Spoiled by a freeze, a field of Florida tomatoes illustrates a global threat: Genetic uniformi *bred into crops in*

The World's Food Sup

By ROBERT E. RHOADS Photographs b

ates a global threat: Genetic uniformity bred into crops increases yields but makes each plant identically vulnerable to disaster.

's Food Supply at Risk

By ROBERT E. RHOADES

Photographs by LYNN JOHNSON BLACK STAR

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The first cultivated plants

The grains, fruits, and vegetables we eat today had their origins in wild plants first domesticated thousands of years ago.

In high valleys of the Andes (left), hunter-gatherers may have unearthed and consumed one such plant, the potato, by 8000 B.C., but millennia passed before Andeans first cultivated that tuber.

Early farmers domesticated many other wild species around the world, selecting and sowing the seeds of plants with such desirable characteristics as high yield and resistance to pests, climate stress, and diseases.

Growers cultivated thousands of different strains, each with its own hereditary material, or germ plasm. These traditional varieties are today known as land races.

Some growers continue to raise many of the old varieties—such as potatoes being sold by a woman in Cuzco, Peru (above)—in the regions where they originated. These pockets of traditional agriculture thus serve as natural repositories for the diverse genes of land races and their wild forebears.

Since plant breeders now manipulate germ plasm to produce a relative few "improved" varieties, it has become essential to rediscover and protect the old strains. Their vigor and genetic diversity help provide insurance for the future of our food supply.

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Traditional varieties bow to "progress"

Transforming the land, farmers in Sri Lanka (above) clear and terrace hillsides to plant new varieties of high-yield crops for market. When growers abandon old land races to plant modern varieties, often in single-variety monocultures, the potential for widespread disaster is greatly increased.

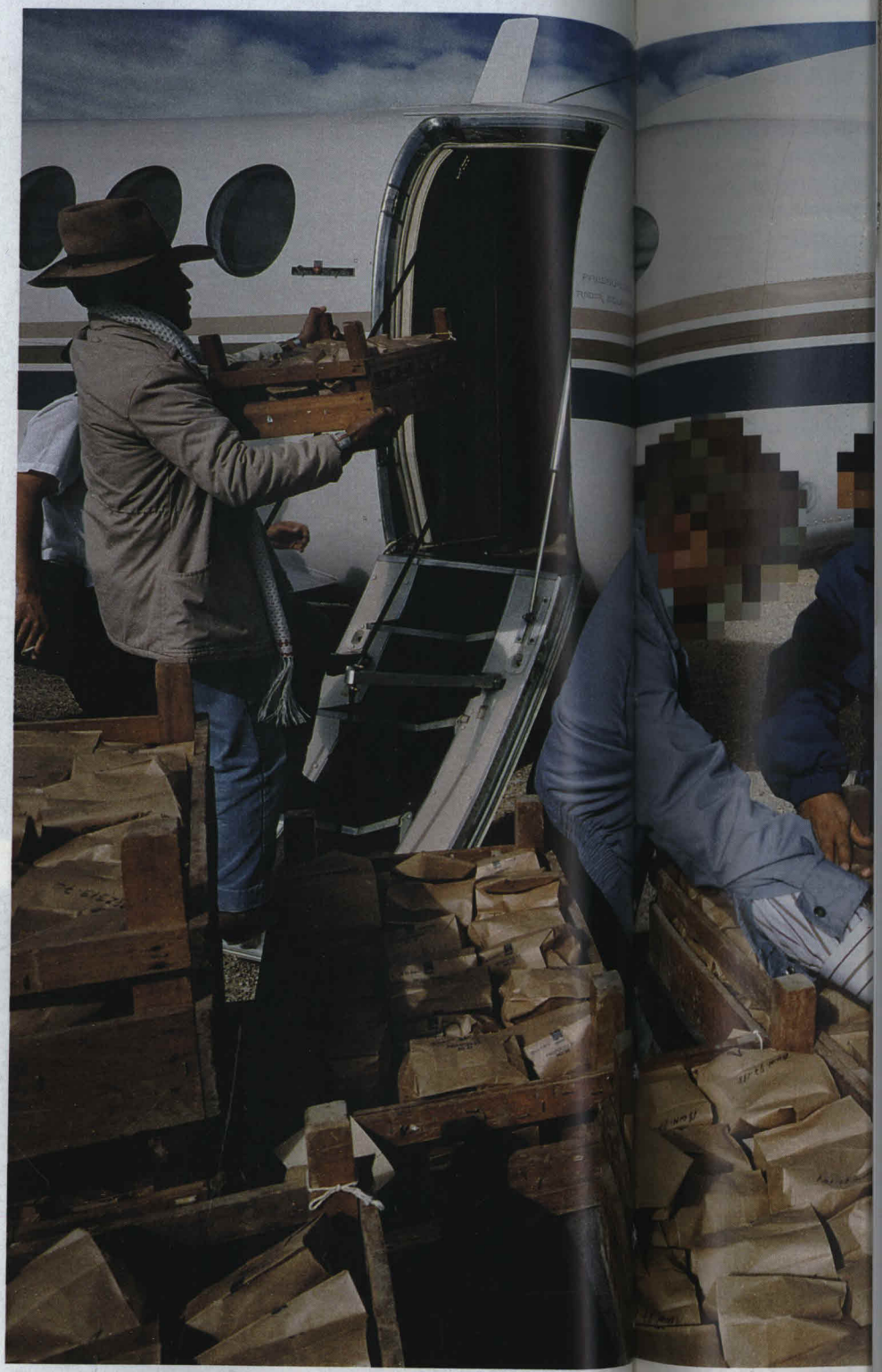
Clear-cutting across virgin lands destroys valuable natural vegetation, and in tropical rain forests—home to half earth's plant and animal species—some 60 acres a minute are denuded. A quarter of the total falls to the saw-toothed bite of commercial timber operations.

The resulting loss of naturally diverse germ plasm—much of it not yet studied—is called genetic erosion. It is estimated that by the middle of the next century, one-quarter of the world's 250,000 plant species may vanish, victims of deforestation, the shift to monocultures, overgrazing, water-control projects, and urbanization.

A treasury under assault

Under armed guard, members of the International Potato Center (CIP) risk their lives to rescue an important collection raised at their agricultural research station in Huancayo, Peru. Eight months earlier a Maoist guerrilla group called Sendero Luminoso, or Shining Path, intercepted a busload of workers en route to the station and killed a guard. Continued threats forced this evacuation and, for safety, require the concealment of identities in this photograph.

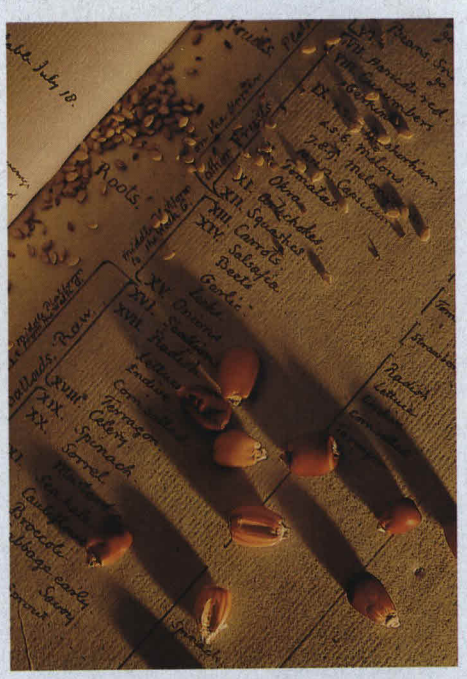
CIP is one of 13 centers of the Consultative Group on International Agricultural Research (CGIAR), whose primary goal is to increase world food production while preserving natural resources. Another center, the International Board for Plant Genetic Resources, coordinates an effort to collect, evaluate, and preserve germ plasm around the world. In more than a hundred countries, gene banks maintained by CGIAR centers (map, pages 84-5), national governments, seed companies, and others form a network dedicated to preserving genetic diversity for world agriculture.




Beechcraft

THE RANGERS of Ruhunu National Park cannot fathom why we are risking our necks to collect a plant they call "pig's weed." Cursed by local farmers, disdained by cooks, and useful mainly to sorcerers, the weed grows in a part of Sri Lanka inhabited by crocodiles, wild elephants, and terrorists. My job is to watch for crocs and mollify our nervous escorts, whose guns have recently been stolen by rebels.

For all that, my colleague, Balendira Soma Sundaram, the country's chief plant explorer, seems unconcerned. Gripping a pencil in his teeth, he hitches up his rubber boots, adjusts the faded canvas bag on his shoulder, and wades into a lagoon. He scans the shore until he sees the object of our search, a tuft of scraggly weeds half-hidden in the shallows. Reaching out, he plucks a few golden panicles from the stalks, slips the grains into an envelope, and smiles.



"Each time I come here, I find some," he says, happy to have a few more specimens of pig's weed, the wild rice known to scientists as *Oryza nivara,* one of the world's most valuable resources. At least one strain of this endangered species contains an ancient gene that resists grassy stunt virus, a rice pathogen that, sweeping through the paddies of Asia, would be capable of destroying the mainstay of three billion people. Even a 15 percent drop in Asian rice harvests could bring mass starvation.

Balendira and I handle the seeds with due respect, noting the plant's location within the park and labeling a few specimens for shipment to the Philippines. There the rice will be stored in a gene bank in Los Baños, at the International Rice Research Institute. This bunker of concrete and steel is reportedly the strongest building between Tokyo and Frankfurt. Should a new rice virus strike, scientists could obtain *O. nivara* from the bank, attempt to extract a resistant gene, and insert it in other rice varieties to ward off disaster.

Scientists transfer genes between related plants by traditional cross-pollination techniques or, in recent experiments, through genetic engineering. Genetic engineers identify a section of the plant's DNA from which they wish to borrow material. Then, using chemicals, they extract the segment, isolate the gene in a solution, and splice it into the DNA of another plant. In its new home the gene goes to work, repelling insects or fighting diseases just as it had done before.

But biotechnologists cannot *invent* the gene. That must come from wild sources or from one of the many varieties —which scientists call land races—traditionally bred by farmers. And therein lies the problem. The rice we recovered from Sri Lanka was still there only because it happens to grow in a wildlife reserve. That affords the grass a measure of protection. Outside the park *O. nivara* is disappearing faster than it can be saved. Around the world the same thing is happening to the wild relatives and land races of other major food crops—corn, wheat, and potatoes.

"What people call progress—hydroelectric dams, roads, logging, colonization, modern agriculture—is putting us on a food-security tightrope," said Te-Tzu Chang, head of the rice institute's gene bank, where 86,000 varieties of rice from all over the world are stored. "We are losing wild stands of rice and old domesticated crops everywhere."

Ironically the loss of genetic diversity accelerated with the green revolution of the 1960s. Back then, with the best intentions, scientists

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ROBERT E. RHOADES, former senior anthropologist at the International Potato Center outside Lima, Peru, wrote "The Incredible Potato" for the May 1982 NATIONAL GEOGRAPHIC. He recently joined the faculty of the University of Georgia in Athens. Photographer LYNN JOHNSON's byline appeared previously in the magazine on "Chicago's Hancock Center," in the February 1989 issue.

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developed new "miracle" seeds by carefully crossbreeding plants to increase food production—mostly rice and wheat—in poor nations.

The results were dramatic. The new seeds, resistant to insects and diseases, yielded millions of additional tons of grain a year. Indonesia and India, formerly dependent on imports to feed themselves, soon were self-sufficient; India now produces a surplus for export to Sudan and other hungry countries.

The miracle seeds were not perfect, however. Opportunistic insects and viruses mutated and unlocked the genetic resistance of the new seeds. The pests sent scientists scurrying, searching for genes to withstand the threats. They have been successful so far. Meanwhile, the old varieties and wild plants are disappearing from many places, replaced by improved crops that are genetically uniform.

In Sri Lanka, where farmers grew some 2,000 traditional varieties of rice as recently as 1959, only five principal varieties are grown today. In India, which once had 30,000 varieties of rice, more than 75 percent of total production comes from fewer than ten varieties.

The trend toward single-variety monoculture, the planting of one strain instead of many varieties, leaves modern plant breeders little margin for error, says Garrison Wilkes, a professor of biology at the University of Massachusetts and a leading authority on genetic erosion. "The extinction of local land races by the introduction of improved varieties is analogous to removing stones from the foundation to repair the roof," Wilkes adds.

At present rates of extinction, as many as 60,000 plant species—one-fourth of the world's total—may be lost or endangered within the next 50 years. Meanwhile, there are more mouths than ever to feed.

A red tide of cranberries, one of North America's few original food crops, swirls around Jack McMahon and his sons in their Oregon bog. Keen to increase the nation's wealth of crops, Thomas Jefferson once wrote, "The greatest service which can be rendered any country is to add an useful plant to it's culture." Jefferson's garden book (left, with sesame seeds and corn) is preserved at the Massachusetts Historical Society in Boston.

WHEN FARMERS began harvesting the first domesticated plants about 8000 B.C., the earth's population was around four million. Today that many people are born every ten days. If the trend continues beyond the year 2000, we will have to grow as much food in the first two decades of the new century as was produced over the past 10,000 years.

The key for meeting that monumental demand for food may be wild plants. Inside each seed is the germ plasm containing the DNA, the genetic code evolved over millions of years in the wild that dictates each plant's development. This "stuff of life" determines a plant's resistance to pests, disease, drought, and similar natural catastrophes. The germ plasm controls the taste, appearance, and preserving qualities of food as well.

"The genes in wild species and old varieties have incalculable value to plant breeders looking for natural resistance to disease and pests," says Gene Saari, a staff scientist with

the International Maize and Wheat Improvement Center in El Batán, Mexico, who has introduced improved, high-yield seeds from India to Egypt. "Problem is," he adds, "the old varieties are disappearing as farmers take up modern ones."

Modern farmers prefer the modern varieties, the plants redesigned by genetic scientists who borrow the best attributes from various seeds and blend them into new ones to increase productivity, to meet the taste of consumers, and to provide maximum protein, among other reasons.

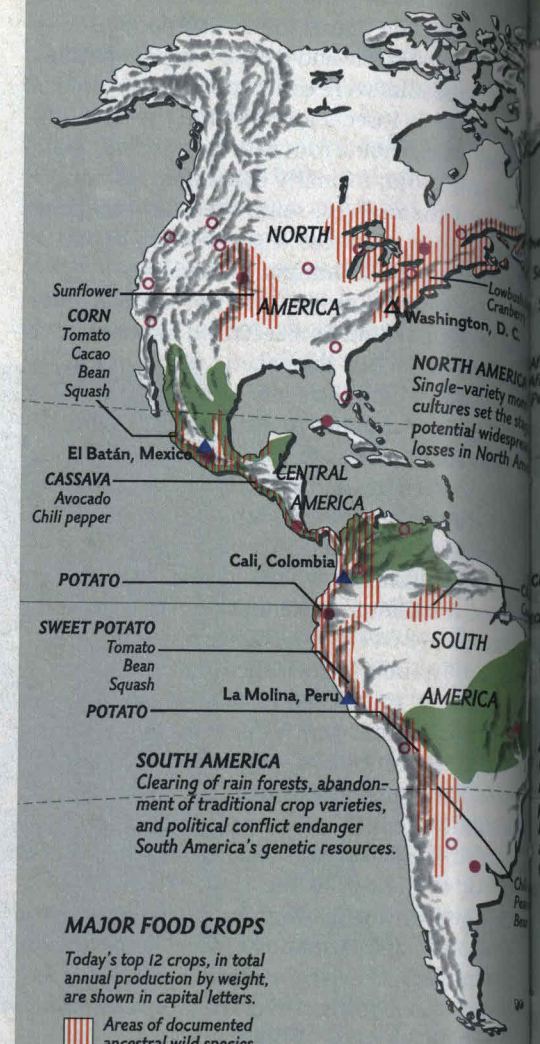
But there is a trade-off. By relying on a few crop strains instead of many, farmers open themselves to disaster. In the U. S., for instance, billions of rows of essentially identical corn are planted each year, making the entire crop vulnerable to a single pest or disease.

United States farmers learned that the hard way in 1970, when an unexpected epidemic of corn leaf blight wounded the pride of the world's most agriculturally advanced nation. A virulent new strain of fungus appeared in south Florida that winter and raced north like a killer flu. Since each ear of corn was a copy of every other, there was no margin of safety. The fungus destroyed half the crop from Florida to Texas. Nationwide losses amounted to 15 percent, at a cost of perhaps one billion dollars.

A SCIENTIST ON A U. S.-SOVIET PLANT EXPEDITION COLLECTS A SIBERIAN FORAGE GRASS, *DESCHAMPSIA CAESPITOSA*.

Such disasters are nothing new. Throughout history the sowing of uniform crops has led to a harvest of tragedy.

The collapse of Classic Maya civilization around A.D. 900, some anthropologists speculate, resulted from farmers' planting a mere handful of maize varieties, which were destroyed by a virus. Ireland's infamous potato famine of 1845 started with a fungus accidentally introduced from Mexico. That scourge, spreading through millions of genetically similar spuds, left the Irish without their main food source, and nearly a million people starved to death. A few decades later a fungus wiped out the homogeneous coffee plantations



The race against genetic erosion

"The diversity of our genetic resources stands between us and starvation on a scale we cannot imagine," warns leading plant geneticist Jack Harlan. Preventing such catastrophe requires tracking down the wild relatives of modern crops in habitats thought to favor their survival (green on map)—then preserving their germ plasm in a worldwide network of gene banks and protected natural settings. As population growth continues to degrade the environment, preserving the world's biological diversity is crucial to future food production.

NGS CARTOGRAPHIC DIVISION
SOURCES: JACK R. HARLAN, PROFESSOR EMERITUS, PLANT GENETICS, UNIVERSITY OF ILLINOIS; JOHN BARTHOLOMEW & SON, LTD., LONDON

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Taming wild wheat

Humans domesticated wheat about 10,000 years ago from plants whose wild relatives (1) still survive. Today land races (2) and modern varieties number about 22,000 and belong to two major species: wheats used to make bread (3) and wheats used to make pasta (4).

PAINTING BY WILLIAM H. BOND, NATIONAL GEOGRAPHIC ARTIST

of Ceylon, transforming that island into one of the world's major tea producers. And as recently as 1984 a bacterial disease struck Florida, forcing 135 nurseries to destroy 18 million citrus trees and seedlings.

Luckily, America's bruising by that corn fungus reshaped attitudes toward genetic resources. The National Academy of Sciences set out to assess U. S. vulnerability to crop disaster. The findings were sobering: Half the U. S. wheat acreage is planted in a mere nine varieties, three-fourths of the potato crop in four varieties, half the cotton in three varieties, and more than half the soybeans in six.

Even before the corn blight, agricultural research organizations such as the International Potato Center had been established to broaden and improve the genetic foundation. The potato center, located in La Molina, near Lima, Peru, is one of 13 research groups in the Consultative Group on International Agricultural Research (CGIAR), a consortium conducting some 300 million dollars' worth of research annually. Individual research centers strive to identify, rescue, and preserve wild species and land races of plants. Plant explorers are searching the world over for fresh genetic material.

I ARRIVED in the Soviet Union with a team of scientists sponsored by the U. S. Department of Agriculture (USDA). Our mission was to hunt for seeds in Siberia, but first we stopped in Leningrad to pay homage to one of the giants of modern botanic exploration, Nikolay I. Vavilov.

Vavilov, working in the 1920s and '30s, identified eight specific geographic areas around the world where he believed farmers first domesticated plants. Those areas still have the greatest diversity of major food crops. Directing a staff of 20,000 in more than 400 research stations across the U.S.S.R., Vavilov urged his seed collectors to store plant materials for safekeeping. Long before others realized the value of such collections, Vavilov understood that a cache of diverse genetic material could determine whether a nation's larder was empty or full.

His associates knew it too. During the 900-day siege of Leningrad in World War II, Vavilov's staff faced starvation rather than eat the precious stocks they had painstakingly gathered from the far corners of the earth. In a gesture of stubborn optimism, curators straggled out into the besieged city and planted specimens from their collections. They had to regenerate stocks for the future. During the siege many curators died in the laboratories, their stomachs empty. Surrounding the corpses were the boxes of seeds and sacks of potatoes they had been saving.

Vavilov did not live to witness the suffering of his colleagues. Packed off to prison in Saratov after a scientific dispute with Stalin's pet agronomist, Vavilov died there, accused of spying and agricultural sabotage.

Yet his work continues at the Vavilov Institute of Plant Industry, on an old tsarist estate that is now a favorite location for filming Soviet Sherlock Holmes films.

"Vavilov is not yet as famous as Galileo, but his time will come," Vladimir Krivchenko, then director of the Vavilov Institute, told me. "He admonished us to preserve the plant diversity created over millions of years before it is too late," said Krivchenko, a robust Russian who motions with callused hands that speak of his own involvement with the soil.

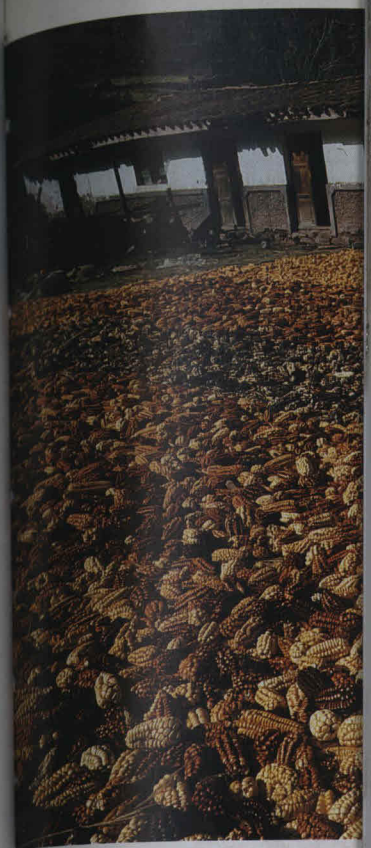
A few days later, accompanied by a few of Krivchenko's colleagues, I ventured deep into Siberia, hunting for grass seed with Vasiliy Malofeev, an expert on Siberian plants. Kay Asay, a USDA grass breeder from Logan, Utah, led the American team.

We bounced along in canvas-covered trucks on the only road linking the remote industrial city of Novosibirsk with Mongolia. Each time we spied a promising plant, we stopped. We scoured mountain slopes, storage bins, haystacks—even overgrown graveyards where the dead of the Russian Revolution sleep. All in the search for forage grass.

"Most Americans think this stuff is hayseed," said Kay Asay, showing me a handful of crested wheatgrass. "It's the key to our successful western ranching operations."

Around the campfire one night I learned of our long-standing reliance on Soviet imports. Orchard grass, bromegrass, wild rye, meadow fescue, clover—all came to us from the Soviet Union. Even the pride of the Great Plains, hard red winter wheat, descends from Ukrainian varieties that crossed the ocean with Mennonites in the late 19th century.

Guided through Siberia by Vasiliy and Kay, I stripped handfuls of ripened seed and put them into separate envelopes, carefully labeling each one: "Species: *Bromus* sp. Location: Ust Sema, Katun River, Siberia.



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Rainbow harvest of corn dries in the yard of an Andean girl's home. Cultivating different land races not only assures a grower that no single pest or disease will destroy an entire crop, it also helps prevent the world's agricultural gene pool from drying up.

Elevation: 1,100 meters. Date: August 13, 1988. Collector: Robert Rhoades." This information would help scientists find the grass again, should it be needed in an emergency.

As the tiny seeds trickled from my palm into the envelope, a thought flashed across my mind: Could one of these grains contain a gene for a minor agricultural revolution? Like the wheat land race from Turkey with a disease resistance worth 50 million dollars annually to the U. S.? Or the Ethiopian barley that protects California's 160-million-dollar annual crop from a dreaded yellow dwarf virus?

Even the most obscure plant can work a minor miracle—on the farm or in the pharmacy. AIDS researchers have found a substance in Chinese cucumber roots that may work against the disease. An extract from the rosy periwinkle of Madagascar has proved effective in treating childhood leukemia. A Mexican yam contributed to the first oral contraceptive. Wild tomatoes, growing in the salty air of the Galápagos Islands, have been used to adapt California varieties to the state's heavily irrigated—and increasingly saline—farmlands. Nature has equipped plants with magical properties that science is only just beginning to discover.

CONSIDER THE MYSTERY of the Mexican bean weevil, an insect with a nasty reputation and cumbersome scientific name. *Zabrotes subfasciatus,* a brown bug about the size of a pencil eraser, destroys as much as 25 percent of the beans stored in Africa and 15 percent in South America. Spraying this major food crop with insecticides might kill the weevil, but it would also harm people. It is safer to repel the bean weevil naturally, by breeding a genetic resistance into its food. That brings scientists like César Cardona into the picture.

For five years Cardona and his colleagues at the International Center for Tropical

To separate grain from chaff, a Peruvian farmer and his family winnow their wheat by using the strong winds in the Urubamba Valley. First domesticated in the Near East, wheat crossed land and water carried in the packs of explorers, pioneers, and immigrants. Likewis originated elsewher the potato from the belt owes its girth to

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immigrants. Likewise, many countries' "homegrown" crops originated elsewhere: Sixteenth-century conquistadores brought the potato from the Andes to Europe, and the Midwest's corn belt owes its girth to germ plasm that originated in Mexico.

Reaching toward the Peruvian rain forest canopy with a pruner, Percy Núñez Vargas (above) snips samples for the Missouri Botanical Garden. Passing the torch in Indonesia, 84-year-old master botanist Achmad Jahja Kostermans (below) continues his life's work on tropical Asian plants by dictating notes to an assistant at Bogor's botanical garden. His collection may take 50 scientists 50 years just to record and analyze. Such institutions play vital roles in collecting and identifying plants and helping scientists track related species for breeding programs.

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Percy Núñez Vargas (above) rch in Indonesia, 84-year-old s life's work on tropical Asian den. His collection may take ns play vital roles in collecting s for breeding programs.

Agriculture in Cali, Colombia, searched for a bean the weevil would find unpalatable. Ten thousand samples later, Cardona was ready to concede defeat. No cultivated bean, he concluded in a scientific paper, was immune.

"Those little scoundrels tormented me," Cardona recalls, underscoring the memory with a vivid stream of Spanish curses. "I came to hate them!"

A year later, a package of tiny, strange-looking beans appeared on Cardona's desk: They were ugly, blackish brown, trapezoidal, wild beans from Mexico.

"They didn't look like beans," Cardona remembers. "I was laughing at them." But, as a matter of routine, Cardona set them in front of the weevil and waited to see what happened. Nothing happened. The bean's secret armament proved to be a protein, detectable only under chemical analysis, that somehow repulsed the weevil. That protein could be transferred to its cultivated cousins—and was. Now the resistant beans are en route to Africa, a new weapon in the war against famine.

An American plant collector, Howard Scott Gentry, discovered the wild Mexican beans more than 20 years ago, during an expedition to the rugged hills of Guerrero. Exploring on muleback, Gentry spotted vines he had never seen before. He dismounted, gathered a few, labeled them, and forwarded the specimens to the USDA in Beltsville, Maryland. The beans were assigned a plant introduction number—P.I. 325690—and shipped to a plant introduction station in Pullman, Washington. There the beans sat on a shelf, unnoticed and unused, until—in a routine exchange of plant material—the USDA scientists in Pullman shipped a few specimens to their counterparts in Cali.

Gentry, meanwhile, went on with his life, oblivious to the wonders his discovery had wrought. On a visit to his laboratory at the Desert Botanical Garden in Phoenix, I had the immense pleasure of informing Gentry, 87, of the good deed his discovery had set in motion.

A smile spread across Gentry's face. "It makes me very happy that they are headed for Africa," he said, turning back to his plants.

Throughout history people have valued seeds, taking them as prized possessions when they left home. Rice made its way throughout Asia with traveling Buddhist monks. The Pilgrims carried sacks of peas, wheat, barley, and rye, among other seeds, on the *Mayflower*. African slaves often brought a handful of seeds with them to the New World, even if they had nothing else.

Like American music, language, or politics, American agriculture comes from all over. Consider a simple breakfast: Orange juice is squeezed from a fruit that originated in Southeast Asia; toast is made from a grain domesticated in the Near East; hash browns from an Andean tuber; coffee from a wild Ethiopian bush; peach preserves from China.

Trace the lineage far enough, and you learn that the turf at the golf course is Caribbean; the popcorn at the ballpark, Mexican; the Fourth of July watermelon, African; and the amber waves of grain in "America the Beautiful," probably Iraqi.

THE DANGER of importing plants, particularly from a center of diversity, is that they may carry diseases or pests that evolved with them over the centuries. It is for this reason that the borders of the U. S. and many other countries are protected by plant inspection stations. They are the first line of defense against silent invaders that could destroy the standing food supply.

"Are you carrying any plants?" queries an agricultural officer at Miami International Airport.

"No," I reply, handing over my documents. She considers my answer with suspicion, then directs me toward a sign that reads AGRICULTURE. There my luggage rolls through a scanning machine capable of detecting seeds, roots, and stems the way other machines reveal guns. I'm clean.

Deborah Baker, the inspection officer in charge, waves me through. "We deal with all kinds of people. Some try to smuggle endangered orchids. Others bring home a favorite house plant from abroad. Most don't realize how a few seeds in their pockets might introduce a disease."

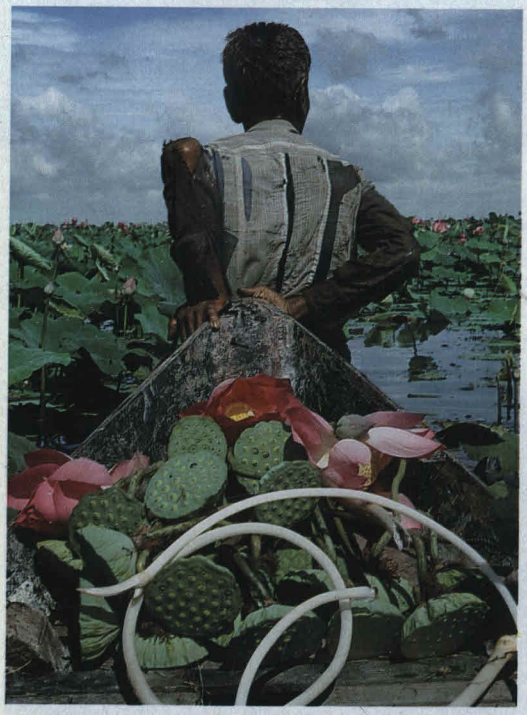
I ponder how Thomas Jefferson, an incurable seed collector, would react to the fuss. Jefferson knew that America's future depended on new seeds for a viable and varied agriculture, and he encouraged his fellow citizens to import new plants.

"The greatest service which can be rendered any country is to add an useful plant to it's culture," he wrote. In fact, if the United States were forced to live off the plants originating on its own soil, the fare would be slim pickings indeed—sunflower seeds, pecans,

strawberries, cranberries, blueberries, and Jerusalem artichokes are among the most palatable items.

As if anticipating Jefferson's advice, Benjamin Franklin, who was serving a stint as Pennsylvania's emissary in England, sent new varieties of seeds to America. By 1827, U. S. consular officers had standing orders to ship home any promising plant they found abroad. In that era, of course, genes were unknown, and there was no concern over introduced diseases or, for that matter, today's baffling new threat to plants and genetic diversity—terrorism.

Maoist guerrillas who call themselves *Sendero Luminoso,* or Shining Path, have overrun a valley high in the Peruvian Andes where my fellow scientists maintain the World Potato Collection, a stockpile of more than 13,000 specimens gathered and cultivated in South America, where the potato originated. Our complacency that the terrorists would not harm their own national heritage was shattered when a busload of workers from the International Potato Center was intercepted by guerrillas in December 1988. One guard was killed. The workers were released, shaken but otherwise unharmed.



By the boatful, Chen Nhim harvests lotus outside Phnom Penh. Cambodians brew lotus-seed tea to reduce fever. Boiled, its dried flowers help induce labor in pregnant women.

Nigerians stick leaves from a "headache plant" to their aching foreheads (right). Since only 2 percent of the world's plants have been scientifically analyzed, folk healing may help identify species useful in producing new drugs.

A year later three storage buildings at the experiment station were dynamited, forcing the evacuation of the scientific staff to Lima. Suddenly, after years of helping others, the potato center faces an adversary that takes aim upon humanity itself. How do scientists fight that threat?

"I've built this collection through revolutions and earthquakes," says Richard Sawyer, the pistol-packing director general of the potato center. "So I'm not about to kowtow to anybody."

Sawyer, a plain-spoken potato farmer who hails from Maine, has seen worse times. A prisoner of the Germans in World War II, he survived a death march by eating spuds. After that ordeal he became convinced that the plant that saved him could also save the world from hunger. To ensure a healthy potato supply for everyone, Sawyer founded the potato center more than 20 years ago.

Now Sawyer is preparing for what promises to be a protracted struggle. Saving seeds is no longer a matter of simple botanical technique, he tells us. To safeguard the potato collection, we pack samples in bags, stash seeds in airtight metal pouches, and insert plantlets in test tubes—all will be sent to safer regions of Peru and to other gene banks around the world.

"Time is running out," says Carlos Ochoa, a Peruvian who has stalked wild spuds from North America to the tip of Tierra del Fuego. The specter of civil unrest weighs heavily on Ochoa, who sees his life's work imperiled by forces few understand.

ASK ANY AMERICAN schoolchild where the country's most valuable national treasure is stored, and the answer will surely be Fort Knox. But the greatest wealth may be tucked away at a USDA facility on the campus of Colorado State University at Fort Collins, Colorado. Here, in an unassuming two-story building, 228,000 samples of seeds containing trillions of genes are cached in the National Seed Storage Laboratory, the central reserve bank of germ plasm in the U. S. The storage vaults

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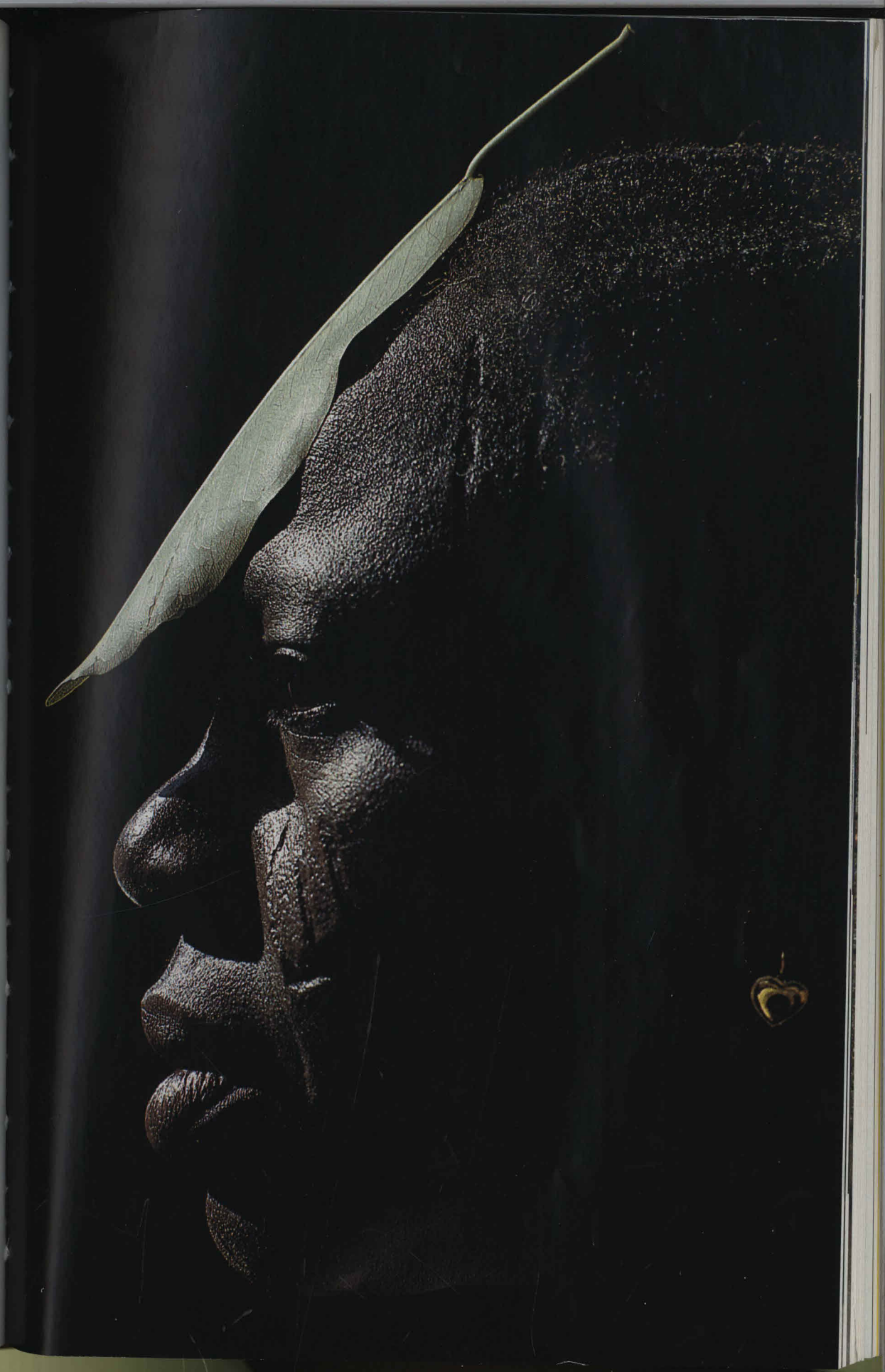
National Geographic, April 1991



Ultracold safety deposit: A technician at the National Seed Storage Laboratory in Colorado closes a tank that stores seeds in the vapor of liquid nitrogen. While periodic planting of seeds helps maintain their viability, cryogenic storage may preserve some seeds for centuries.

"Nobody will continu who stores seeds the whose natural resis

are protected by ultramodern security systems—microwave scanners and infrared sensing devices. Recently Congress authorized twelve million dollars to expand this national gene bank.

"No one knows when a pest will mutate and attack our crops," says Steve Eberhart, director of the laboratory. "Most Americans don't know how close we came to being a food importing nation during the 1970 southern corn blight. Now if we hear that a new corn blight has attacked China, our scientists can prepare to fight it by the time it gets here."

Dr. Eberhart leads me through rooms where his colleagues are testing seeds for viability and preparing them for storage. Some 3,000 seeds of each plant are kept on hand for eventual distribution to any plant breeder who needs them.

Some of these seeds can be kept viable for decades, preserved in stainless steel cryovats in the frigid vapor of liquid nitrogen kept at minus 196°C (above). From Washington, D. C., to Hawaii, scientists in 19 germ-plasm research stations have kept alive seeds and cuttings from thousands of plants, some of which arrived in the New World more than a hundred years ago.

"The world is different today from what it was in the age of the great plant hunters," says Dr. Eberhart. "Before, we could go to a plant's center of origin and find what we needed. Today many varieties in our collections are extinct in their natural habitats. And many governments have closed their borders to collecting."

WHO OWNS the genetic resources of a plant? Is germ plasm a natural resource—like oil or timber—to be exploited, controlled, or sold? Or is it the common property of all humankind? Like automobiles or toasters, some genetically engineered crops can be

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"Nobody will continue this work," reflects 85-year-old Ben Talachy of Española, New Mexico, who stores seeds the old way—in airtight jars. Small-scale gardeners keep alive many land races, whose natural resistance to pests and disease can be bred into modern varieties.

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HO OWNS the genetic resources of a plant? Is germ plasm a natural resource—like oil or timber—to be exploited, controlled, or sold? Or is it the common property of all ? Like automobiles or toasters, tically engineered crops can be patented. This means that genetic material taken from land races and wild species could make large profits for seed companies.

"The risk with plant patent laws," explains Canadian Pat Roy Mooney, a farmers-rights activist with the Rural Advancement Foundation International, "is that the seed companies obtain monopoly profits, whereas the farmers and countries that donated the genes receive nothing.

"For example, among tens of thousands of structural genes in a corn variety nurtured over the centuries by farmers, only a handful generally are altered by commercial breeders to produce a new hybrid. Does that give the breeder a right to patent it and reap the profits—profits sometimes earned by selling the hybrid back to the country where the genes originated?"

Mooney argues that commercial seed companies should be required to contribute a fraction of their profits to an international fund that would subsidize traditional farmers.

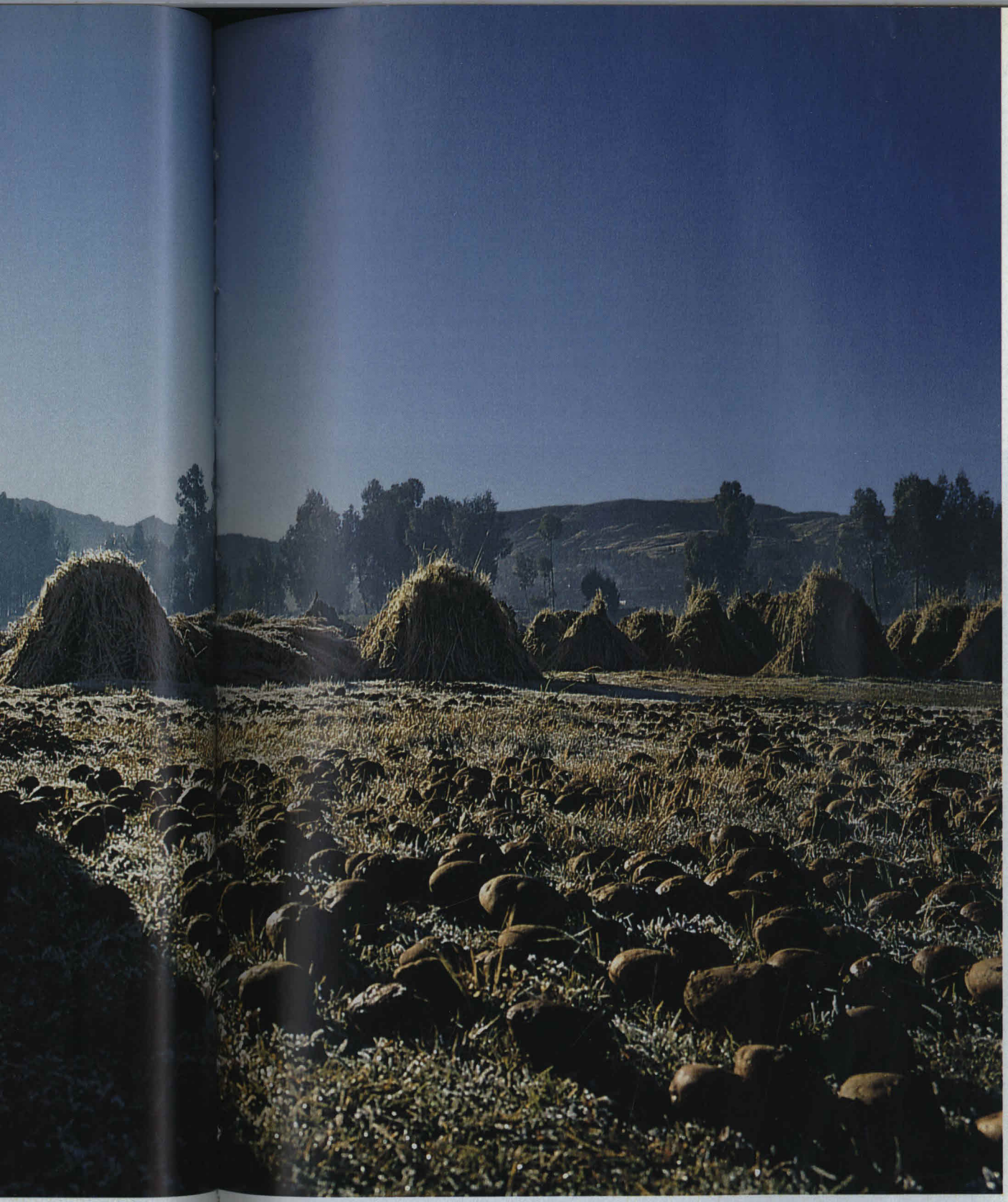
Back in the U. S., I got another view from Donald Duvick, then senior vice president for research at Pioneer Hi-Bred International, Inc., a company with annual sales of 870 million dollars.

"Over 90 percent of Pioneer's seed is sold in the U. S., Canada, and Europe," says Duvick. "Only a small fraction goes to poor farmers in developing countries." According to Duvick, it has taken a huge investment—more than ten years of time and tens of millions of dollars—to develop some of the successful new varieties.

"It's a bit like crossing a house cat with a wildcat," says Duvick. "You don't automatically get a big docile pussycat. What you get is a lot of wildness that you probably don't want lying on your sofa."

Attempts to control the flow of plant wealth are nothing new. During the spice wars of the 17th and 18th centuries the Dutch uprooted

Mashing potatoes with her feet, a woman in Peru's highlands follows an ancient Andean practice of forcing water from native tubers. She then leaves the potatoes in the field to dry. This staple, called chuño, is usually made using bitter, traditional land-race varieties with be stored for years. By co potato varieties, Peruvia of plant diversity.



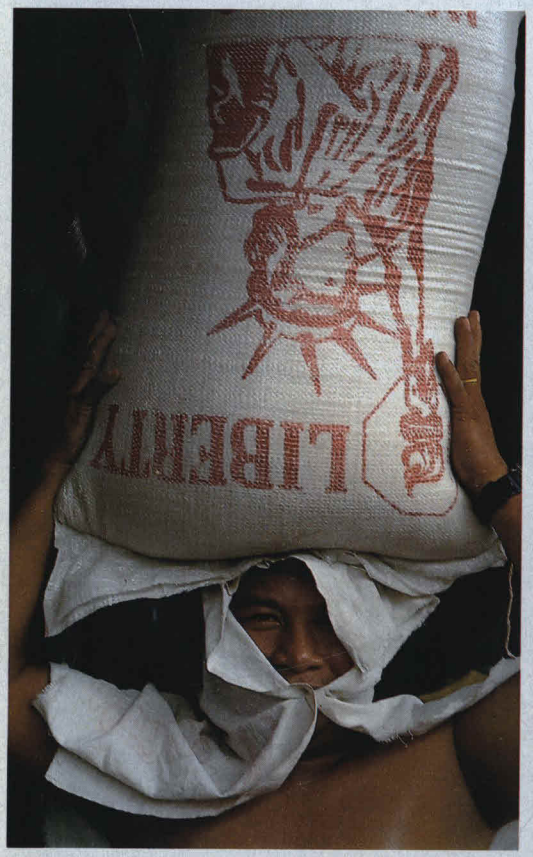
an in Peru's highlands forcing water from native the field to dry. This sing bitter, traditional land-race varieties with low water content. Once dry, chuño can be stored for years. By continuing to cultivate thousands of old potato varieties, Peruvian farmers serve as natural guardians of plant diversity.

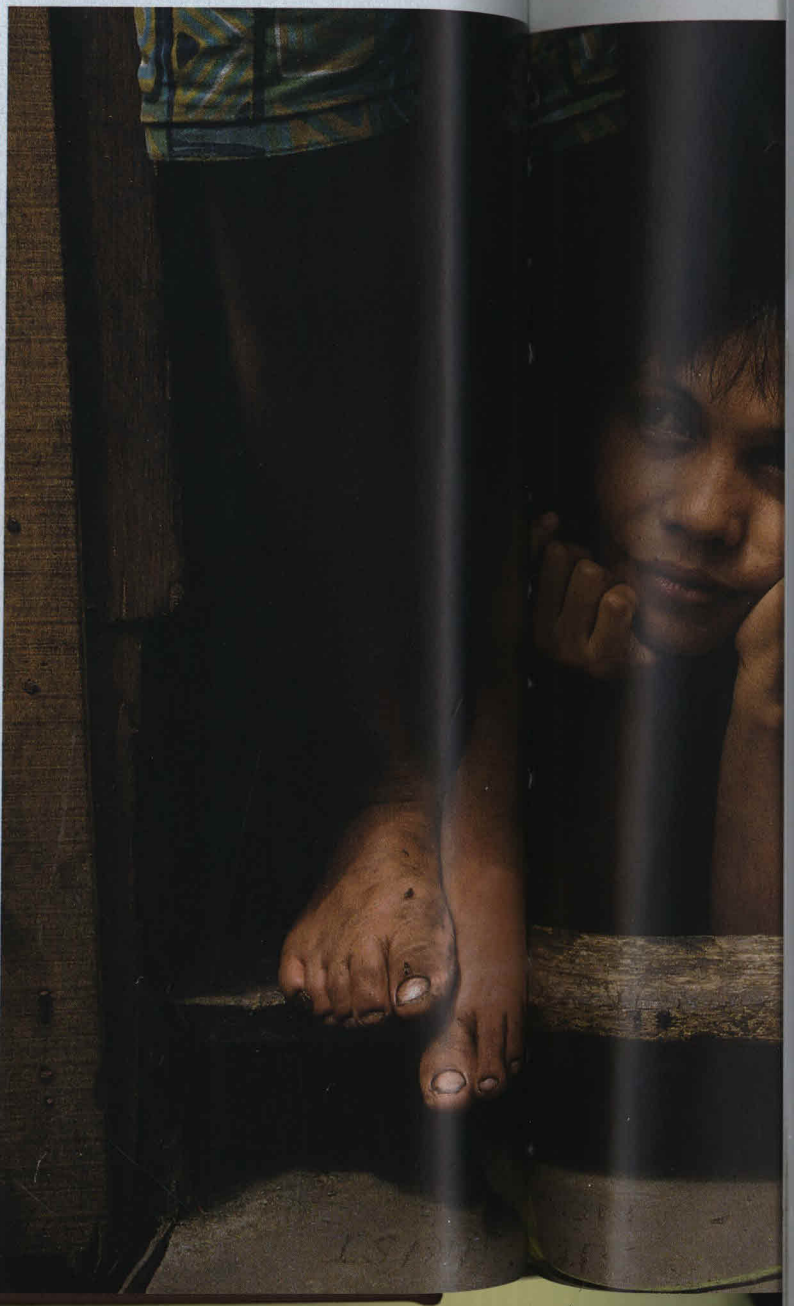
groves of nutmeg and clove trees—to keep prices high and to cut their competitors out of the market. And a sticky disagreement persists over rubber trees the British transplanted from Brazil in 1876, transforming millions of acres in their Asian colonies into lucrative rubber plantations.

DESPITE the verbal bombshells over seed sovereignty, I found an astonishing degree of cooperation among scientists and governments. In 1988 the USDA distributed 30,000 samples of seeds and cuttings to some 80 countries. If war or famine destroys native crops, international seed banks can replace them. Valuable potato varieties were lost to Bolivia after workers at the Belén seed bank rose up in protest over low wages and ate the national collection. The International Potato Center sent duplicates of the most important varieties to replenish the supply.

Many of Cambodia's indigenous food plants were lost in the Khmer Rouge reign of terror in the late 1970s. When that strife finally subsided, the International Rice Research Institute dipped into its reserves, returning more than 400 rice varieties to Cambodia, so the country could make a new start.

The spirit of reciprocity has been captured in a traditional Asian saying: "You cannot pick up a grain of rice with one finger alone."





Rice production in the Philippines has doubled since 1966 following the green revolution, in which careful crossbreeding produced high-yielding "miracle seeds." Though largely self-sufficient since 1977, the country had to import rice in 1990 (above) because of drought and typhoons. Despite advances, rapid population growth and rural poverty have forced many families, like this one in a Manila slum, from field to city in search of work.

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MANY HANDS ARE AT WORK in the U. S., where local seed hunters search old fields, rocky hillsides, and abandoned farms to identify and save long-forgotten seeds. Often laymen, these enthusiastic collectors exchange information and germ plasm, hoping their efforts will provide a needed dose of variety to America's kitchen gardens and small-scale farms.

The largest North American seed-gathering network is Seed Savers Exchange, founded and run by Diane and Kent Whealy from their 140-acre farm in the Amish country near Decorah, Iowa. The inspiration came in 1975, when Diane's grandfather, Baptist John Ott, gave them seeds from Bavaria that her family had brought to this country four generations before.

The Whealys—realizing that such "heirloom" seeds were being lost all over the United States—took up the challenge of developing a grass roots organization to save and swap such seeds. In the past 15 years the network has grown from a handful of people to some 5,000 backyard gardeners who maintain more than 12,000 heirloom fruit and vegetable varieties.

Today the heirloom gardening movement is spilling over to living history farms, where modern crops are being replaced by those of the appropriate era. These historical varieties

are becoming as much a part of the farms as heirloom reapers or grinding mills.

At Thomas Jefferson's Monticello outside Charlottesville, Virginia, I find John Fitzpatrick, director of the Center for Historic Plants. "We have over 500,000 visitors a year," he told me. "And we're finding that more and more they prefer to take home as a souvenir a plant Jefferson himself once tended instead of a dust-catching knickknack."

STORING SEEDS as heirlooms is better than letting them vanish, but many plants are best preserved in their original habitats.

"Most countries in Asia have centers for the conservation of art, music, and religion, but only a few have them for seeds," says Gerry Jayawardene, the proud head of Sri Lanka's new Plant Genetic Resources Centre. A few other places offer similar encouragement. In Mexico's Sierra de Manantlán Biosphere Reserve I found a small patch of *teosinte,* the closest wild relative of maize, growing in an area defended by park rangers fending off illegal herders.

But in Texas I discovered miles of pavement and screeching jets where valuable stands of wild grapes once flourished. Now the land is covered by the Dallas-Fort Worth International Airport. Perhaps the loss of a few grapes is a small price to pay for progress, until one thinks back to the 19th century, when an American louse, *Phylloxera,* brought the European wine industry to its knees.

Accidentally introduced into Europe in the 1860s, the louse ravaged thousands of vineyards before a solution was found. Since the American louse attacked European roots, someone finally hit upon the idea of grafting the European vines to American rootstock. Perhaps the New World roots had evolved a genetic resistance to the pest? The plan worked. The American roots kept the louse at bay, and the grateful Europeans were soon drinking wine again. But if a new breed of phylloxera should appear, to whom would the world turn today?

Rock stars and activists decry the loss of rain forests, and an admiring public leaps to the defense of pandas and snow leopards. But who speaks for a weedlike potato too bitter to eat or scraggly rice that spoils the pot?

These thoughts ran through my mind the last time I visited Luther Burbank's Gold Ridge Farm in Sebastopol, California, and saw the three remaining acres of the plant wizard's spread in a state of disrepair. Overgrown with weeds and brush, sandwiched between a housing project called Burbank Orchards and a cemetery, the old farm had been threatened by development. It seemed a fitting symbol of our society's indifference to genetic diversity. I was happy to learn later that the development had been abandoned after community organizations complained, and the farm was being revived.

From 1885 until his death in 1926, Burbank conducted his pioneering experiments with plants here. I saw his arbor of seedless grapes, his hardy Chinese-hybrid orange trees. Burbank bred hundreds of new plants, among them improved varieties of squash, plums, tomatoes, lilies, poppies, and roses. Yet he never obtained a patent. Not until four years after his death did Congress pass a plant patent act, which protects certain new varieties.

"You can almost see the old man working out there, pruning that old Royal walnut he planted in 1885," says Bob Hornback, a local horticultural historian who, working with the Western Sonoma County Historical Society, is among those helping to restore Gold Ridge to its former glory.

"THE SCIENTISTS BLAME the loggers. Loggers blame the settlers. Settlers blame the government. All of them are full of contradictions. Too many people who want too much."

The speaker, Achmad Jahja Kostermans, talks rapidly as he pads barefooted through the botanical garden in Bogor, Indonesia. Though he is 84, I have trouble keeping pace with Professor Kostermans, the greatest living botanist of the Asian tropical rain forest. The disappearance of food crops, he says, is part of a larger problem. The genetic diversity of the entire plant community is eroding, and nowhere is the rate of destruction greater than in parts of Southeast Asia.

"The chain saw sounds like an angry beast eating up the forest—*rrrrgh . . . rrrghhhh!!!*" Kostermans cries, mimicking the sound.

"Protected areas!" Kostermans laughs. "They exist only on paper in poor countries. Once I found a new tree species in a protected area in western Java. Only one of its kind, and loggers cut it down in a week."

This aged botanist appreciates the practical

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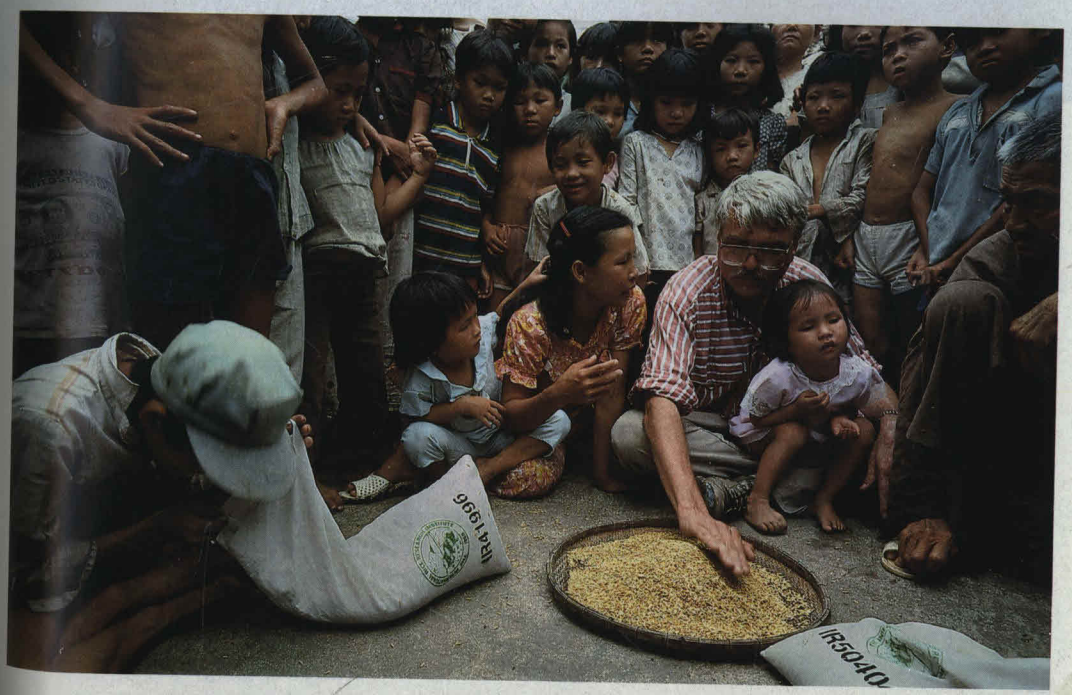
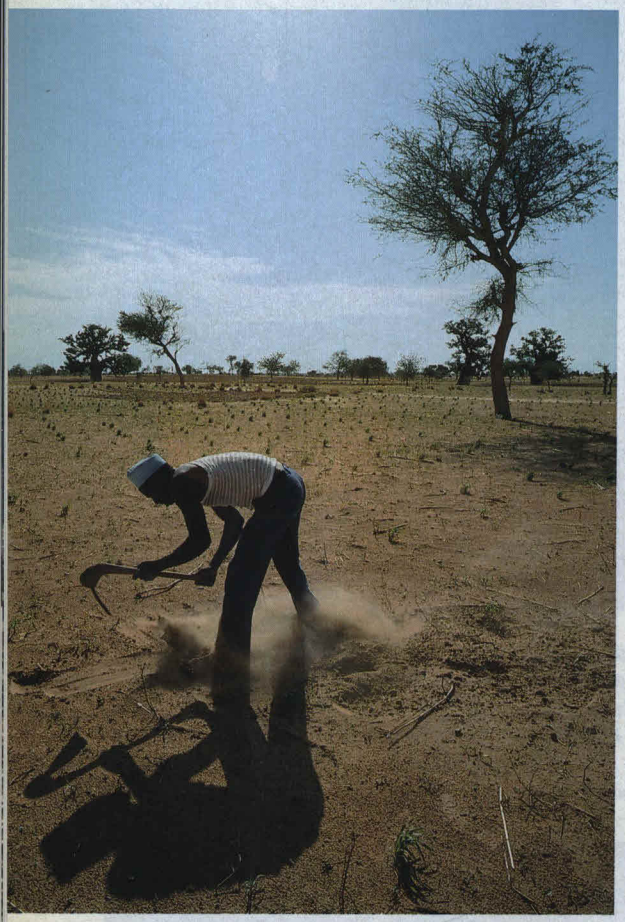
Sowing seeds of peace, Tom Hargrove (below) returns to Vietnam's Mekong River Delta. When he served as a U. S. military adviser in 1969, Hargrove brought "miracle rice" to local farmers and thus was spared by the Viet Cong. Now he brings a new variety developed by the International Rice Research Institute in the Philippines. It was bred from a disease-resistant land race abandoned by Vietnamese farmers for the strains Hargrove and others introduced in the 1960s. Today half of Vietnam's fields, like this seedling bed (above), are planted in improved varieties.



Scratching a living in Nigeria's dry northern region, Abubakar Ladan plants seeds in soil turned to dust. The future of farming here may depend on finding drought-resistant land races of sorghum and millet—and improving their yields. But how long can the hungry wait? Throngs of schoolchildren in Oyo, Nigeria, give voice to the growing demand for food.



value of tropical forests. They saved his life when he was a prisoner of the Japanese in World War II. Kostermans, conscripted to help build the bridge over the River Kwai, survived on forest plants, using them for food and medicine. Of the 20,000 other prisoners, 18,000 died. When the war ended, a grateful Kostermans dedicated his life to the study and preservation of natural flora. He has also adopted students, so that others can continue his work.

He points to one of his protégés, a young Frenchman named Jean Marie Bompard, a researcher for the International Board for Plant Genetic Resources. "I am the past," says Kostermans, with an uncharacteristic softness in his voice. "He is the future."

Bompard's future will be busy. It is said that Kostermans has gathered enough plant material to keep another 50 scientists working for 50 years, just cataloging and testing it. Somewhere in Kostermans' collection may be the wonder seed of tomorrow or the raw material for a miracle drug that will cure AIDS—not so farfetched when you consider that about 25 percent of U. S. prescription drugs come from plants.

More than even life-saving drugs or food, plants and seeds carry a powerful symbolism in many cultures. From the Hopi of Arizona, for example, I learn that seeds represent a sacred link to their past, handed down through

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ional Geographic, April 1991

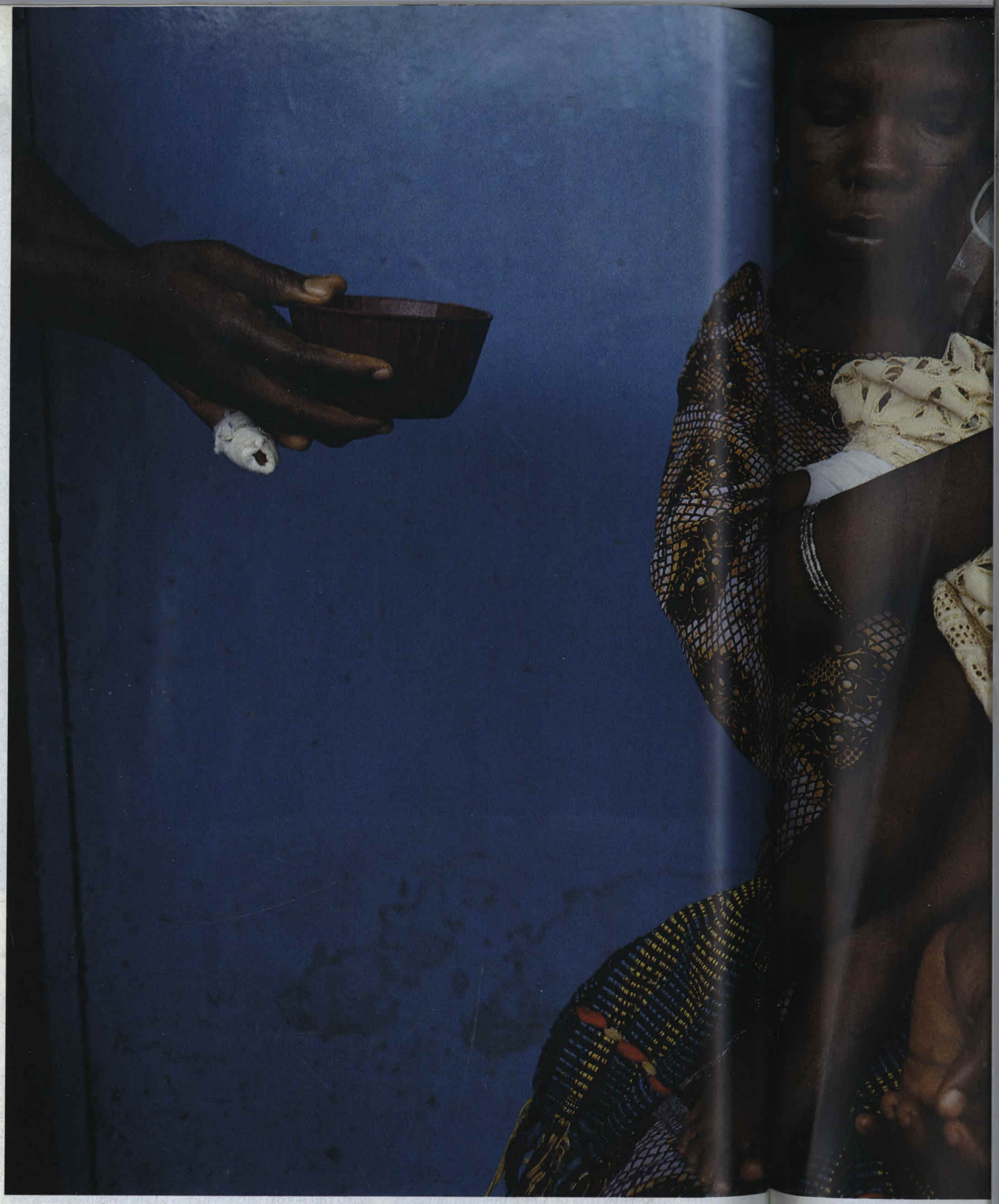
ceremonies from generation to generation. To them, each seed represents hope for the future as well.

MY JOURNEY ENDED in southeastern Turkey, somewhere near the Garden of Eden. In this mystical land, bounded by the Tigris and Euphrates Rivers, Adam was doomed to work "accursed" soils that yielded the "brambles and thistles" of Genesis.

Here too, according to Sumerian epics, the legendary Utnapishtim landed his ark after a monstrous flood, finding a home for "the seed of all living things." This was one of several far-flung areas where prehistoric humans made their first bold experiments with wild plants, sowing seeds to grow their own food.

Even though the forests have vanished and the surrounding hills are denuded, the grain bursts forth with the spring, as in all the seasons before. I found scattered stands of wild wheat and barley.

But the cycle may end soon, when the valley is swallowed by another flood. If all goes as planned, Turkey will build 21 dams on the Tigris and Euphrates by the early 21st century. Perhaps that is a fitting symmetry. The land between the rivers will be green again, an irrigated area the size of the Netherlands and Belgium combined. But the Garden of Eden will be lost forever.



Cradled by her mother, a young girl near death from malnutrition receives syringefuls of soy milk at the Kersey Home for Children in Ogbomosho, Nigeria. Crossbreeding soybean varieties from Brazil and Indonesia produced this high-protein food,

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which has saved many lives. Hunger already afflicts one-fifth of earth's five billion people. With population expected to double by 2070, food production must likewise increase. Now, as ever, the seed of humanity depends upon the fruits of the field. □