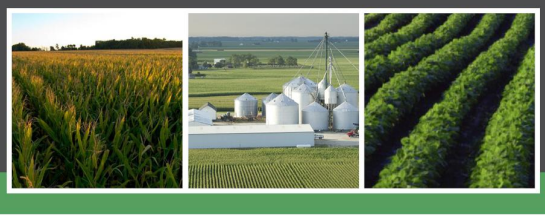

# Agronomic Spotlight

## A Systems Approach to Hydroefficency

- DroughtGard® Hybrids products are part of a systems approach combining best agronomic practices, drought-tolerant germplasm, and crop protection traits for improved drought tolerance and insect and weed control.
- DroughtGard Hybrids products have demonstrated an advantage over competitor products in drought conditions, yet have the potential to maintain top-end yield in well-watered conditions.
- DroughtGard Hybrids products can do more with less water during severe drought stress and can have fewer barren plants and more kernels per ear.

### Introduction to DroughtGard® Hybrids Corn Products

Water availability is the most limiting factor for crop production, and limited irrigation acres are increasing in the United States each year. Researchers have been working for decades to enhance drought tolerance in crops through plant breeding techniques.[1] DroughtGard Hybrids corn products can deliver hydroefficiency with a systems approach that includes agronomic recommendations, top-performing germplasm selected for native drought-tolerance characteristics, and crop protection traits including traits for insect and weed control as well as the industry's first drought-tolerant biotech trait for corn.

The drought-tolerant biotech trait in DroughtGard Hybrids corn products was developed by inserting a gene from the soil bacteria, Bacillus subtilis, that encodes cold-shock protein B (CspB) into corn. This protein allows the plant to acclimate to stress quickly and utilize water more efficiently during drought stress. Regulating the stress response helps preserve soil water during the vegetative stages making more soil water available for future growth. This is called hydroefficiency.

The first key to the systems approach is the use of agronomic management practices to enhance water storage in the soil and reduce evaporative losses. Selection of adapted, drought-tolerant genetics is the second key in hydroefficiency. Finally, the inclusion of the drought-tolerant biotech trait allows DroughtGard Hybrids corn products to slow down water consumption during drought stress (using the water more efficiently) to help endure the stress, potentially leading to increased kernel numbers and greater yield in drought conditions compared to conventional corn. Additionally, DroughtGard Hybrids corn products can leave more water in the soil during drought stress, allowing more water to be available later in the season (Figure 1).

### What is Drought Tolerance?

Drought-tolerant plants can withstand drought stress for a finite period, grow with less water, or use water more efficiently than other plants of the same species.[2] For a drought-tolerant corn product to be useful in agriculture it must be able to provide drought tolerance without sacrificing yield potential.

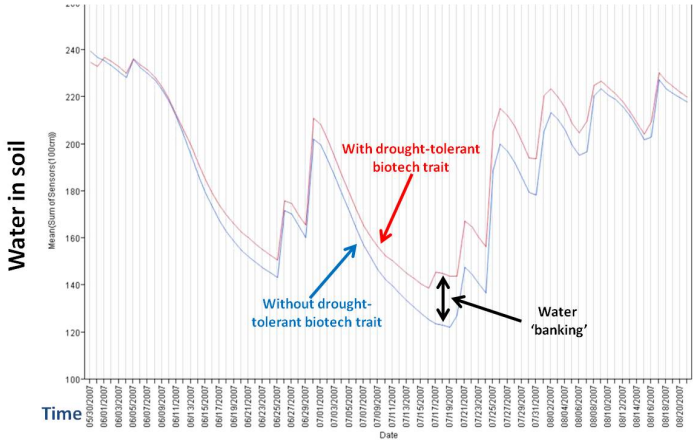


Figure 1. DroughtGard® Hybrids corn products can leave more water in the soil during drought conditions compared to corn products without the drought-tolerant biotech trait. Source: Monsanto Yield and Stress Discovery Team. Davis, CA, 2007.

DroughtGard Hybrids corn products have demonstrated an advantage over competitor products in drought conditions, such as in the 2012 and 2013 growing seasons, yet have the potential to maintain top-end yield in well-watered conditions, such as in the 2014 through 2016 growing seasons.

### DroughtGard® Hybrids Biotech Trait Research

In research trials conducted from 2009 to 2011, products containing the drought-tolerant biotech trait in DroughtGard Hybrids corn products and a conventional control were tested under adequate water and limited water treatments applied during mid-vegetative to mid-reproductive stages.[2] When averaged across years (2009-2011), yield increased in the limited water treatment by 6% for the products containing the drought-tolerant biotech trait when compared to the control. No consistent differences were noted in the adequate water treatments.

The products containing the drought-tolerant biotech trait responded to limited water conditions with decreased leaf growth, which decreased water use by the plant and lessened water stress. This physiological response resulted in increased ear growth during silking, which subsequently increased the number of kernels, harvest index, and overall grain yield when compared to the control.



MONSANTO

# A Systems Approach to Hydroefficency

In yield evaluations for the limited water treatments, the products containing the drought-tolerant biotech trait had higher yield than the control corn product in 2007 (9.3%), 2008 (7.0%), 2009 (11.7%), and 2010 (7.3%). Yield differences were not observed in 2011, possibly due to mild environmental conditions during the grain-fill stage.

Based on the results of the study, a model was proposed that the CspB protein in DroughtGard® Hybrids corn products may work by temporarily reducing leaf growth when the plant is under stress. Reduced leaf growth may lead to a reduction in water use (observed by reduced sap flow and higher residual soil water content). The reduced water use resulted in higher water use efficiency and less stress during the silking phase, which may have led to increased ear growth when compared to the control corn product. The larger ears then attracted more assimilates during grain fill increasing kernel set, harvest index, and grain yield.

## Advantages

DroughtGard Hybrids corn products have shown strong performance in yield trials from 2012 (a year of severe drought) through 2016. Yield trials conducted in the Great Plains states demonstrated a yield advantage of greater than 5 bu/acre over competitor drought products in 2013 and 2014, 3.7 bu/acre in 2015, and 4.5 bu/acre in 2016. In the non-irrigated locations of the western Great Plains states, with lower yields in these higher drought-stressed environments, 2014 yield trials showed a 6.5 bu/acre advantage (Figure 2) and 2016 showed a 5.4 bu/acre advantage. Yield trials in the central Midwestern states showed a yield advantage of greater than 5 bu/acre in 2014 and 2015. 2016 (a year with plenty of rain at the critical crop growth stages) still showed an advantage in central Midwestern states of 2.9 bu/acre over competitor drought products.

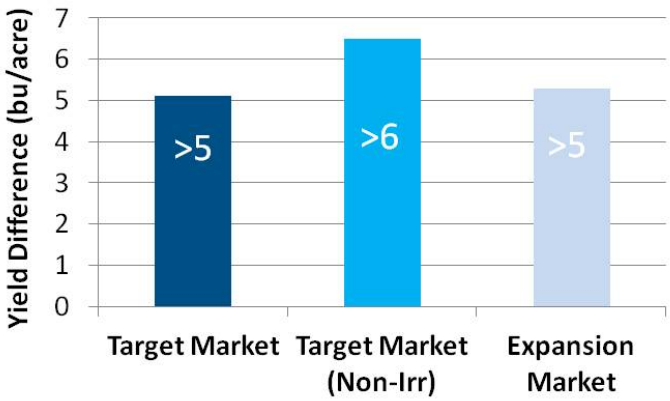


Figure 2. DroughtGard® Hybrids corn products average yield advantage versus drought competitors. Data from 2014 Technology Development yield trials. Target market = the western Great Plains states. Expansion market = central Midwestern states.

Monsanto research trials conducted in Colorado and Nebraska from 2014 through 2016 evaluated the water use differences between DroughtGard Hybrids corn products and competitor corn products with and without water-saving genetics. Results of these trials showed that DroughtGard Hybrids corn products used less water than competitor products resulting in an average of 7% water savings. DroughtGard Hybrids corn products provided a total water savings of 1.8 inches over Pioneer® brand AQUAmax® products and 2.5 inches over Pioneer brand products without AQUAmax (Figure 3).

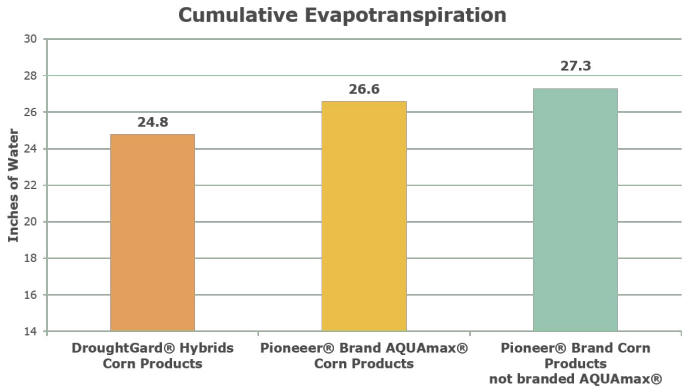


Figure 3. Cumulative evapotranspiration of DroughtGard® Hybrids corn products vs. competitor corn products with and without water-saving genetics. DroughtGard Hybrids corn products used less water than competitor products. Source: DroughtGard Hybrids Crop Water Use. 2016 Learning Center Summary.

DroughtGard Hybrids products can give farmers more value from their seed investment including the opportunity to help mitigate risk with drought protection and greater yield potential in dorught conditions. DroughtGard Hybrids products can provide farmers with peace of mind during both optimal and challenging growing seasons because these products can protect yield potential during times of drought and maintain top-end yield potential in the absence of drought.

### Sources

[1] Campos, H., Cooper, M., Edmeades, G.O., Loffler, C., Schussler, J.R., and Ibanez, M. 2006. Changes in drought tolerance in maize associated with fifty years of breeding for yield in the U.S. corn belt. Maydica. vol. 51(2). 369-381.

[2] Nemali, K.S. et al. 2015. Physiological responses related to increased grain yield under drought in the first biotechnology-derived drought tolerant maize. Plant Cell Environ. vol. 38(9). 1866-1880.

Other sources: Waltz, E. 2014. Beating the heat. Nature Biotechnology. vol. 32. 610-613. DroughtGard Hybrids Crop Water Use. 2016 Learning Center Summary. Technology Development and Agronomy. 150715110953

For additional agronomic information, please contact your local seed representative. Developed in partnership with Technology Development & Agronomy by Monsanto.

**IMPORTANT IRM INFORMATION:** RIB Complete® corn blend products do not require the planting of a structured refuge except in the Cotton-Growing Area where corn earworm is a significant pest. SmartStax® RIB Complete® corn blend is not allowed to be sold for planting in the Cotton-Growing Area. See the IRM/Grower Guide for additional information. Always read and follow IRM requirements.

**Individual results may vary,** and performance may vary from location to location and from year to year. This result may not be an indicator of results you may obtain as local growing, soil and weather conditions may vary. Growers should evaluate data from multiple locations and years whenever possible. Always read and follow IRM, where applicable, grain marketing and all other stewardship practices and pesticide label directions. DroughtGard®, RIB Complete® and SmartStax® are registered trademarks of Monsanto Technology LLC. All other trademarks are the property of their respective owners.  150715110953 050917CAM