

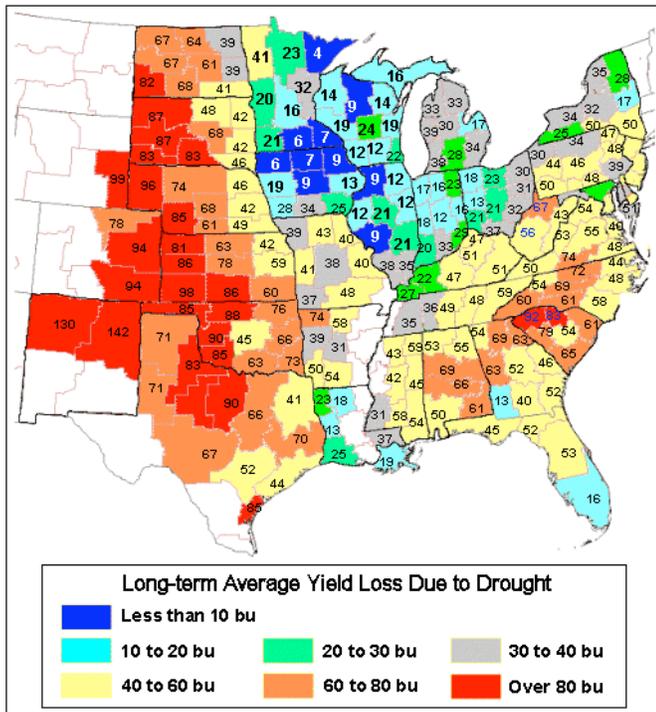
Corn Fields Impacted by Late-Season Drought

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Introduction

Drought stress is responsible for more lost bushels of corn yield than any other cause, costing farmers in the US more than three billion dollars annually. Among the corn-growing states of the Midwest, severe drought conditions are most common in the Great Plains states from Texas to North Dakota, but all states have some drought-stressed areas nearly every year. In fact, every corn field is likely to experience some limitation of available soil moisture during the growing season that reduces yield, even when corn yield approaches 200 bushels per acre.

Because of the impact of drought on corn yields, developing hybrids with drought tolerance has been a primary goal of Pioneer corn breeders for decades. To accomplish this goal, researchers have selected for native corn genes that confer drought tolerance by testing breeding populations, parent lines and hybrids in environments that normally experience moderate to high levels of drought. Although this has resulted in significant hybrid improvement, Pioneer researchers are now employing new technology tools that promise to increase both the rate and consistency of drought tolerance improvements.



Types of Drought Stress

When drought conditions develop in the non-irrigated Midwest, it is usually during August grain fill. This occurs as available soil moisture is progressively depleted from the root zone due to high summer temperatures and insufficient rainfall. In the semi-arid Great Plains, moisture limitations are also most common during grain fill, but are diminished by irrigation where available. For dryland corn in this region, however, drought conditions can also occur at other growth stages including pollination and sometimes even vegetative growth. Pioneer researchers are focusing on drought stress at pollination and drought stress during grain fill as their primary targets for development of drought tolerance traits.

Water demands by the plant are high during pollination, especially for silk elongation, pollen germination, and pollen tube growth. Under drought conditions, silk emergence may be delayed compared to pollen shed. If this delay is several days, pollen may be limited when silks emerge, resulting in incomplete pollination and reduced kernel number. Because the last silks to appear come from the tip of the ear, barren or poorly filled ear tips can result. Drought and high temperatures can also lead to desiccation of silks, causing poor pollen germination and pollen tube growth. This may also result in reduced kernel number.

In addition to disrupting pollination, drought during the early reproductive period can result in kernel abortion. The tip kernels, the youngest and most distant from the source, are most susceptible to abortion. Kernels are most susceptible during the first two weeks following pollination. Because of the critical relationship between available moisture and successful pollination and early kernel development, yield losses may be as high as six bushels per acre per day when severe drought occurs during this period.

Drought stress during the dough and dent stages of grain fill decreases grain yield primarily due to decreased kernel size, rather than decreased kernel number. Drought reduces the rate of photosynthesis in the plant, resulting in less assimilate production. Drought may also cause premature black layer formation in the kernels, terminating starch deposition. If drought is so severe that leaf or plant death results, yield will be significantly reduced. Finally, drought often results in stalk rot development, which can reduce harvestable yield. Researchers estimate that drought stress during the grain fill stages of development can cause yield losses of up to three bushels per acre per day.

Drought stress at pollination

- Kernel number is being determined
- Yield loss potential = six bushels/acre per day

Drought stress during grain fill

- Kernel size is being determined
- Yield loss potential = three bushels/acre per day

Selecting Hybrids for Drought Tolerance

Because drought is the major stress affecting most corn acres every year, growers should select hybrids with drought tolerance for all fields that commonly face this problem. These products must also provide competitive performance if adequate or excellent soil moisture conditions develop. To help customers identify such products, Pioneer provides drought tolerance ratings for all its hybrids, as well as yield information from diverse environments.

Below is an explanation of plant traits that contribute to drought tolerance, how drought ratings are assigned to Pioneer hybrids, and how these ratings can be used to help choose appropriate products for the drought risk faced in each field.

Drought Tolerance Characteristics in Hybrids

Hybrid characteristics that contribute to drought tolerance are complex and may not be readily apparent. For example, corn leaf rolling is often considered to be a drought tolerance mechanism to reduce moisture loss. But if a hybrid has rolled leaves when hybrids beside it do not, it is not clear if that hybrid has better drought tolerance or is showing drought stress sooner than other hybrids. Because of this uncertainty, the best indicator of drought tolerance is corn grain yield under moisture stress. Known hybrid traits that contribute to drought tolerance include a well-structured root system, insect and disease resistance traits, strong silking characteristics and yield stability across diverse environments.

Root System: A drought tolerant hybrid must have a root system that efficiently accesses all available moisture in the soil. A broad and shallow root structure may not provide adequate drought protection to the plant even though it may support the plant against lodging. A root system that penetrates deeply into the soil is preferred for reaching soil moisture as drought develops. Root systems must also be healthy to impart drought tolerance. If they are impaired by insects, diseases, or physical conditions such as compaction or cultivator pruning, the plant will be more vulnerable to drought.

- **Insects:** Corn roots can be attacked by soil insects from germination through grain development. Seedlings may be attacked by white grubs, wireworms, grape colaspis larvae and corn nematodes.



Severe drought stress during pollination and grain fill can greatly reduce yields of susceptible hybrids. This shows the importance of selecting drought-tolerant hybrids.

A fast-growing plant and root system is the best genetic defense against these early feeders. In addition, Pioneer's standard seed treatment contains a mid-rate insecticide to help protect against several secondary soil insects.

The insect most damaging to corn roots by far is corn rootworm. Pioneer® brand hybrids with the Herculex® RW (HXRW) or Herculex XTRA (HXX) traits offer the best protection available against northern, western and Mexican corn rootworm larvae. Under drought conditions, the value of in-plant genetic root protection is magnified, and consistently more effective than chemical control.

Data from drought stressed regions in 2005 and 2006 repeatedly confirmed the value of transgenic CRW control for protecting yield under drought. For this reason, the HXRW and HXX traits can be accurately classified as drought tolerance traits. (For refuge acres, Poncho 1250 insecticide seed treatment is available on Pioneer seed as an option to help protect against corn rootworm.)

- **Diseases:** Seedling diseases can reduce root systems and drought tolerance of hybrids. Pioneer hybrids rated highly for stress emergence have the ability to establish good stand characteristics under cool soil conditions and are less affected by common seedling diseases. In addition, Pioneer offers a combination of Dynasty® and Maxim® XL fungicides plus a mid-rate insecticide as the standard seed treatment on all Pioneer corn hybrids. This seed treatment combination helps protect against seedling diseases like Pythium and several secondary soil insects that open the door to diseases by feeding on roots.

Silking: Drought stress in June and July often delays corn reproductive development. Under this stress, some hybrids delay silk emergence much more than pollen shed. When silk emergence is delayed several days, pollen shed may be mostly complete before silks finally emerge. This can result in poor pollination and dramatically reduced yield. Hybrids

with strong silking characteristics under drought exhibit less yield loss by maintaining synchronization of pollen shed and silking during this critical period.

Yield Stability: Hybrids with proven yield stability across environments usually tolerate a variety of stresses, including drought. When selecting hybrids, growers should examine data from various environments, including fields that are lower yielding due to drought, to identify those that perform well under diverse conditions.

Other Considerations: Drought tolerant hybrids can adjust their plant growth to reduce excess vegetation that wastes water. Many other plant traits can contribute to drought tolerance in the plant, but because of complex interactions between these traits, they have not provided reliable predictions of drought tolerance. For that reason, growers should not depend on these secondary traits when selecting products for drought environments. Rather, they should focus on the drought ratings provided for all Pioneer corn hybrids for that express purpose -- helping growers select drought-tolerant products.

Pioneer Drought Rating Scale

The Pioneer scale for drought ratings is from 9 = best to 1 = worst. But because “9” is being reserved for future “drought trait” products, and hybrids rating “3” and below are discarded during testing, commercial Pioneer hybrids have drought ratings of “8” to “4”. These ratings are described in detail in the sidebar on the next page. It is important to remember that ratings are relative and that hybrid performance can vary depending on the timing, duration and severity of moisture stress during the growing season.

Improving Drought Tolerance

The level of drought tolerance achieved in today’s best hybrids stands in stark contrast to that of hybrids of just 20 years ago, which often protected only half of the average low-stress yields under drought. Many corn growers and researchers have estimated that if today’s hybrids had been grown during the drought of 1988, corn yields could have easily been double what they were that season. This estimate is based on more recent hybrid performance measures under drought stress such as the 2005 drought in central and northern Illinois. Although 2005 drought stress levels in that area were similar to those of 1988, yields of over 100 bu/acre were common in 2005.

With continued progress in improving hybrid drought tolerance, the next 20 years may result in even more impressive gains. Corn plants will never be able to tolerate totally arid conditions and produce grain, but the ability to withstand significant periods of moisture stress can be improved. All growers, regardless of the yield level of their fields, stand to benefit from hybrid improvements and new

Pioneer Drought Rating Descriptions

In Pioneer testing under a range of drought stress conditions from moderate to severe:

- Corn hybrids with a rating of "8" performed among the best hybrids tested and compared favorably to Pioneer’s best established hybrids for drought tolerance. These hybrids are an excellent choice for fields that **regularly** experience drought stress due to soil type, topography and/or prevailing weather patterns.

Although hybrids rated an "8" represent the best choices available for fields with the **most severe** risk of drought, it may not always be advisable to grow corn in those fields. Because moisture stress usually limits all corn yields to some degree, these hybrids may also be the best choice for low or moderate drought risk *.

- Hybrids with a rating of "7" had very good performance under Pioneer’s drought testing system, but yields were reduced more than those of the top-tier hybrids. These hybrids are a good choice for fields that regularly experience yield-limiting drought stress, except in fields with usual extreme drought conditions that may result in crop failure.
 - Hybrids with a rating of "6" had good performance under Pioneer drought testing. These hybrids showed more visual effects of drought stress than hybrids rated higher, in addition to greater yield reductions. Hybrids rated a “6” are a good choice for fields that usually experience only low or moderate drought stress with little risk of severe drought.
 - Hybrids with a rating of "5" had only average performance in drought-stress locations. Visual effects of moisture stress were very evident compared to hybrids rated higher, and yield reductions under drought were significant compared to yields in low-stress environments. These hybrids are expected to perform best in fields with high water-holding capacity that usually receive timely rainfall, as well as in irrigated fields.
 - Hybrids with a rating of "4" only approached their yield potential in low-stress environments. Visual symptoms were often noticeable under moderate stress and significant under severe stress. Yield losses under severe stress sometimes approached 50%. These hybrids should be reserved for fields where irrigation or natural rainfall and soil water-holding capacity are adequate to maintain good soil moisture availability throughout the season.
- * Other hybrid traits should always be considered in selecting a product, regardless of the drought rating of the hybrid or the drought risk in your field. Your Pioneer sales professional can assist you in selecting appropriate hybrids for your fields.

technologies that will protect the yield potential bred into their hybrids.

Today's best drought-tolerant hybrids developed through conventional breeding often yield within 75 to 80% of their average low-stress yields under drought stress. Adding a specific "drought trait" to corn hybrids is expected to protect yields above and beyond that provided by the best conventional hybrids. In fact, researchers believe that targeted drought traits currently in testing may increase corn hybrid yields even under low moisture stress conditions, as well as providing more protection under drought stress. Yield gains of 10% over current top hybrids are within expectations for drought traits in testing today. Future drought traits could increase yields even more.

Fall Management of Drought-Stressed Corn

If corn fields have been severely stressed by drought and yields are significantly reduced, growers should be aware of plant development issues that could further decrease yields. This includes the potential for stalk lodging, ear droppage, and excess ear or kernel losses at the corn head during harvest.

Stalk lodging: Drought stress reduces photosynthetic rates due to direct effects on water relations and CO₂ and O₂ exchange within the corn plant. In addition, leaf rolling due to drought reduces the effective leaf surface for collection of sunlight. When photosynthesis is unable to supply the demands of the developing kernels, the plant redirects root and stalk carbohydrates to the ear. Stalk rot organisms can then invade weakened and dying plant tissues.

Ear droppage: Plants naturally shed leaves, flowers and fruits in response to internal plant signals triggered by maturity development and/or environmental stresses. The process of shedding these plant organs, known as abscission, is controlled by the plant hormone abscisic acid and ethylene. As ethylene builds up, it triggers the ripening process and a progressive weakening of cell membranes in the abscission zone, resulting in detachment. Under hot, dry conditions stressed corn plants produce higher amounts of abscisic acid to signal the closure of stomata and reduce water vapor losses. This may also increase production of ethylene and premature ear drop.

Monitoring drought-stressed fields: Careful scouting and harvesting fields according to crop condition can help prevent field losses due to low stalk quality or poor ear attachment. Weak stalks can be detected by pinching the stalk at the first or second elongated internode above the ground or pushing the plant sideways at ear level. If the stalk collapses, advanced stages of stalk rot are indicated. Check 20 plants in five areas of the field. If more than 10 to 15% of the stalks are rotted, that field should be considered for early harvest.

To mimic the effect of fall winds and storms on ear drop, grasp the corn stalk below the point of ear attachment and shake (moderately). Dropped ears represent direct yield loss. If more than 1 to 2% of plants show potential for premature ear drop, continually monitor that field and harvest in a timely manner.

Combine considerations: Drought-stressed ears are usually narrower and may be subject to losses at the corn head. To reduce these losses, the snapping bars (stripper plates) should be adjusted narrower to account for the smaller ears. Proper adjustment will not only prevent the ears from being pulled through the snapping rolls with the stalk, but will also prevent the butt of the ear from contacting the rolls, where shelling losses would occur. Fan speed adjustments may also be needed to prevent lighter kernels from being blown out the back of the combine.

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