THE HOW OF GREAT CORN YIELDS IN A DROUGHT YEAR

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The 2005 crop season was drier than usual: by April 19 the federal drought monitoring office marked the NE corner of the state as "Abnormally Dry," and by July 26 they mapped "Extreme" drought in the SE corner, "Severe" all along the eastern one-third of the state, and "Moderate" everywhere else (wwww.drought.unl.edu/dm/archives). Corn leaves were tightly curled across much of the state by mid-July; rainfall for the April-August period at the Arlington Agricultural Experiment Station was the third lowest (between 1989 and 1988; 1962 is the record low) in the 44 years of record there.

Yet remarkably the official USDA statewide average yield is predicted to be a new record, at 150 bu/acre, a nearly 5% increase over the previous record set in 1999. UWEX Corn Agronomist Joe Lauer (Lauer, 2005) reports that at 10 of 12 sites of the UW hybrid corn performance trials yields were solidly above the 10-year average, most by more than 10%. It was indeed a year in which the corn crop "pulled it off," delivering across much of the state great yields, inspite of what was officially a drought year. I share here some "back-of-the-envelope" calculations to show that this remarkable performance is understandable (at least in retrospect).

Grain yield depends on proper development of specific plant parts and the capture of sunlight, CO_2, mineral nutrients, and water. The development steps, like formation of ovules, tassel emergence, silking, and pollination, are to various degrees sensitive to environmental stress, but must have occurred successfully in fields that yielded well. There was widespread rainfall between July 21 and 25, probably just in the nick of time to allow pollination to occur in many fields. Subsequently concern turns toward resource capture, and here we consider sunlight and water.

Does it seem possible that resource capture following the late-July rains was sufficient to support the average yield at Arlington in the UW trials (227 bu/acre)? First, consider solar radiation. The amount of leaf area in a crop's canopy is often expressed as the "leaf area index" (LAI), which is the area of all the leaves, spread horizontally, above a given area of land. So if all of the leaves in a square yard of crop were cut and spread over the same land area, the number of times the land area could be covered is the LAI. For corn crops LAI can reach 8 (Figure 1). The role of this leaf area is, of course, to intercept and absorb solar radiation, thereby powering photosynthesis. Much research has shown that an LAI of 3.5 or 4 will effective absorb 90% or more of the incident photosynthetically-active radiation (PAR), so most crops typically have lots more leaves than are necessary from this perspective.

During the 40 days starting with August 1, some 425 MJ (megaJoules) of PAR fell on each m^2 around Arlington. The crop was certaintly in suffering water stress by mid-July, but in many areas growth until then had been reasonable. If by the time that the worst stress set in the crop had managed to grow to a LAI approaching 4, it would have been capable of absorbing almost all incident PAR after the late July rainfall permitted the leaves to unfurl. With corrections for incomplete absorption the crop could have captured about 370 MJ/m^2 during the 40 days following 1 August. The "radiation use efficiency" of corn, defined as the amount of biomass created per unit of PAR absorbed, is typically estimated to be about 3.7 g/MJ (Longquist et al. 2005), so the 370 MJ/m^2 absorbed could yield 1.37 kg/m2, which in terms of new biomass is equivalent to 242 bu/acre. Perhaps 10% of this photosynthesis went to grow the cob, though, so the equivalent corn grain growth is about 218, just 4% short of the 227 bu/acre observed yield.

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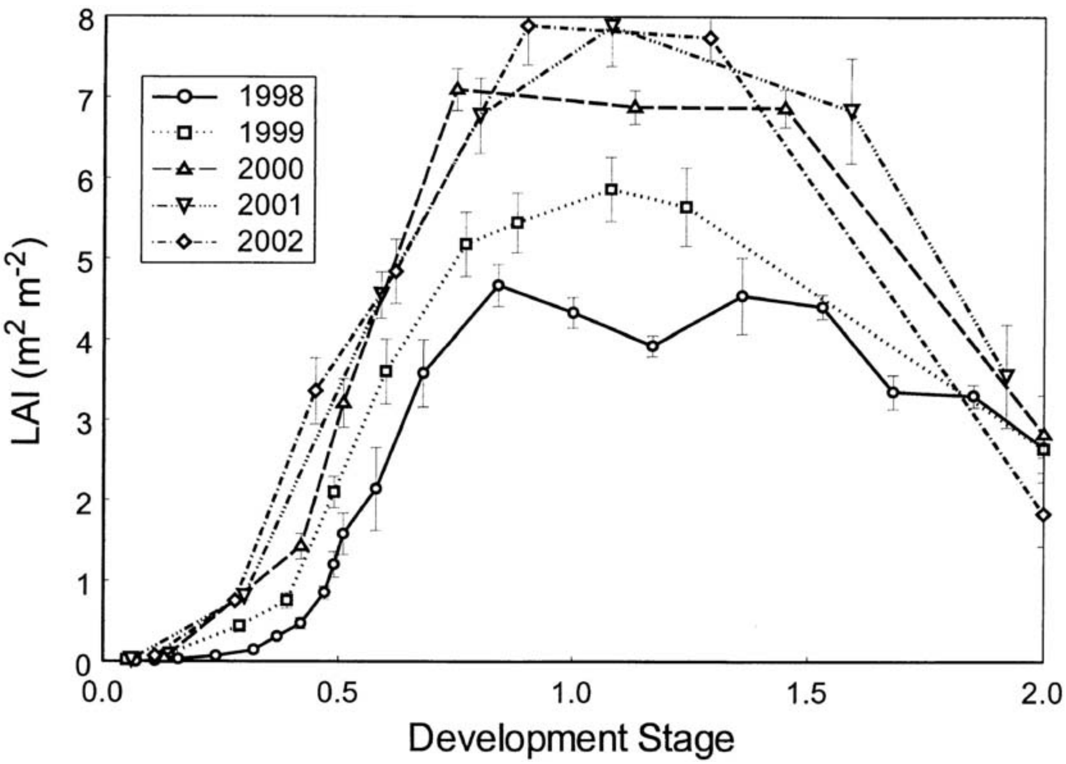

Figure 1. Development of LAI through several seasons in Nebraska (Lindquist et al. 2005)

The other resource we consider here is water. A crop growing under conditions of adequate soil moisture will extract soil water to meet the potential evapotranspiration demand imposed by the environment. In Wisconsin (and lots of other places) this can be estimated using the Priestley-Taylor equation, and values observed in 2005 were typical (Figure 2).

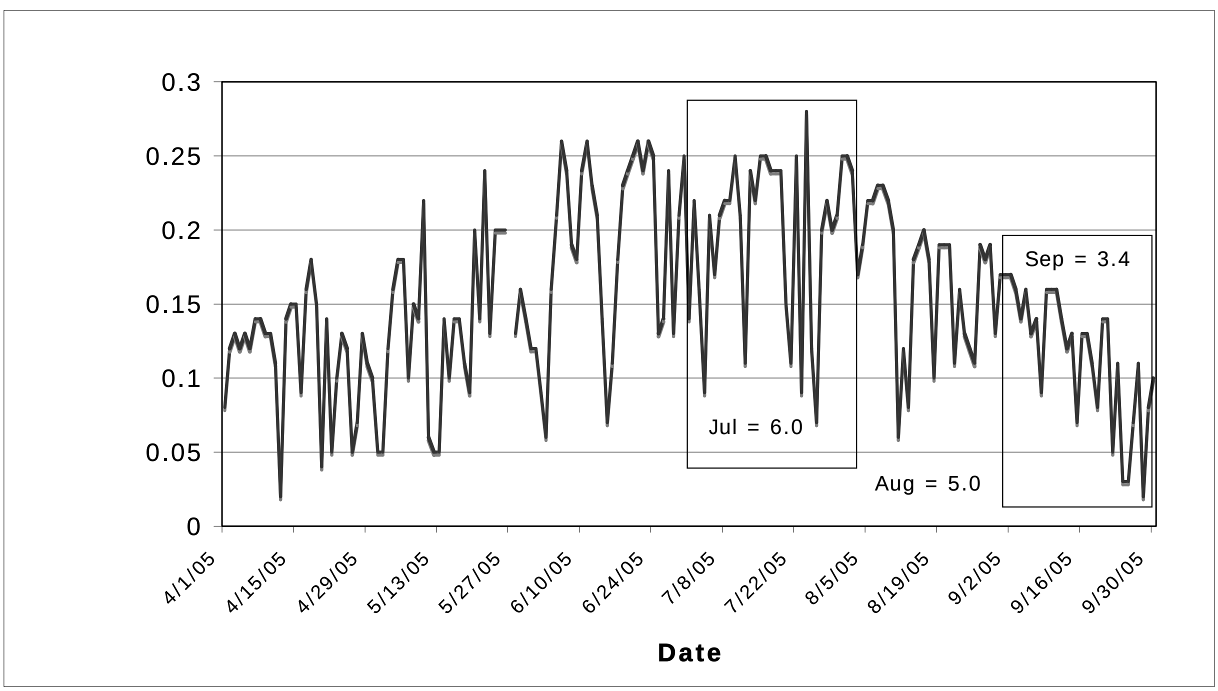

Figure 2. Estimated potential evapotranspiration at Arlington, WI, for 2005

The water demand placed on the corn crop during August and early September was about 6 inches (Figure 2). If the soil could provide this much water the corn could keep its stomates open and maintain photosynthesis. Rainfall at Arlington from late July through the end of August was approximately this (Figure 3; 13-6=7”).

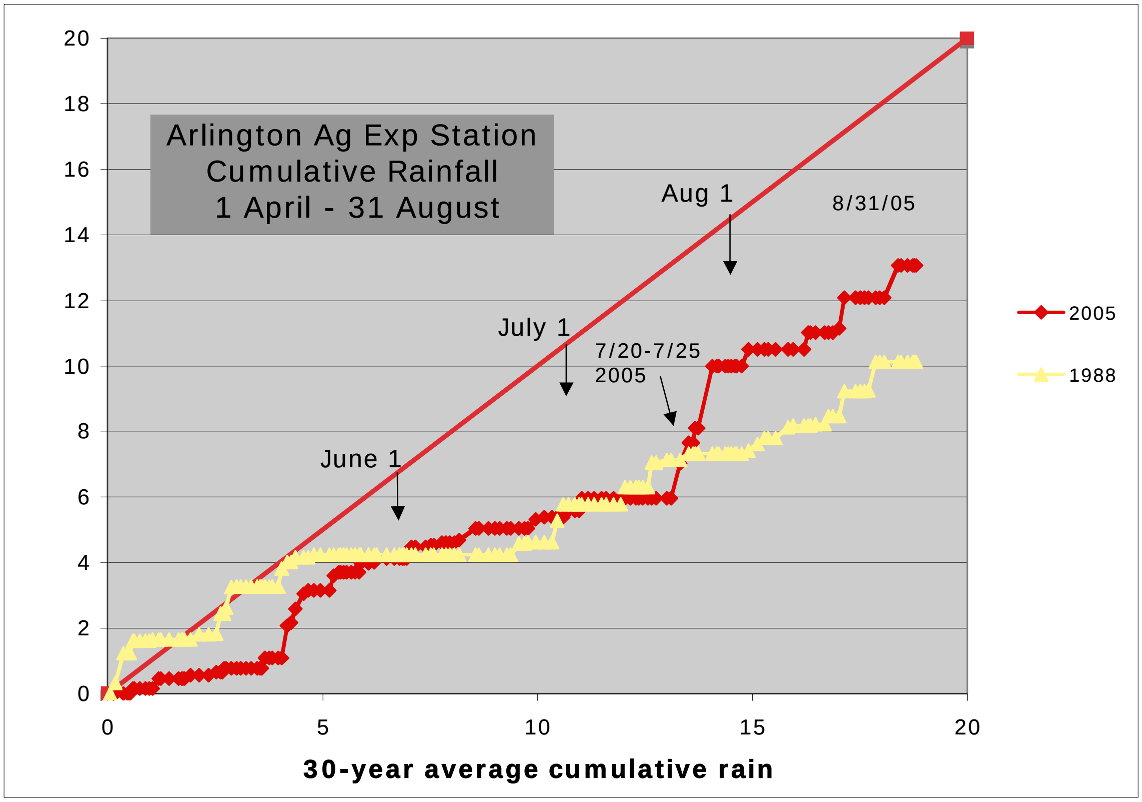

Figure 3. Cumulative rainfall during April-August at Arlington. If a particular year’s rainfall equals the 30-year average the points would follow along the 45-degree diagonal. Data from 2005 and 1988 are compared to the average, and both years had below-normal rainfall during this period.

The approximately 4-inch rainfall at the end of July fell on very dry soil, and likely flowed deeply into the cracked soil through macropores. The relatively dry season had encouraged deep root development, so this rainfall was accessible to the crop, but largely protected from evaporation directly from the soil surface.

The remarkable recovery from drought conditions of much of the 2005 corn crop in Wisconsin is testimony to the tremendous adaptability of this plant. If we assume that LAI had reached 4 or so by mid-July, we showed that there was adequate photosynthetically-active radiation and soil water for the crop to growth the observed yield.

References

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