Physiological Basis of Corn Response to Drought Stress and Nitrogen Supply

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Corn (*Zea mays* L.) is grown on about 30% of U.S. cropland (USDA-NASS, 2014). The U.S. Corn Belt is highly productive, but a significant portion of the corn in this region regularly experiences drought stress. New drought-tolerant corn hybrids could reduce the risk of yield loss when drought occurs. However, grain yield did not differ between drought-tolerant and non-drought-tolerant corn hybrids under intense drought and heat stress in Indiana in 2012 (Roth et al., 2013). Another study found that grain yield of drought-tolerant hybrids was greater than that of non-drought-tolerant hybrids only under moderate drought stress (Wesley, 2012).

Corn grain yield is dependent on dry matter accumulation and harvest index, which are influenced by morpho-physiological attributes such as leaf area, chlorophyll content, the rate and duration of photosynthesis, time of flowering, dry matter partitioning during silking, and leaf stay green (Tollenaar and Lee, 2006). Water utilization also affects grain yield in corn. Water use in corn is greatest during the late vegetative through early grain filling stages (Kranz et al., 2008), and reductions in corn grain yield due to drought stress are most severe when drought occurs during pollination and early grain fill (Bruce et al., 2002; Cakir, 2004). Drought stress during these stages predominately reduces grain yield through reductions in kernel number.

Water and nutrient availability influence root system architecture and development (Dwyer et al., 1988; Lynch, 2013). With moderate drought stress during corn vegetative stages, rooting depth typically increases, allowing more efficient uptake of water and nutrients from deeper within the soil profile (Robertson et al., 1980). However, corn root growth under moderate drought stress during the vegetative stages had been shown to differ among hybrids with contrasting root morphology (Eghball and Maranville, 1993).

In order to address the physiological basis of corn response to drought stress and nitrogen (N) supply, a drought-tolerant corn hybrid and a non-drought-tolerant corn hybrid were evaluated in three field experiments conducted on a Hubbard-Mosford loamy sand complex (sandy, mixed, frigid Entic Hapludolls and sandy, mixed, frigid Typic Hapludolls) in 2013 at the University of Minnesota Sand Plain Research Farm in Becker, MN. Each experiment followed a different previous crop in order to create differences in soil N supply potential: alfalfa (*Medicago sativa* L.), soybean (*Glycine max* (L.) Merr.), and winter rye (*Secale cereale* L.). A split-plot arrangement in a randomized complete block with four replications was used for each experiment. Main plots were three durations of sustained moderate drought stress, defined as corn leaf rolling beginning around mid-day on each day except on days after irrigation: none, from the V14, 14-leaf-collar corn developmental stage (12 days before silking) until maturity (R6), and from the R2, blister corn developmental stage (12 days after silking) until maturity (R6). Sustained moderate drought stress was achieved through a combination of coarse-textured soils, limited rainfall, weekly measurements of volumetric soil water content, estimates of crop water use, and managed drip irrigation. Split plots were a factorial arrangement of two corn hybrids and three fertilizer N rates: sub-optimal (50% below optimal), optimal, and supra-optimal (50% above optimal).

The objectives of this study were to: 1) compare the agronomic performance of drought-tolerant and non-drought-tolerant corn hybrids; 2) identify the morpho-physiological characteristics that influence agronomic performance; and 3) estimate water use efficiency (WUE) relative to grain yield, aboveground biomass, and photosynthetic rate. The hypothesis
for the first objective is that grain yield of the drought-tolerant hybrid is greater than that of the non-drought-tolerant hybrid under moderate drought stress, and that reduced grain yield caused by drought is exacerbated by N deficiency. Agronomic components such as grain yield and grain yield components, harvest index, and N uptake will be used to compare hybrids and their response to previous crop, the duration of drought stress, and fertilizer N supply.

The hypothesis for the second objective is that duration of moderate drought stress and the level of N supply influence morpho-physiological characteristics of the corn hybrids. Numerous in-season morpho-physiological characteristics were measured, including plant height, anthesis-silking interval, leaf area index, leaf chlorophyll content, leaf temperature, photosynthesis, transpiration, leaf stay green, and root length density. These data will be analyzed to determine the morpho-physiological attributes that influence grain yield.

It is also hypothesized that WUE of the drought-tolerant hybrid is greater than that of the non-drought-tolerant hybrid under moderate drought stress. Measurements of weekly volumetric soil water content, total dry matter at maturity, photosynthesis, transpiration, and daily evapotranspiration will be used to determine WUE relative to grain yield, aboveground biomass, and photosynthesis.

Grain yield was greater for the drought-tolerant corn hybrid when there was sustained moderate drought stress from the 14-leaf collar developmental stage until maturity. However, there was no difference in grain yield between the two hybrids in the absence of drought stress or when there was moderate sustained drought stress from the blister developmental stage until maturity. The drought-tolerant hybrid had greater grain yield than the non-drought-tolerant hybrid with the supra-optimal fertilizer N rate but not with the optimal or sub-optimal fertilizer N rates, indicating a higher N requirement for the drought-tolerant hybrid. Grain yield was lowest with the sub-optimal fertilizer N rate for all durations of drought stress, but the difference in grain yield between the sub-optimal and supra-optimal fertilizer N rates was greatest when there was no drought stress. These results demonstrate that drought-tolerant corn hybrids have the potential to tolerate sustained moderate drought stress better than non-drought-tolerant hybrids, especially when the drought stress occurs during silking. Further data analyses will be conducted to answer the remaining objectives of this study.

References


