
Less Water, More Biotech: Drought Resistance Is the Goal, But Methods Differ

By Andrew Pollack

GRAND ISLAND, Neb. — To satisfy the world's growing demand for food, scientists are trying to pull off a genetic trick that nature itself has had trouble accomplishing in millions of years of evolution. They want to create varieties of corn, wheat and other crops that can thrive with little water.

As the world's population expands and global warming alters weather patterns, water shortages are expected to hold back efforts to grow more food. People drink only a quart or two of water every day, but the food they eat in a typical day, including plants and meat, requires 2,000 to 3,000 quarts to produce.

For companies that manage to get "more crop per drop," the payoff could be huge, and scientists at many of the biggest agricultural companies are busy tweaking plant genes in search of the winning formula.

Monsanto, the biggest crop biotechnology company, says its first drought-tolerant corn will reach farmers in only four years and will provide a 10 percent increase in yields in states like Nebraska and Kansas that tend to get less rainfall than eastern parts of the Corn Belt.

At a recent farm show here called Husker Harvest Days, a few thousand farmers were guided past a small plot on which Monsanto had grown its drought-tolerant corn next to a similar variety without the "drought gene." A transparent tent had shielded the plants from any rain through the hot Nebraska summer.

The results were, to be sure, less than miraculous. Both the drought-tolerant and the comparison plants were turning brown and shriveling, and they were about three feet shorter than the lush green irrigated corn growing nearby. But the drought-tolerant plants, which also contained a second gene to protect their roots from a pest, were a little greener and a few inches taller. Continued on Page 6 than the comparison plants, and their cobs were missing fewer kernels.

Monsanto said the improvement was significant. And the Nebraska and Kansas farmers who toured Monsanto's plot, many of them facing water-use restrictions and soaring pumping costs for irrigation, said any improvement would be welcome.

"We pump water like there's no end, and that's not going to last forever," said Tom Schuele, a farmer in Cedar Rapids, Neb. Monsanto's competitors, including DuPont's Pioneer Hi-Bred unit and Syngenta, say they also plan to introduce water-efficient corn in a few years. And companies are working on plants that can stand up to heat, cold, salty soils and other tough environments.

A small California company called **Arcadia Biosciences** is trying to develop crops that need only half as much nitrogen fertilizer as a conventional plant. Fertilizer is crucial to modern food production, but the large quantities used today damage the environment. And because fertilizer is made from natural gas, its costs have soared along with other energy costs.

Public sector scientists are also on the hunt. Researchers at the University of California and the International Rice Research Institute in the Philippines are developing rice that can survive flooding, which causes major crop losses for poor farmers in the lowlands of India and other

countries. While rice is typically grown in standing water, the plants will die if submerged for more than a few days.

Many of these advanced crops are being developed using genetic engineering. The technology, already used to make crops that can resist weeds and insects, has spurred worldwide controversy. But in an era in which people are marching in the streets of many countries to demand more food at lower prices, low-water crops might win over areas that now shun biotech crops, such as most of Africa.

"Drought tolerance to me is the most critical entry point," said Calestous Juma, a professor of international development at Harvard who has advised African governments on biotechnology. "This is kind of reopening the window for genetic modification."

Critics accuse the biotechnology industry and its backers of exploiting the recent global food crisis to push a technology that has been oversold and that could have unanticipated health and environmental effects.

Indeed, many past predictions of how biotechnology would create novel crops have not come to fruition. And some experts say Monsanto and its peers have not published enough information to prove they can make drought-tolerant crops.

"I want to see more, I guess, from the Monsanto work before I'd be convinced they've got it," said John S. Boyer, an emeritus professor at the University of Delaware.

Safety questions must also be answered. Changing the water needs of a plant requires a more fundamental alteration of its metabolism than adding a gene to make the plant resistant to insects. "The potential for unintended side effects is greater, so the testing has to be greater," said David A. Lightfoot, a professor of genetics and genomics at Southern Illinois University.

How much could be gained by use of these new crops is not yet clear. A report in 2007 by the International Water Management Institute, which is part of a network of agricultural research centers, concluded that genetic improvements would have only a "moderate" impact over the next 15 to 20 years in making crops more efficient in using water.

"Greater, easier and less contentious gains," it said, could come from better managing water supplies, rather than trying to develop crops that can flourish with less water.

But many experts say the situation is grave enough that all approaches must be tried simultaneously.

Poor growing conditions can reduce crop yields by 70 percent or more below their potential. American farmers, for instance, average about 150 bushels of corn an acre. But David K. Hula of Charles City, Va., won a competition last year by achieving nearly 386 bushels an acre, a measure of what modern crop varieties can achieve under optimal conditions.

In many areas, lack of water is the biggest limiting factor, and supplies of water for irrigation could be reduced further in coming years in order to supply more water to growing cities and proliferating factories.

Global warming is also expected to lead to drier conditions and more frequent droughts in some parts of the world. Scientists at Stanford, for instance, have projected that corn yields in southern Africa could drop 25 percent by 2030 because of warmer, drier weather.

Breeding water-efficient crops would seem to be straightforward: Just grow crops under dry conditions and choose the ones that do best for the next round of breeding.

It does not quite work that way, however. After several generations, the crops are indeed more resistant to drought. But there is a downside in that they often turn out to have lower yields when there is plenty of rain.

So scientists are harnessing the same genetic techniques that have yielded insights into human health to decipher how plants control water use and adapt to stress. "We've probably made more progress in the last 15 years than we have in the last 5,000 years," said Ray A. Bressan, a professor at Purdue.

In particular, he said, studies have overturned the conventional wisdom that water use is so complex that no single gene could have a big impact on it. "Single genes are having effects in the field that we never thought would be possible," he said.

That has opened the door for genetic engineering, which allows scientists to add a gene from another species to a plant, or even an extra copy of one of the plant's own genes.

Critics say that biotech seeds, which are patented and tend to be costly, might not be suitable for poor farmers in developing countries. The Alliance for a Green Revolution in Africa, a group working for improved farm productivity on that continent, has said that for now it would avoid genetic engineering because greater gains for small farmers can be made at lower cost using conventional breeding.

Indeed, there has been progress developing drought-tolerant crops using conventional breeding, despite the obstacles.

Syngenta, a big Swiss seed and agricultural chemical company, says it will introduce drought-tolerant corn developed by conventional breeding in 2011, followed by a genetically engineered version in 2014.

The International Maize and Wheat Improvement Center in Mexico, the institute that sparked the output improvements of the Green Revolution decades ago, has bred drought-tolerant corn that is already being grown in Africa. Marianne Banziger, director of the global corn program for the center, said the yields are 20 to 50 percent higher than local varieties during droughts, with no loss of yield in wetter years.

Still, her institute, with financing from foundations, is working with Monsanto to develop genetically engineered corn that would be even more water-efficient.

Monsanto has said it would not charge royalties for using its technology in the African corn, to keep the seed affordable. It says that corn customized for Africa could be ready by 2017, only five years after it starts selling drought-tolerant corn to American farmers.

Various other approaches are being tried to make less thirsty crops.

Performance Plants, a Canadian company, adds a gene that causes the plant to start preserving its water more quickly as a drought begins. In one field test, the yield of its genetically engineered canola barely fell when irrigation was cut in half. The yield of a comparison crop fell 14 percent.

Monsanto is going in the opposite direction — trying to keep the plant producing seed when a drought starts, even when its natural response would be to slow down in order to preserve water.

"You don't want a cactus," said Jacqueline Heard, who directs Monsanto's program for drought-tolerant crops. "You want something that keeps a plant very active."

Monsanto will not say exactly what genes it is using, or in which species they originated. But one approach involves transcription factors, which are like master regulators, able to turn on dozens of other genes to orchestrate a plant's response to lack of water.

But with so many downstream genes activated, there could be other effects on the plants besides less need for water. At a recent biotechnology conference, a university researcher showed a photograph of a cotton plant with an inserted gene for a transcription factor. The plant was missing most of its leaves.

No single approach is likely to suffice for all types of dry conditions. "Probably no one has found the magic gene yet," said JianKang Zhu, a professor of plant biology at the University of California, Riverside. "Probably there is no magic gene."