

From an abandoned coal mine deep in the Norwegian permafrost to farms in the blazing African savanna, the race is on to preserve the world's priceless genetic diversity, the building blocks of man's food and fiber supply. Geneticists collect and study the wild ancestors of modern crops. They gather "landrace" varieties selected over thousands of years by farmers around the world. And they catalogue varieties bred by commercial and institutional breeders. Each sample represents its own piece of the world's genetic pie.

It's a truly international effort. Scientists from the Nordic Gene Bank (which operates the storage facility in the Arctic coal mine) helped colleagues establish a gene bank in Zambia.

Polish scientists have helped Russians conserve potato specimens. And U.S. Department of Agriculture geneticists have helped around the globe.

Linking the world. More than 100 countries are involved in genetic diversity conservation, creating gene banks that vary in scale from massive, cutting-edge storage facilities to local conservatories. Awesome or humble, each gene bank is a vital link in a chain that connects agriculture around the world.

Today, wheat growers should tip their hats to Ethiopian farmers, who provided resistance to barley yellow dwarf virus that was bred into California wheat

lines in the 1960s. Nearly all the wheat grown in the Pacific Northwest contains genes from a rust- and bunt-resistant variety that came to the U.S. from Kurdistan via Turkey in the 1940s. And an Afghan landrace variety that had been stored in the U.S. Department of Agriculture collection for 50 years turned out to provide drought and salt tolerance for Syrian wheat farmers—though American collectors had never realized that it had any salinity tolerance in the first place, notes Ardeshtir Damania of the Genetic Resources Conservation Program at the University of California, Davis.

Future treasures remain undiscovered. Mildew resistance in Canada's vast sea of

barley could rest in the DNA of wild grasses in Iran. Insect tolerance in Iowa soybeans may hinge upon landrace varieties in remote Asian villages.

To the field. An increasing amount of the world's gene banking is taking place outside the cold-storage room, in small fields around the world.

Axel Diederichsen, curator of the Canadian gene bank at Agriculture and Agri-Food Canada's Saskatoon Research Centre, explains that conserving genetic diversity is now seen as a two-pronged effort: safeguarding samples in gene banks and breeding some of them out in the field.

"Gene banks are very essential—many plant types would

have been lost forever without them," Diederichsen says. "For the on-farm sector, it will be important to strengthen efforts for diversification, including the usage of material from gene banks to develop that material, experiment with it."

Breeder's bounty. Gene banking has its roots in the collecting expeditions of legendary Russian botanist Nicolai Vavilov in the 1920s and 1930s. (See story on next page.) Vavilov traveled the world to collect landrace varieties and their wild ancestors to supply Soviet breeders. University of Illinois geneticist Jack Harlan identified a broader benefit of gene collect-



Three-part cover story

FIGHTING AG'S GENETIC EROSION

As farmers raise only top-performing crops and livestock, international scientists are racing to preserve valuable DNA

"We don't know what our breeding needs will be 20 years from now, or even longer"

—Ardeshtir Damania





PHOTO: GETTY IMAGES

Above: Genetic diversity, the focus of gene banks, is crucial to farmers in this African village.

ing: stemming what he called "genetic erosion," the extinction of landraces washed away by the high-yielding commercial varieties developed during the Green Revolution.

In the late 1960s and early 1970s, several U.N. agencies, the World Bank, national governments, universities, and private foundations raised billions of dollars to conserve dwindling genetic resources by establishing a worldwide network of gene banks.

At the start of the scramble, the world hosted fewer than 10 gene banks with a total pool of fewer than a half-million samples.

By 1996, that number had grown to more than 1,300 gene banks around the world, housing more than 6 million samples.

Next phase. In the decades following the gene-bank boom, scientists have focused on duplicating, regenerating, and cataloging their collections. International networks and databases abound with detailed descriptions of varieties and genetic information, but there is still a long way to go before the collections are fully catalogued.

Meanwhile, though 6 million samples represent a lot of seed, vast numbers of scarce varieties remain to be found. New landraces need to develop, generation after generation.

"We don't know what our breeding needs will be 20 years from now, or even longer," says Damania. "It's good that these genetic changes can take place so the plants with desirable genes are keeping up with environmental vagaries such as global warming." /Steve Werblow



PHOTO: GETTY IMAGES

A QUESTION OF SURVIVAL

The Vavilov germ plasm collection survived the Nazi siege of Leningrad. Today, it faces another challenge: Russia's faltering economy

Olga Voskresenskaya eyed sacks of stunted potatoes stacked against the wall of the freezing basement. Outside, German artillery rained death from the skies as it had since September. In the street, bodies piled up. By spring of 1942, nearly 500,000 residents of Leningrad would succumb to starvation or shelling during the first brutal winter of the 900-day siege.

Weakening as her bread ration was cut to a mere four ounces per day, Voskresenskaya faced the all-too-real prospect of starving to death—in a room full of food. Still, she stuck to her assignment; guarding the world's leading collection of

potato germ plasm, gathered from around the world by renowned botanist Nicolai Vavilov and his colleagues.

The harvest that yielded the sacks of spuds in Voskresenskaya's care had been particularly challenging. Plots were planted on an experimental farm on the city's outskirts, and in the public square downtown. She harvested her early-maturing European varieties and prepared them for storage. In the weeks that followed, Abraham Kamerax slept in the fields through unrelenting artillery barrages, moving portable shelters over plots of Andean potatoes, artificially shortening the days to tease the vines into setting tubers.

Difficult harvest. In late fall, Kamerax moved his harvested tubers from the experimental farm to the basement that Voskresenskaya guarded, then enlisted as an army scout. Legendary botanist Vadim Likhonovich relieved Voskres-

enskaya, convincing her to leave her post before she starved to death. Likhonovich spent the rest of the winter scrounging firewood and fighting rats to preserve the collection. Voskresenskaya survived the war. So did the potatoes.

Post-war boom. Today, Leningrad has returned to its pre-Soviet name of St. Petersburg, and Russia's breeding program operates under the umbrella of the N.I. Vavilov All-Russian Scientific Research Institute of Plant Industry (VIR). A network of 14 research stations and 1,000 employees reaching across the nation, VIR is home to 320,000 samples representing more than 532 plant species.

Through the Cold War era, VIR was a world-leading gene bank and research institution. More than 150 million acres in Eastern Europe and Central Asia are planted to varieties developed from VIR's collection. Eighty percent of Russia's wheat varieties and 78% of its potatoes trace their lineage back to VIR. So do 66% of the former Soviet Union's grain crops and half of its vegetables and pulses.

Return home. Started in the 1920s and '30s, VIR's germ plasm collections are so old and extensive that they have been used to reestablish valuable plants in their homelands. Over the past five years alone, VIR has sent about 40,000 germ plasm samples abroad, according to Sergey Alexanian, VIR's head of foreign relations.

To scientists in Ethiopia, the institute sent 200 samples that had gone extinct in their native ranges. Because Vavilov's col-

lection predates Scandinavian genetic collection efforts by 50 years, VIR was able to supply the Nordic Gene Bank with samples of cabbage varieties that had been bred in the 1920s by Swedish breeders. And geneticists at the institute sent their American colleagues a special gift—old American wheat varieties that were not found in U.S. gene banks. Those samples provided U.S. breeders with genes for resistance to Russian wheat aphid.

Despite the flow of samples around the world and more than a dozen collecting missions conducted in concert with international gene teams since the mid-1990s, Vavilov's collection is nearly as threatened as it was when Hitler's army blazed across Russia.

Storage Concerns. Hundreds of thousands of VIR's samples are refrigerated in airtight containers, relatively durable as dormant seeds. The main collection is housed in a facility renovated in 1996 with funds from the U.S. Agency for International Development (USAID). With money from the Russian Ministry of Agriculture and the U.S. Department of Agriculture, VIR recently built a backup storage facility in St. Petersburg.

But other facilities are in deeper trouble. VIR's fruit tree orchards—home to 35,000 samples—are in disrepair. The institute's potato-storage facility lacks climate-control systems, says Alexanian, and cracks in the building's foundation offer easy pathways for rodents.

Perhaps the most daunting problem is regeneration, the process of growing more seed or plants for storage or for distribution to foreign plant breeders. More than 70,000 samples must be regenerated annually, and VIR doesn't have the resources to keep up.

"The most burning problem is funding," says Alexanian. "Very low salaries of the staff and inability to acquire modern

Left: Stepen Kiru tends potato seedlings in a spartan greenhouse at Russia's Vavilov Institute.

Below: N.I. Vavilov pioneered gene banking in the 1920s and '30s. Right: Olga Voskresenskaya nearly starved to death guarding Vavilov's precious potato collection during the Siege of Leningrad.



PHOTOGRAPH BY STEPHEN KIRU



equipment are challenges created by this problem."

Alerted to the dire straits of the VIR collections, international agricultural groups have scrambled to help.

The International Plant Genetic Resources Institute directed funds to bolster VIR's efforts. Joint projects with colleagues in Germany and The Netherlands have helped computerize the collection's data and make it available on the VIR Web site.

The Cornell-Eastern European-Mexico International Collaborative Project in Potato Late Blight Control (CEEM) has arranged the transfer of many potato-sample duplicates to a plant-breeding center near Warsaw, Poland. There they are being grown, multiplied, cleansed of viruses that would make them unfit for breeding, and carefully stored.

CEEM researchers from the U.S. and Poland have also trained VIR personnel on virus screening, the latest molecular management techniques, and other vital skills.

Uncertain future. Still, the future of VIR remains uncertain. Russia's leaders are trying to build their nation with a weak currency and a faltering economy. Other countries can be slow to come to the rescue when faced with preserving and building gene banks of their own.

This is not the time for the world to be shortsighted, warns John Niederhauser of the University of Arizona, a world-renowned American potato breeder who worked under Vavilov in 1935 during a year-long stint in Russia. "If we want to have the genetic base to confront the problems of the world, we'd better have that as a gene bank so we have the privilege of using what has evolved over millions of years," Niederhauser says.

Sure, he notes, many of VIR's samples appear in other gene banks. "But it's a matter of security, the same reason that someone investing doesn't invest it all in one stock," he says. /Steve Werblow

IN THE NICK OF TIME

Hindsight reveals that serious U.S. germ plasm preservation efforts almost came too late

The building looks like any other on the Colorado State University campus, but there are some differences. Its thick walls are solid concrete, stuffed with rebar, designed to withstand floods, storms, earthquakes, and objects falling from the sky.

To enter the building, you must be employed there or be met by someone who is. Even the facility's vision statement uses the word "security," an uncomfortable reminder of the times in which we live.

The National Center for Genetic Resources Preservation is a bank, of sorts. But the treasures in its vaults are stored in tanks of liquid nitrogen or in subzero bins in hopes that those seeds and cells will remain viable hundreds, perhaps even thousands, of years from now.

Aphid aid. It was not built a moment too soon. "The Russian wheat aphid is a good example of why we feel such urgency," says Henry Shands, the center's director. "When the aphid struck, we tested 47,000 wheat samples, and only 100 expressed resistance. It was a close call. But the real issue, I think, concerns the public. Do they understand the risks we face if we lose genetic diversity? Or do they even care?"

Certainly, the risks are great and they are immediate.

Take, for example, the Holstein breed. Even up until 1988, the breed's genetic base was broad. Today, however, because of advanced reproductive technologies like artificial insemination, superovulation, and in vitro fertilization, that base

has shrunk dramatically. In fact, Shands says, only 36 head are now required to represent the genetic diversity of the entire Holstein population.

In corn, he says, the entire pool of genetic diversity can be found in only 25 breeding lines. And the trend is clear for most prized plants and animals.

Inbred Arabians. "Take the Arabian horse," says Ginny Schmit, a biological science technician at the Center. "They were brought out of the desert, and after a few hundred years of intense breeding they all go back to only 14 animals. As a result, many foals now die from immunosuppression. The Arabians are too inbred. What happens is that while you improve some traits, the same bad genes continually get linked on the chromosomes, so now the foals are susceptible."

"It's like in milk cows if you breed only for milk production you might breed bad feet as well. Even slaughter houses have brought about a narrowing of the genetic base in beef cattle because of continual selection for a certain-sized animal. The problem is really broad."

What to do? "We need to go out and collect germ plasm from the top studs and from Joe Farmer's Bessie, too," says Shands. "That way you get representation from every genotype. In pigs, for example, we want 100 boars per breed represented that are as unrelated as we can find."

That effort is underway on a worldwide basis, and that international link is critical to the gene bank's long-term success.

"To get real diversity we must



PHOTO COURTESY OF THE NATIONAL CENTER FOR GENETIC RESOURCES PRESERVATION

Above: Germ plasm stored in liquid nitrogen is frozen at a temperature of -196 degrees Centigrade.

collect germ plasm from other countries as well as our own," Shands explains. "You see, most of the soybean germ plasm originated in China. But most of the beans are now grown in Brazil, Argentina, and the United States. Plants, animals, and countries are interdependent in the genetic world."

For the most part, international cooperation works well.



Genetic material is received from overseas almost on a daily basis, and germ plasma is sent to scientists overseas just as often.

Better sharing. "We are stewards here at the Center," Shands says. "We distribute more genetic material than all the international centers combined, with 30% of it going to foreign countries.

"But it's not enough," he adds. "We need to be better cooperators politically. We need more treaties among countries to encourage access to the world's

germ-plasm base."

While the need for more and better cooperation is Shands' long-term goal, his short-term goal is to safeguard the nearly half-million seed samples and the thousands of animal samples now stored at the Center.

Unknowns. That involves research. Fact is, no one really knows how best to store these samples. No one knows what temperatures are optimum; how long samples will last; or for that matter, even how best to



Top: Nearly 500,000 bags of seed are stored in subzero bins. Capacity is 750,000 bags. **Above:** Henry Shands, director of the Center, checks on some potatoes being propagated by tissue culture.

thaw them out. Shands is deeply involved in real science.

"Absolutely this is a work in progress," he says. "For example, you'll hear that liquid nitrogen cryopreservation will preserve a seed for 600 years. But who really knows? No

one has ever tried to germinate a seed after being frozen in liquid nitrogen for 600 years. All we can really do is monitor the respiration in that seed.

"So we are involved in very important research. It's one thing to gather the material. It's completely another to maintain its viability over centuries. But it's important because we serve as a defense against bioterrorism, while at the same time we are a repository so that breeders can further improve quality." /Dale McDonald