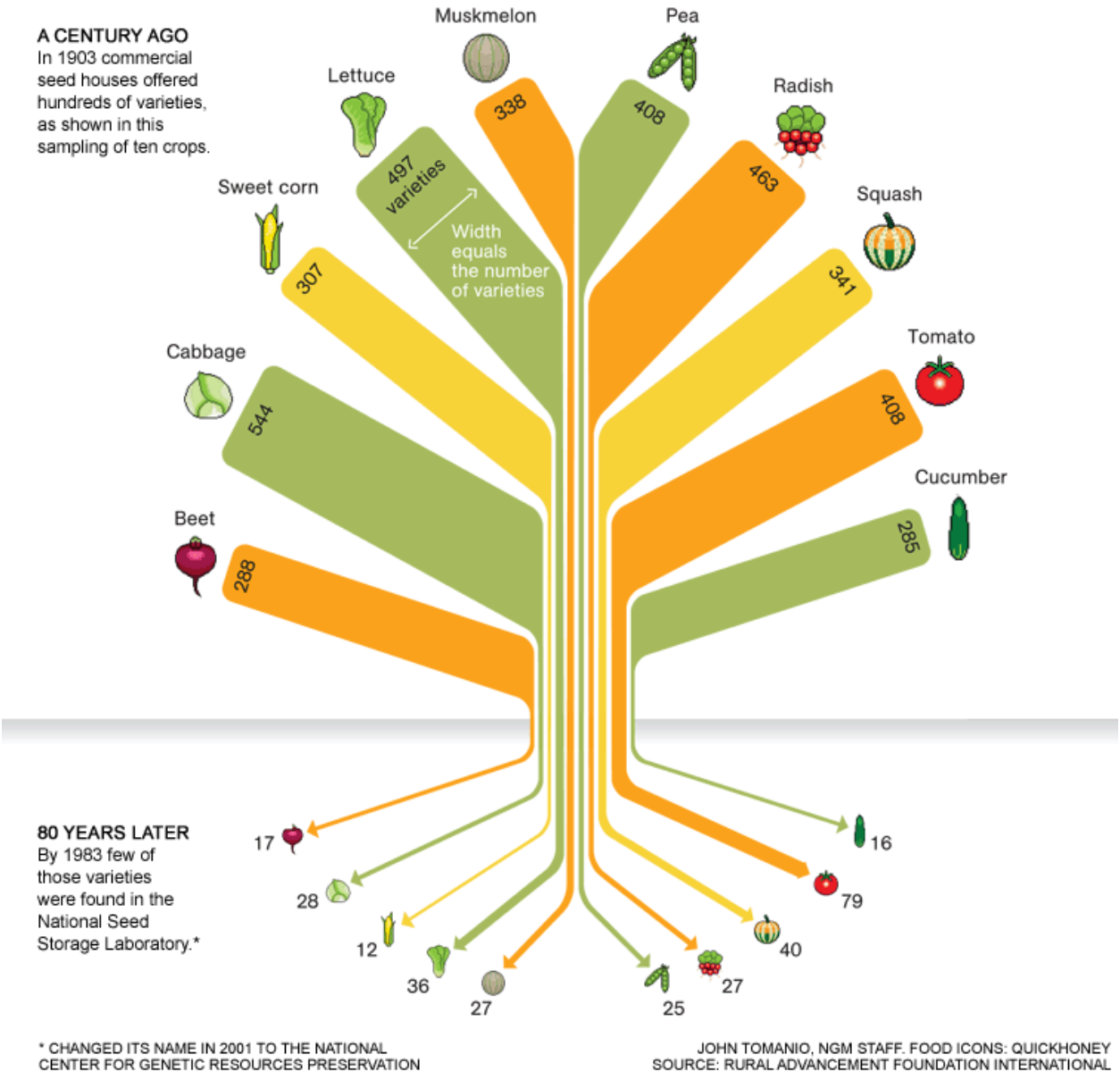
Still, storing seeds in banks to bail us out of future calamities is only a halfway measure. Equally worthy of saving is the hard-earned wisdom of the world's farmers, generations of whom crafted the seeds and breeds we now so covet. Perhaps the most precious and endangered resource is the knowledge stored in farmers' minds.

Forty-year-old Jemal Mohammed owns a five-acre, hillside farm outside the tiny hamlet of Fontanina in the Welo region of Ethiopia's northern highlands. It is in the heart of one of the centers of diversity that Nikolay Vavilov visited on his 1926 expedition.

Stepping foot on Mohammed's land is like tumbling back in time to an ancient way of farming. His circular, thatched-roof hut with walls of dried mud and straw is the same dwelling that has dotted Ethiopia's countryside for centuries. A pair of oxen lies to the right of the hut in the shade of a jacaranda tree. Three or four chickens strut across a bare front yard. His fields, tilled with an ox-drawn plough and planted by hand, are a jumble of crops: tomatoes, onions, garlic, cilantro, gourds, sorghum,

wheat, barley, chickpeas, and teff, a grain used to make injera, a flatbread. Our Dwindling Food Variety

As we've come to depend on a handful of commercial varieties of fruits and vegetables, thousands of heirloom varieties have disappeared. It's hard to know exactly how many have been lost over the past century, but a study conducted in 1983 by the Rural Advancement Foundation International gave a clue to the scope of the problem. It compared USDA listings of seed varieties sold by commercial U.S. seed houses in 1903 with those in the U.S. National Seed Storage Laboratory in 1983. The survey, which included 66 crops, found that about 93 percent of the varieties had gone extinct. More up-to-date studies are needed.



The image of the traditional, small farmer's life is one of simplicity. And yet compared with the mechanized operations of modern agriculture, Mohammed's work is a dynamic and highly nuanced juggling act in the face of constant threats like drought, untimely downpours, and disease. He plants legumes and grain together to make the most of limited space. Such intercropping is also a natural way of fertilizing: The legumes growing at the base of the taller sorghum add nitrogen to the soil.

Welo was one of the regions hit hardest by the devastating 1984 famine in Ethiopia that killed hundreds of thousands. The experience is still seared in Mohammed's memory. He shows me a collection of hollowed-out gourds filled to the brim with what look to be colored pebbles. "I keep these stocks as my security, my backup," he says, looking down at the gourd casks filled with what I now realize are seeds. He has seeds for all of the crops growing in his fields. Mohammed's wife has rubbed the seeds in ash to protect them from weevils. "If we have total crop failure from drought or floods," he says, "I can at least plant my fields again."

I look into the intent faces of Mohammed and his family, then down at those ashen pebbles: all incipience, gnarled knots of built-in urge, suggesting neither the centuries of selection that informed them nor the full-fleshed foods they'll eventually become, his own personal seed bank.

This is the beguiling paradox of seeds. They are, for all their obvious significance, so readily dismissible, especially by those of us in the well-fed world, who have forgotten where our food even comes from. Mohammed takes me to a farm across the road, where he and his neighbor lift a stone slab to reveal an earthen chamber six feet deep and wide: an emergency underground food store. In a few weeks, when the harvest is complete, they will line the chamber with straw, fill it with grain, and then pull the slab back over, allowing the earth's chill to keep it fresh.

When I ask how much they had to rely on their emergency store during the famine of 1984, they bow their heads and mumble a response before falling completely silent, their eyes welling with tears. My interpreter signals with a wave of a finger not to pursue the subject any further.

It is hard for them to even think of that time, he explains. They had sold their stored grain, never anticipating a sudden drought. Things got so bad that they had to eat all their reserves. A number of family members died of starvation. They were left with nothing but their seeds. Conditions were so inhospitable to planting that their empty stomachs soon had them planning to do the unthinkable: eat their seeds, their future.

Ethiopia's east central highlands were once one of most botanically diverse spots on Earth, but by the 1970s farmers here were down to growing just teff and a few varieties of wheat distributed to them for its high-yield potential. Today the region has been transformed: Local varieties of legumes and wheat are thriving again. Given the common depiction of Ethiopia as famine prone, it is startling to drive an hour northeast of Addis Ababa and see ample fields of a bushy, purple-seeded durum wheat, a variety found only in Ethiopia that is thriving across the country. Used for pasta, durum is largely resistant to stem rust. In one field is another local variety native to Ethiopia known as *setakuri,* which translates as "pride of women," because it makes the sweetest bread. It is doing even better against stem rust.

Ethiopia's turnaround can be traced in part to the efforts of renowned plant geneticist Melaku Worede, who received his Ph.D. from the University of Nebraska in 1972, then returned to Ethiopia with the goal of preserving—and rebuilding—the country's rich biodiversity. Training a new generation of plant breeders and geneticists, Worede and his staff at the Plant Genetic Resources Centre in Addis Ababa set about collecting and storing native plants and seeds, known as landraces, from across the country. In 1989 Worede initiated the Seeds of Survival program, a network of community seed banks that save and redistribute the seeds of local farmers.

Worede is hopeful that new efforts to increase food production—such as the Gates Foundation's Alliance for a Green Revolution in Africa—will not repeat the mistakes of the past. Attempts are being made to include local farmers in decision-making. "The people planning this are aware that the first green revolution failed over time. There are some intelligent ideas," Worede says. "But they are still placing too much emphasis on a narrow range of varieties. What about the rest? We'll lose them. Believe me, I'm not against science. Why would I be? I'm a scientist. But contextualize it. Combine science with the local knowledge, the farmer's science."

Worede believes it is crucial to preserve the region's diversity not just in seed banks but on the ground and in close consultation with local farmers. Although yield is obviously important to farmers, even more crucial is hedging their bets against famine, spreading the risk by growing many crops, over many seasons, in many locations. In this way if one crop gets diseased, or one harvest succumbs to drought, or one hillside is flooded, they have alternatives to fall back on.

The challenge has been to show it's possible to increase productivity without sacrificing diversity. Worede wanted to prove that deciding between having enough to eat today and preserving food biodiversity for tomorrow is a false choice. And he has done precisely that. He has taken the varieties farmers selected for their adaptability and determined which of them promise the best yield. The use of high-yielding local seeds—in combination with natural fertilizers and techniques such as intercropping—has improved yield as much as 15 percent above that of the imported, high-input varieties. A parallel effort is under way with local indigenous livestock breeds. Keith Hammond, a UN expert on animal genetics, says that in 80 percent of the world's rural areas the locally adapted genetic resources are superior to imported breeds.

Still, a 15 percent increase is far from the doubling of our food supply experts say we'll need in future decades. Preserving food diversity is only one of many strategies we'll need to meet that challenge, but it is a crucial one. As the world warms, and the environment becomes less hospitable to the breeds and seeds we now rely on for food, humanity will likely need the genes that allow plants and animals to flourish in, say, the African heat or in the face of recurring blight. Indeed, Worede thinks scientists may well find the Ug99-resistant varieties they're looking for in Ethiopia's fields. "Even if the disease mutates into a new form, it will not wipe out everything here. That is the advantage of diversity."

Yet Worede balks at the idea of the developed world treating Vavilov centers like Ethiopia as wild seed banks from which to withdraw traits whenever the next plague strikes. He cites the outbreak in the early 1970s of yellow dwarf virus, which threatened to wipe out the world's barley crop. A U.S. scientist who had come to Ethiopia in the 1960s had happened to grab some barley samples from a field for his own study. When the virus hit, he handed over the samples to one of the scientists trying to stop the virus. Sure enough they found a resistant gene. "It changed everything," says Worede, "at no cost to them. No genetic engineering, nothing. Just a natural source of resistance taken from the very part of Ethiopia where people were suffering from starvation."

Mohammed and his neighbor stood in silence above their own private earthen seed bank that afternoon in Welo. Since the famine of 1984, they don't even think of selling any grain until they know what the harvest has brought. I asked whether the bounty I'd seen in their fields had them feeling a bit more secure and optimistic.

"It will be nice to have some extra money," Mohammed began, "so we can send our kids to school in good clothes, but…" He paused, looking over at his neighbor, then gave an answer I've come to think might perfectly describe the attitude we all should adopt when it comes to securing our future food supply.

"We're positive," Mohammed said. "But we're very sensitive to risk."