Genetic diversity, when collected and stored, provides the raw material for improving crops

By Guy Webster

Twenty years ago, yellow-dwarf virus was causing serious damage to barley crops in the Southwest. UA plant breeder Dr. Robert T. Ramage wrote to the U.S. Department of Agriculture's world collection of cereal crops in Beltsville, Maryland. He asked for seed samples from all of the lines of barley that had been collected in a region of Ethiopia where he suspected resistance to the virus might be found.

Of more than 300 Ethiopian barley types Ramage received and grew, he found four that were resistant to yellow-dwarf virus. He crossed these resistant plants with other barley plants to transfer genes for that resistance into barley with good growth and yield characteristics. As a result, farmers can buy seed for barley that will not be damaged by that disease. Barley breeders are now working on putting that genetic resistance into varieties adapted to the North Central states, where the virus is becoming a serious problem.

The seeds that Ramage got from Beltsville were from barley types collected in the early 1920s. The preservation of the genetic potential of these collected barleys avoided, at the least, a new, costly field-collection effort 40 years later. Quite possibly, by the 1960s barleys with the desired resistance could not have been found in the field at all.

The genetic material, or germplasm, of selected or collected plants is the raw material for using desired characteristics of those plants in the future. However, just what characteristics will be needed in the future is often unpredictable. The preservation and storage of germplasm prevents the loss of potentially valuable genes of plants that cannot be kept alive in the meantime.

Seed Sources

Germplasm is most conveniently stored as seed. Regional, national and international programs to collect and store seed have increased markedly in the past 30 years.

The stored seeds come from both wild and cultivated plants. Many domesticated crops still have wild relatives with which they can be crossbred. Though the wild varieties are much poorer in yield than varieties improved by centuries of human selection, they sometimes have valuable traits, such as an environmental tolerance or disease resistance, that can be added to a cultivated variety.

Seed-storage collections include many cultivated varieties that are adapted to specific locations through repeated selection of one year's seed from the choicest plants in the preceding year's harvest. The Ethiopian barleys that Ramage tested were of this type, sometimes called "folk," "land" or "dooryard" varieties.

A third category of stored seed includes the results of scientific plant-breeding. Besides the samples from successful crop-improvement projects, by-products or stepping stones from the project may be preserved. Breeders often identify traits that could be beneficial, but are not part of their immediate goals. They can see that germplasm determining such traits is preserved for future use, and made available to other plant breeders.

Barley breeder Dr. Thomas Ramage and graduate student Rebecca Walcutt use a small binder machine to harvest test plots of barley in Tucson.

Source of Resistance

Agricultural research at the University of Arizona has provided many successes that illustrate the value of ready access to a wide variety of plant germplasm. Outbreaks of crop pests or disease-causing organisms have triggered many of these projects besides Ramage's.

For example, plant breeder Dr. Melvin H. Schonhorst used germplasm collected in India and stored by a U.S. Plant Introduction Station when he first developed a variety of alfalfa resistant to damage by the spotted alfalfa aphid.

That insect first appeared and rapidly multiplied in the Southwest in the mid 1950s, nearly wiping out alfalfa as a commercial forage crop in Arizona. All of the commercial varieties of alfalfa growing in the state at that time were highly susceptible to the aphid.

Schonhorst obtained seed from 178 different varieties of alfalfa and planted them at Yuma and Mesa. He found one variety from India, called Sirsa #9, that was suited to Arizona's climate and was resistant to the spotted alfalfa aphid. By testing of progeny, superior plants were identified and intercrossed to create a new variety, Mesa Sirsa. It has been popular with state alfalfa growers ever since. More recently improved varieties, El Unico, Hayden and Lew, also have aphid-resistance traceable to the germplasm from India.

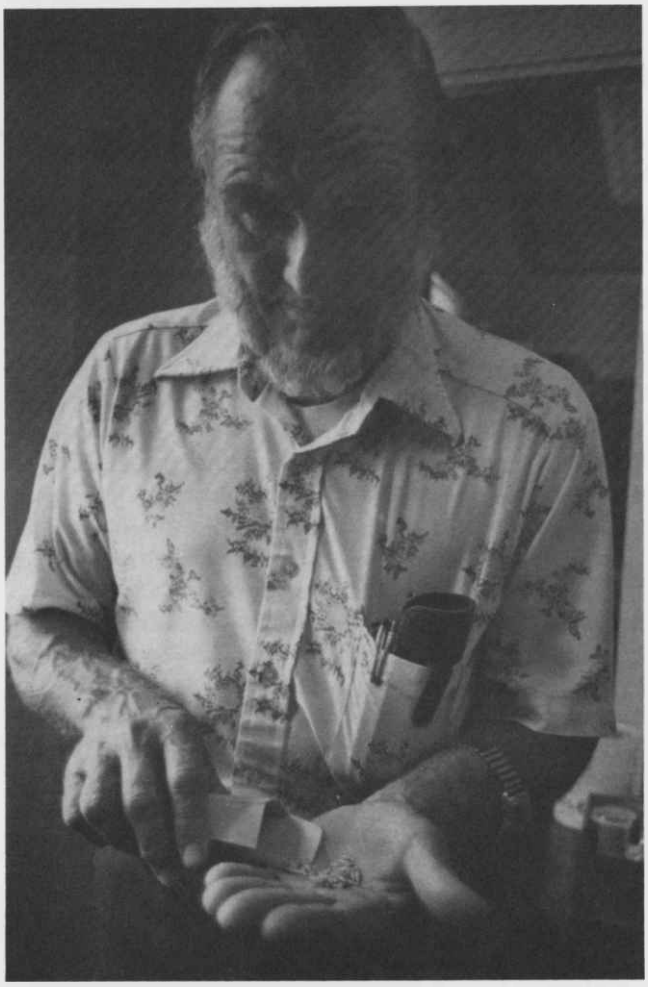
Improving resistance to disease-causing organisms (pathogens) is probably the most common use for stored collections of plant germplasm. Ramage described the pattern of events: "A new pathogen hits the country, or a pathogen already here has a mutation that makes it more damaging. This causes a scramble for a new source of resistance. Scientists get large portions of the germplasm collections for the crop and screen them for the desired characteristics."

New Plant Uses

However, collected and stored germplasm has been used in several other types of projects, too. One type is the search for plants to meet new uses and needs. In 1975, UA plant-breeder Dr. David D. Rubis began testing guayule as a possible drought-hardy, rubber-producing crop. Twenty-year-old seed he got from the National Seed Storage Laboratory in Colorado gave him a running start.

Guayule had been investigated in California during World War Two, when supplies of rubber-tree rubber were cut off, but that research tapered off and terminated by 1959. Since then, the need for a domestic source of natural rubber, and the appeal of guayule's low water use has once again made it likely to become a commercial crop in the Southwest. Fortunately, seed from the best 25 lines of guayule were saved when the research stopped. These were the seeds Rubis used to start the current guayule program.

"Preservation of these seeds gave us the advantage of 15 years of research that could have been lost," said



Ramage checks a sample of barley seed he obtained recently from the World Barley Collection.

Rubis. "We planted them out to increase the amount of seed, and now these varieties are being tested in Arizona, California, New Mexico and Texas. The best varieties will be used to start commercial production of guayule."

Rubis also coordinated collection trips for wild varieties of guayule and related species in 1976 and '77. Dr. Charles T. Mason of the UA Herbarium and Dr. Reed C. Rollins of Harvard made 163 collections from 14 Mexican states. The varieties have been planted for evaluation in Arizona, California, and Coahuila, Mexico.

Dr. Gilbert L. Jordan, UA range plant scientist, is testing more than 70 varieties of saltbush to find ones well suited to other new uses of plants: mine reclamation and highway beautification in arid regions. Plants are needed that grow with minimum maintenance on dry, alkaline soils. They would help stabilize the bare surfaces of mine spoil heaps and highway cuts and fills.

Jordan's test plants include several species from Australia and Africa as well as North America. Some Southwestern varieties were collected specifically for his plantings, but others had been stored for years as seed after classification at a U.S. Plant Introduction Station.

"It would take a tremendous amount of time and money to go out and collect all of these again from scratch," said Jordan. "With some luck, we'll find one or two out of these that suit our purposes better than what's used now."

Return to Origin

Germplasm storage can also safeguard plant types that are adapted to a specific area so that they can be returned to that area if other sources are lost through disuse or disaster.

Hopi Indian elders believed recently that the cotton variety that their people had grown and used for centuries had been lost. Crop losses and use of newly introduced cotton varieties had left them and other Pueblo Indians without any seeds of their traditional cotton since the 1940s. The loss was greater because of the Hopis' use of cotton in religious ceremonies.

Fortunately, UA research technician Gary P. Nabhan and cotton breeder Dr. Lee S. Stith located some long-stored seeds of the Pueblo cotton in a U.S. Plant Introduction Station in Mississippi. They planted out some of these seeds to increase the number, and Nabhan handed some to grateful representatives of Hopi and Santo Domingo pueblos last year.

This traditional Pueblo cotton, with its drought-tolerance and good spinning quality, was used extensively by cotton breeders from the 1910s through 1930s. "There are genes from it in many of the commercial cotton varieties used all across the Cotton Belt now," said Stith.

Nabhan commented, "This has been an important cotton to breeders and cotton growers. It is important in another way to the people who have developed it over a thousand years or more, but they would have lost it forever if some of the seed hadn't been preserved."

The capability of preserving another type of germplasm for returning to its origin is one project that UA's Dr. James O. Anderson is working on in his tissue-freezing laboratory (see accompanying article). Douglas fir trees growing in a given valley have evolved, over the centuries, to environmental conditions in that valley that may be different from conditions two or three valleys away. A lumber company is supporting some of Anderson's research in order to find a way to store fir germplasm. Then, when reforestation of an area is necessary due to fire or other loss, saplings could be used that are adapted to that specific area.

Lost Potential

The collection of germplasm from farflung sources for the sake of finding better crop plants is nothing new. All of the major food crops grown in the United States originated outside the national borders, including several brought by Indians. But systematic storage of germplasm for future use has developed only in recent decades.

The occasional loss of some valuable genes was the initial incentive. One example was a cotton variety called Meade. "It was supposed to be the best spinning cotton ever developed, but somehow it was completely lost by the early 1900s," said cotton-breeder Stith. "Maybe it wasn't really better than some we have now, but we'll never know for sure."

Range plant scientist Dr. Gilbert Jordan is evaluating more than 70 types of saltbush, including the Australian variety pictured, as potential plantings for mine and highway revegetation.

The beginnings of professional plant breeding about 100 years ago increased both the advantages and the need for collecting and storing germplasm. Breeders have developed modern crop varieties with more and higher-quality yields. As farmers began using these improved varieties, their productivity climbed dramatically, and use of hundreds of locally adapted "folk" varieties was discontinued. For example, many Midwest corn farmers who usually planted with seed from their own preceding crop switched to hybrid corn in the 1930s and '40s.

Efforts have steadily increased to preserve samples of seed from locally adapted crops, to use in future breeding or production. But many varieties were lost in this country, and the process of shifting from local "folk" varieties to higher-yielding, improved varieties is still underway in many developing countries.

Gil Jordan explained, "In many countries where primitive agriculture is still common, farmers keep their own seed for next year and plant the same selection over and over. It performs well in that local niche. There may be literally hundreds of these local varieties in one country, but many of them are being lost every year." Some of the wild relatives of food crops are also disappearing as their habitat is altered by human land use.

UA sorghum breeder Dr. Robert L. Voight collected more than 4,500 varieties of sorghum in North Yemen while working there for the U.S. Agency for International

Development in 1977–1979. "Already, it would be impossible to go back and find many of these," he said.

Agriculture in Yemen, at the southern end of the Arabian peninsula, had changed little for centuries until the 1970s. Many families grow millet or sorghum on tiny, terraced fields with little rainfall. Their seeds have been selected for local conditions of each village for thousands of years. Many farmers keep two varieties of seed, each adapted for a different planting time, since they wait for unpredictable spring rain before planting. In the past decade, foreign aid attracted by Yemen's strategic location, and access to lucrative oil jobs in Saudi Arabia have changed Yemeni lifestyles. Many families who once grew sorghum now buy their food instead, and grow high-income vegetable crops.

The sorghums that Voigt brought back are being grown for evaluation and to increase seed by another UA sorghum breeder, Dr. Orrin J. Webster. "We won't know for years and years just what qualities some of them have that are valuable for breeding," said Voigt. "The important thing is to have them when they are needed. They may become useful back in Yemen, where many of these varieties are not being preserved. People there may need to go back to growing more sorghum someday."

U.S. Corn Blight

In this country, the 1970 corn leaf blight dramatized the importance of maintaining variation in the germplasm supply. Almost all of the corn planted in the United States that year included genes from a Texas strain that allowed hybrid-seed production without expensive detasseling by hand. Unfortunately, these genes also carried susceptibility to a new mutant of the leaf-blight fungus. The blight cut the national corn crop by 15 percent in 1970, with some states suffering 50 percent losses.

Crop improvement work drew criticism after that epidemic for making crops too genetically uniform, said Dave Rubis. "But the critics don't mention that we had enough germplasm and enough knowledge to breed resistance back into these corn lines and supply farmers with the new varieties all within two years. Nobody starved, like they did in crop epidemics before we had this ability."

Most crops now have working collections of germplasm at several locations. For example, barley scientists have categorized barley types, and have divided responsibilities for the working collections among several research centers. The University of Arizona stores three categories, totalling about 700 of the 20,000 varieties of barley.

"We're responsible for maintaining the purity of these lines and providing viable seed to be used by anyone in the world," said Ramage.

Such decentralized working collections have been described as checking accounts compared to the safety-deposit box description of the National Seed Storage Laboratory in Fort Collins, Colorado. The NSSL, founded in 1958, keeps billions of seeds, representing about 100,000 varieties of almost 1,500 species. Samples of seeds are checked periodically for germination ability, and are planted out to produce fresh seed when necessary.

How long seeds will maintain their ability to sprout, and how closely the genes of the sprout match those of the plant that bore the seed vary greatly among plant species. NSSL scientists have been experimenting with the freezing of seed in order to keep them viable longer. Most seeds there are now stored at 4 degrees Celsius (39 Fahrenheit). Convenient, reliable storage of germplasm from plants whose seed is not a good genetic copy of the seed-bearing plant is the aim of the tissue-freezing research described in the accompanying article.

Villagers harvest sorghum in Yemen. Modernization can hasten the loss of some locally adapted varieties.