Resetting Sorghum's Internal Clock

Program to convert tropical plants is unique among crops.

As a boy, Fred Miller noticed that the chrysanthemums dotting the farms and homesteads of Central Texas where he grew up flowered in November, long after most other plants were finished for the season.

Those popular garden flowers, he later discovered, are thought to have evolved in Central America, near the equator, where the 24-hour day is evenly divided between 12 hours of daylight and darkness. This remains constant throughout the year. And along the equator, mums bloom after a set number of 12-hour days.

But if these same chrysanthemums are planted farther from the equator, where summer days can stretch up to 15 hours or more, the plants won't produce flowers—at least not until the shorter days of fall roll around.

Scientists have long observed the same flowering pattern in sorghum, a crop that also evolved in the Tropics.

In 1963, a team of sorghum researchers, Joseph C. Stephens, Keith F. Schertz, Harry B. Warmke, George F. Sprague, and Darrell T. Rosenow met at a research station near Chillicothe, Texas. They planned to map out a long-term breeding program to tap the valuable gene pool of tropical sorghums that could be used to improve the American crop.

From 1965 to 1970, Miller interrupted his doctoral studies to work for the USDA in Puerto Rico on developing what is now called the Sorghum Conversion Program.

Sorghum is thought to have originated about 5,000 years ago, just north of the equator in Africa in what are now the countries of Ethiopia, Sudan, and Chad. Because it evolved near the equator, sorghum—like the chrysanthemum—is sensitive to day length, or photoperiod.

Most native sorghums from tropical parts of Africa and Asia need consistent daylight of up to 12 hours to trigger an internal genetic mechanism that tells them to stop producing leaves and other vegetation and to channel energy into reproduction—first flowers and then seed.

The seed, of course, is the harvestable grain that is used to make breads and other food products around the world. In 1992, 45.4 million hectares of sorghum were planted worldwide. The U.S. crop area that year was about 5.4 million hectares, with an estimated U.S. farm value of $1.7 billion. In this country, the grain is used primarily as a feed crop for livestock and poultry.

"In the United States, at least some of the beef or chicken that we consume has been produced with grain sorghum as feed," says Jeffery A. Dahlberg, a plant geneticist and sorghum curator with USDA's Agricultural Research Service in Mayagüez, Puerto Rico. "In other parts of the world where rainfall is sparse, sorghum is grown in place of maize [corn] and other grain crops for human consumption."

The goal of the sorghum conversion program, Miller explains, is to convert tropical, photoperiod-sensitive sorghums into plants that will flower and produce seed 50 to 75 days after planting—regardless of day length. This is being accomplished through classical plant breeding and an understanding of basic plant physiology.

JEFF DAHLBERG

At ARS' Tropical Agriculture Research Station in Mayaguez, agronomist Pablo Madera is working on breeding grain sorghum varieties that are not sensitive to day length.

"Essentially, we're changing a plant that is sensitive to day length into a plant that's insensitive to day length. No other crop—no other plant species—has been converted like this," says Miller.

The program, a cooperative effort between USDA and Texas A&M University, has allowed the breeders to tap genes for insect and disease resistance, drought tolerance, food quality, and other traits contained in the tropical sorghums.

Many of the 42,000 accessions in the ARS sorghum germplasm collections maintained at Griffin, Georgia,

and College Station, Texas, are from the Tropics.

"We now estimate that at least 75 percent of all parents used to produce sorghum hybrids have part of their germplasm from the sorghum conversion program," Miller says.

The tropical sorghums are converted in a time-consuming process in which they are crossbred with a variety that is insensitive to day length.

The procedure involves growing plants during winter at the Tropical Agriculture Research Station in Mayagüez, where the tropical sorghums are crossed to an early-maturing U.S. sorghum type. Seed from these crosses is then sent to Chillicothe for planting during the long summer days. There, the genetic variability soon becomes evident—some plants are tall, short, or early- or late-maturing. Seed from the short, early plants is harvested and sent back to Puerto Rico for further crossing.

The crossings are repeated—usually for 5 to 7 years—until the plants are converted. These plants typically flower and begin to produce seed in 50 to 75 days and are ready for harvest after 120 days. They're also the right height to be harvested mechanically—a key factor, because many tropical sorghums can grow from 8 to 12 feet high.

Scientists release the converted plant seed as germplasm lines to commercial seed companies, which breed the germplasm with their own lines to produce hybrid seed that they sell to growers. Nearly 1,600 sorghums are in the program, 583 converted lines have been released, and more are planned in 1996.

"The converted plants have basically had their internal biological clocks reset so that they don't pay any attention to day length," says Dahlberg, who currently handles the tropical breeding portion of the program at Mayagüez.

"If these tropical sorghums hadn't been converted and you tried to plant them in the United States, they would keep growing leaves and stem but wouldn't flower. Or they might start flowering in late fall," Dahlberg explains. "By then, frost would probably kill them before they would produce adequate grain yields."

In late April 1995, program researchers released the latest batch of converted lines—a total of 50 that contain insect and disease resistance, drought tolerance, better grain quality, and other features that breeders can now use to produce new, improved sorghum hybrids for the United States and other temperate regions throughout the world.

FRED MILLER

Diversity of color and shape shows the enormous amount of genetic variation in sorghum species.

"In central and south Texas in the 1950's, a grower could expect to get 1,500 to 3,000 pounds of sorghum grain per acre," Miller says. "Today, a grower who doesn't get 3,000 to 6,000 pounds per acre is not happy. Much of that increase can be attributed to the conversion program."

"The program basically unlocked valuable genes for improving yields," says Dahlberg. "Before the program started, the genetic base of sorghums grown in the United States was very limited. Now it's greatly expanded."

Corn and cotton breeders have noted the success of the sorghum conversion program and have talked about developing similar breeding programs for those crops, Miller and Dahlberg say. The goal of such programs would be to tap tropical cotton and maize genes for breeding with domestic varieties.

"We knew if we could tap the genes of tropical sorghums, we could open a gold mine," Miller adds, "and that's exactly what happened. We've changed the complexion of sorghum—not only in the United States, but around the world."—By **Sean Adams,** ARS.

Jeffery A. Dahlberg is at the USDA-ARS Tropical Agriculture Research Station, P.O. Box 70, Mayagüez, Puerto Rico 00681-0070; phone (809) 831-3435, fax (809) 832-1025. ◆