Union of Concerned Scientists

EXECUTIVE SUMMARY

MAY 2012

HIGH AND DRY

Why Genetic Engineering Is Not Solving Agriculture's Drought Problem in a Thirsty World

Droughts—periods of abnormally dry weather—can be devastating to farmers and food production. The historic Texas drought of 2011 caused a record $5.2 billion in agricultural losses, for example, making it the most costly drought on record. Similar crippling droughts have recently occurred around the world, and climate scientists expect the frequency and severity of droughts to increase, sometimes unpredictably, in some regions as the global climate heats up. Although extreme droughts receive the most attention, mild to moderate droughts actually affect more acreage, and also cause substantial crop losses.

Agriculture accounts for the lion's share of all water extracted from rivers and wells—about 70 percent—setting up conflicts between food production and other uses. And beyond competition for water among various human needs are the requirements of aquatic organisms, such as game fish prized by sportspeople who bring dollars to local economies. Finding ways to protect food production and farmers' livelihoods from devastation by drought—and also to reduce agriculture's need for water—is therefore vital.

The Union of Concerned Scientists (UCS) analyzed the prospects for improving crops in ways that can reduce water use overall, and losses during dry periods. We focused on crop genetic engineering—the lab-based manipulation of genes from any source used to alter plants. Practitioners and proponents have touted the potential of genetic engineering to address drought. Biotech companies, prominent among them Monsanto, have promised to deliver new crop varieties engineered with novel genes that enable them to thrive under drought conditions.

The biotech industry has also suggested that genetic engineering can reduce demand for water from crops even under normal conditions—resulting in "more crop per drop." However, we found little evidence of progress in making crops more water efficient. We also found that the overall prospects for genetic engineering to significantly address agriculture's drought and water-use challenges are limited at best.

Genetic Engineering Offers Modest Results...at High Cost

The biotech industry has so far received regulatory approval—in December 2011—for only one crop engineered for drought tolerance, Monsanto's DroughtGard corn. Available data show that this corn hybrid produces modest results. And according to data supplied by Monsanto and analysis by the U.S. Department of Agriculture (USDA), the variety does so under only moderate drought conditions.

Drought presents a particular challenge for genetic engineering because it can take many forms. Droughts vary in their severity and their timing in relation to crop growth. Related factors such as soil quality affect the ability of crops to withstand drought. These complications make it

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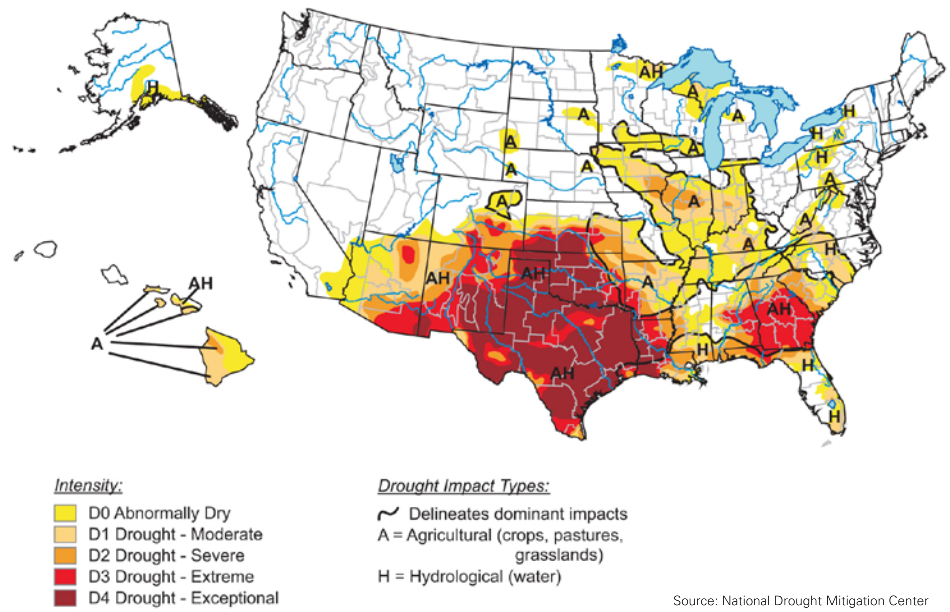
Drought Conditions in the United States, August 30, 2011



As this map shows, a substantial portion of the country was experiencing persistent severe, extreme, or exceptional drought conditions late in the growing season of 2011. It is unlikely that drought-tolerance genes like Monsanto's *cspB* would be of practical value under such conditions.

unlikely that any single approach, or any one gene used to make a genetically engineered (GE) crop, will be useful in all—or even most—types of drought. What's more, drought tolerance can be determined by many parts of the plant including roots, leaves and flowers, which are controlled by many different genes. This is a particular challenge for genetic engineering, which so far can manipulate only a few genes at a time.

Evidence is also scant that the technology will help crops and farmers use water more efficiently in the foreseeable future. Very few experimental GE crops designed to use water more efficiently have been field tested, and none are approaching commercialization.

In an era of reduced government spending, the cost-effectiveness of different technologies for improving agriculture—often supported by public research funding—is important. We found that although genetic engineering is beginning to have some success in enhancing the drought tolerance of crops such as corn, other technologies, such as classical and newer forms of breeding, continue to be more effective and less costly.

Improved farming practices are also likely to be effective in enhancing the ability of crops to withstand drought. Crop management practices complement genetic approaches such as breeding and genetic engineering, and should receive more public support in the form of government research and incentives. An exaggerated expectation about the capacity of genetic engineering at the expense of other approaches risks leaving farmers and the public high and dry when it comes to ensuring that the United States and other nations can produce enough food, and have enough clean freshwater, to meet everyone's needs.

Major Findings

To produce this report, we analyzed scientific studies on GE drought tolerance and crop breeding, and the USDA's database on field trials of drought-tolerant GE crops. We also reviewed Monsanto's 2009 petition for approval of DroughtGard, and the USDA's environmental assessment based on that petition.

These sources showed that scientists engineered several types of genes, mostly from plants, for drought tolerance in the late 1990s and early 2000s. By the middle of that decade, researchers were using gene switches, called promoters, to turn genes on specifically in response to drought. Other findings:

- The annual number of USDA-regulated field trials of crops engineered for drought tolerance remained below 20 from 1998 to 2003. That number spiked to 82 in 2005, and remained between 82 and 113 for seven years, including 90 trials as of late 2011.
- Developing a new GE trait typically takes about 10 to 15 years, including several years prior to field trials. Given the surge in field trials beginning in 2005, several drought-tolerance genes should be nearing approval and commercialization, if these crops have proved effective and reliable in field trials. However, as noted, the USDA has approved only one GE

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Texas farmer Terry Hash planted 800 acres of cotton, corn, wheat, and sorghum in 2011, and almost all of it was destroyed by that summer's extreme drought.

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While not immune to extreme droughts, sorghum is naturally more drought tolerant than corn and is a promising food and feed crop for farmers in arid regions of the world.

drought-tolerance gene and crop variety for commercial use, and no others have been submitted for approval.

- Monsanto's DroughtGard corn contains a gene called *cspB*. According to the USDA's environmental assessment and available data, *cspB* corn is not expected to be of practical value in severe or extreme drought.
- Monsanto's gene will confer only modest protection against moderate drought—about 6 percent more than non-engineered varieties used in Monsanto's test plots five or six years ago. This outcome, based on only two years of field trials with widely varying results, may not accurately predict the level of drought tolerance once the product is grown more widely.
- By comparison, classical breeding techniques and improved farming practices have increased drought tolerance in U.S. corn by an estimated 1 percent per year over the past several decades, according to one recent study. (Due to the challenges of measuring drought tolerance, this value should be considered a rough estimate.)
- That means traditional methods of improving drought tolerance may have been two to three times as effective as genetic engineering, considering the 10 to 15 years typically required to produce a genetically engineered crop. If traditional approaches have improved corn's drought tolerance by just 0.3 percent to 0.4 percent per year, they have provided as much extra drought protection as Monsanto's GE corn over the period required to develop it.
- Farmers are expected to plant *cspB* corn on only about 15 percent of corn acres in the United States. If this corn reduces the yield normally lost during drought by 6 percent on 15 percent of corn acres, it would increase corn productivity nationwide by about 1 percent. That improvement is about the same as the increase in drought tolerance in a single typical year achieved through conventional means, as determined by the study noted above.
- Although data are limited, Monsanto's *cspB* corn does not appear to be superior to several recent classically bred varieties of drought-tolerant corn.
- Although Monsanto has said it has a goal of getting "more crop per drop," its *cspB* corn does not appear to have improved water use efficiency (WUE): the ability of a crop to use less water to produce an amount of product. The company has not supplied any data measuring water use by *cspB* corn, or otherwise suggested that it has improved WUE. Drought-tolerant crops typically do not require less water to produce a given amount of food or fiber.
- In all, the USDA has approved only nine field trials designed to evaluate the WUE of several

different engineered crops since 1990. This strongly suggests that improved WUE—independent of drought tolerance—is not a serious goal of the biotech industry.

- Several food and feed crops, such as sorghum or pearl millet, are naturally more drought tolerant than corn. These crops are often less productive than crops more familiar in the United States—probably partly because they have received more limited attention from crop breeders. Many have untapped potential for improved yields and other desirable traits, suggesting opportunities to use them more widely in dry regions around the world.

The Challenges of Enabling Crops to Withstand Drought

In contrast to other GE crops now on the market, such as insect-resistant and herbicide-tolerant crops, drought tolerance requires the interaction of many genes. And genetic engineering can manipulate only a few genes at a time.

Some individual genes can affect genetically complex traits such as drought tolerance. However, even if genetic engineering can improve the drought tolerance of crops somewhat, it may not be enough to substantially reduce crop losses in the real world, where drought can vary in severity and duration. Any given engineered gene is likely to address only some types of drought, and then only to a limited extent.

And genetic approaches—whether genetic engineering or traditional

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breeding—are unlikely to substantially mitigate losses from severe or extreme droughts in the foreseeable future. That is because traits that provide substantial tolerance under extreme drought greatly reduce plant growth rates, limiting crop yields.

Yet severe to extreme drought is a significant piece of the drought problem farmers are facing. According to the National Climatic Data Center, severe to extreme drought affected about 23 percent of the contiguous United States in October 2011.

Furthermore, genes involved in drought tolerance often interact in complex and unexpected ways to alter more than one trait. Geneticists call this phenomenon pleiotropy. It can mean that engineered drought-tolerance genes produce additional, undesirable effects on crop growth.

Scientists can reduce harmful pleiotropy by enabling engineered genes to turn on only during drought. However, because droughts are often prolonged, this approach is unlikely to eliminate these harmful effects. Limited field trials and greenhouse tests of GE drought-tolerant crops could miss such effects, which could arise after commercialization.

The Uncertain Market for GE Drought-Tolerant Crops

The number of GE drought-tolerant crop varieties that appear on the market over the next five years should indicate whether the technology, at this stage of its development, can substantially improve this trait. The stalled number of GE field trials for drought-tolerant varieties since 2005 suggests that the pace of discovery of drought-tolerant genes may have slowed, although other explanations are possible.

Several obstacles may limit the commercial success of Monsanto's *cspB* corn. First, DroughtGard is likely to face competition from varieties of drought-tolerant corn produced through less expensive breeding methods. Markets for *cspB* corn and other drought-tolerant varieties will also depend on their other traits, such as overall yield and pest resistance. On the other hand, cross-licensing of the *cspB* trait by other companies, as has occurred with previous engineered genes, could expand its market by reducing competition from other varieties.

Another challenge for *cspB* corn is that farmers buy their seeds well before they plant. Because drought is not reliably predictable, many farmers may not want to pay the higher price of DroughtGard seeds just in case drought occurs. This may restrict planting of *cspB* corn mainly to areas where moderate drought is frequent, such as the western regions of the Corn Belt, which account for about 15 percent of U.S. corn acres.

Herbicide-tolerant or insect-resistant crops can save farmers time and money by reducing chemical pesticide applications, despite higher initial seed costs. However, these factors are unlikely to occur with GE drought-tolerant corn, and are therefore unlikely to drive its sales.

For all these reasons, the markets for DroughtGard corn, and any other engineered drought-tolerant crops, are uncertain.

Recommendations

Given the status of R&D on GE drought tolerance and challenging questions about its prospects, UCS recommends that:

- Congress and the USDA should substantially increase support for public crop-breeding programs to improve drought tolerance. Because large seed companies focus mainly on engineered crops, this would give farmers better access to non-GE drought-tolerant varieties.
- Congress and the USDA should use conservation programs funded under the federal Farm Bill to expand the use of available methods for improving drought tolerance and WUE. These include the use of water-conserving irrigation equipment, which may require considerable investment on the part of farmers, and farming methods that increase soil organic matter, which farmers must consistently use over several years to see substantial benefits. The Farm Bill can offer incentives or subsidies to help farmers at risk of drought adopt such practices.
- The USDA and public universities should increase research devoted to finding better ways to store and conserve soil water, groundwater, and surface water, and better farming methods to withstand drought.
- Public and private research institutions should devote more funding and effort to crops that are important in drought-prone regions in the Southern Hemisphere. These

Congress and the USDA should substantially increase support for public crop-breeding programs, and expand the use of water-conserving irrigation equipment and farming methods that increase soil organic matter.

USDA/Keith Weller

Researchers at the U.S. Department of Agriculture are experimenting with cover-crop and organic mulching systems—which slow moisture loss from soil—to protect corn and other crops from drought. Farm policies should fund further research to maximize the benefits of such practices, along with incentives for farmers to adopt them.

USDA/Scott Bauer

crops, which include sorghum, pearl millet, cassava, and cowpeas, are inherently more drought-tolerant than crops familiar in the Northern Hemisphere.

- Researchers at the USDA and public universities should carefully monitor the efficacy and possible undesirable effects of *cspB* corn. Such monitoring is important because this variety is the first GE commercial drought-tolerant crop, and the resulting information would enhance our understanding of GE drought tolerance. Similar monitoring should occur for any other GE drought-tolerant crops.

- The USDA and public universities should expand their research on using plant breeding to improve water use efficiency—a vital concern that has not attracted major efforts from the biotechnology industry. The public sector should also invest in improving water-saving irrigation methods and the water-holding capacity of soil, reducing water loss from soil, and developing better water storage facilities.

For more information and to read the full report, visit *www.ucsusa.org/highanddry*.

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