Management of Corn Under Limited Irrigation or Rainfall

Because irrigated corn yields are almost 30% higher than non-irrigated yields, irrigated corn accounts for nearly 20% of total U.S. corn production while occupying only 15% of acres (USDA, 2007). This illustrates the importance of irrigation to U.S. corn production. Much of the irrigated corn is cultivated in the semiarid Great Plains region of the U.S., with corn occupying more irrigated acres in this area than any other crop. However, recent concerns have been raised regarding declining surface and ground-water supplies and increased pumping costs in this region. For this reason, improving management practices under declining water supplies is critical for sustaining irrigation water resources. This article highlights irrigation practices and other agronomic management strategies to help maximize grain produced for each increment of limited irrigation water applied.

Soil – Plant – Atmosphere Relationships

Knowledge of the associations between plants and their environment is vital to developing successful irrigation manage-ment strategies (Kranz et al, 2008). Soil characteristics important to irrigation management include water holding capacity, infiltration rate, and presence of soil layers that might restrict water movement and/or root penetration. Plant features include crop development, rooting depth, and daily and total seasonal crop water use. Atmospheric factors are solar radiation, air temperature, relative humidity, and wind. Total available seasonal water supply is also important.

Figure 1. Precision nozzles increase irrigation efficiency under limited water supply. Photo courtesy of G.W. Buchleiter, www.Bugwood.org.

Corn Water Use

Water is acquired, used and lost in a corn production system through the process of evapotranspiration (ET). In this process, water is removed directly from the soil surface to the atmosphere by evaporation and through the plant by transpiration. Plant transpiration is evaporation of water from leaf and other plant surfaces. For corn, evaporation often accounts for 20 to 30% and transpiration 70 to 80% of total ET over the course of a growing season (Kranz et al. 2008).

Transpiration involves a continuous flow of water from the soil profile into the plant roots, through plant stems and leaves, and into the atmosphere. This serves to cool the crop canopy and prevent leaf tissues from reaching lethal temperatures. Additionally, water from transpiration provides positive pressure inside cells that gives plants much of their structure and ability to stand. Finally, the transpiration stream carries water-soluble nutrients like nitrate and potassium from the soil into the plant, providing essential nourishment for plant growth.

Both evaporation and transpiration are driven by a tremendous drying force the atmosphere exerts on soil or plant surfaces. Hence the magnitude of daily ET will vary with atmospheric conditions. For example, high solar radiation and air temperatures, low humidity, clear skies and high wind increase ET, while cloudy, cool and calm days reduce ET. Seasonal water use is also affected by growth stage, length of growing season, soil fertility, water availability and the interaction of these factors. Although the amount of daily water use by the crop will vary from season to season and location to location, it will generally follow the pattern shown in Figure 2.

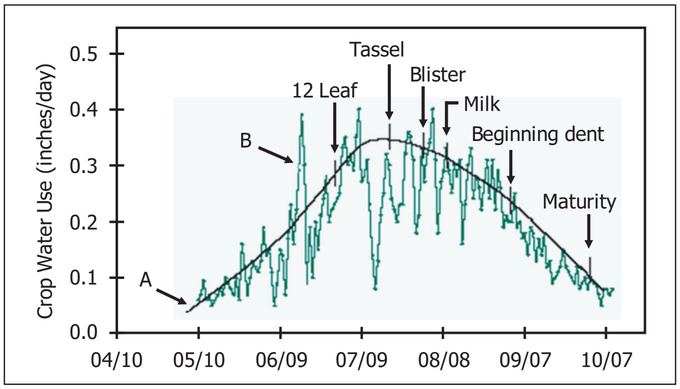

Figure 2. Long-term daily average (black line) and individual year (green line) corn water use by growth stage as per Kranz et al. (2008).

Reported seasonal corn ET averages around 24 inches in the humid eastern area of Nebraska compared to 28 inches for the more semi-arid southwestern region of the state (Kranz et al., 2008). This illustrates the significant effect of atmospheric conditions on crop water use.

What is Limited Irrigation?

Limited irrigation results when water supplies are restricted so that full ET demands cannot be met (Schneekloth et al., 2009). Reasons for limited water supplies include:

1) Restricted capacity of the irrigation well due to limited depth of saturated aquifer.

2) Restricted pumping allocations in regions experiencing declining groundwater levels.

3) Reduced surface irrigation water supplies due to droughts or water transfers in regions that rely solely on surface water for irrigation.

When water supplies cannot fully compensate for crop ET, yields are reduced versus fully irrigated corn. To maximize yields and economic returns under limited water supplies growers must understand how corn responds to water, and how changes in irrigation and agronomic practices can influence water needs. Many of these principles come from dryland water conservation practices and include the relationship between grain yield and water use as affected by growth stage, irrigation timing, crop residue, and hybrid and plant population selected (Schneekloth et al., 2009).

Corn Yield Response to Water

Under water-limited conditions, corn yields typically display a positive association with total seasonal water use. For example, Grassini et al. (2009) found that the linear relation-hip between potential grain yield and seasonal ET displayed in Figure 3 was valid across a wide range of grower fields and climatic conditions located in south-central Nebraska.

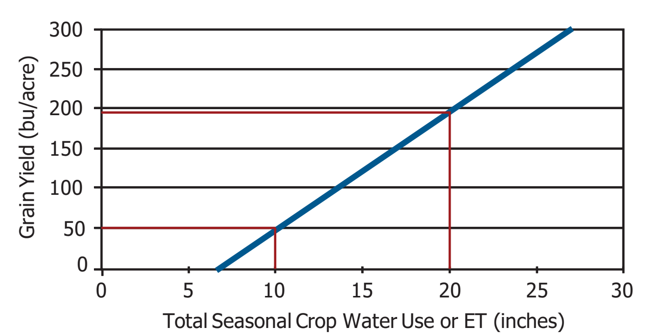

Figure 3. Relationship between grain yield and total seasonal crop water use or evapotranspiration (ET) taken from Grassini et al (2009).

It should be noted that water stress during critical reproductive growth stages can result in significantly lower potential yields than those shown in Figure 3. Nonetheless, this relationship can serve as a general guideline to growers, and be useful for estimating potential corn yield levels at a given level of available seasonal water supply. For example, with around 20 inches of available water (including stored soil water, estimated seasonal precipitation, and irrigation), potential yield levels should average around 200 bu/acre. Conversely, with only 10 inches of available water, yields would be expected to be around 50 bu/acre. Growers can use knowledge of potential yield levels in making agronomic management decisions regarding hybrid selection, plant population and fertilizer rate.

Impact of Water Stress

The impact of water stress on corn grain yields varies with crop growth stage (Figure 4). Corn is very sensitive to water stress from flowering though grain fill, but is relatively insensitive to water deficits during early vegetative growth. This is because water demand is relatively low and plants can adapt effectively, reducing impacts on grain yield. For this reason, judiciously delaying the first irrigation may offer an opportunity to conserve water and maintain profitability.

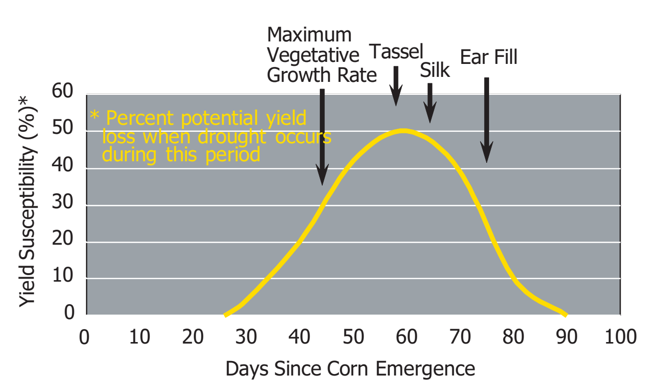

Figure 4. Yield susceptibility to water stress for corn as published by Sudar et al. (1981).

Irrigation Management Practices

In regions with limited water supply, irrigation management is critical to maximizing the efficiency of water inputs. Corn yields respond in a linear fashion to increasing ET up until full seasonal ET requirements have been met (Figure 3). Applying additional irrigation beyond seasonal ET requirements results in diminishing returns on water and does not increase grain yield as much as the previous inch of irrigation. This can lead to leaching and/or water left in the soil (Grassini et al., 2009). This emphasizes the importance of sound irrigation scheduling principles to avoid inefficient use of scarce water resources.

Irrigation Timing – When water allocation cannot meet full crop ET, water should be saved for the reproductive stages where it will have the most impact (Figure 4). For example, research in western Kansas showed that growers can safely delay the first irrigation longer into the season when soil water reserves at planting are ample and irrigation system capacities are sufficient to avoid soil water deficits through the critical flowering stages and beyond (Doerge, 2008). Fields with limited well capacity (<0.25 inches/day) and very low winter soil water recharge should begin irrigation at the V4 to V6 stages. In no cases should the first irrigation be delayed until after the tasseling stage. Sandy soils will also require irrigation earlier in the season if precipitation is low.

Pre-Irrigation – In extremely dry years pre-irrigation may be needed to refill the soil profile. However, the storage efficiency of non-growing season precipitation is reduced as fall available soil water content approaches field capacity (Lamm and Rogers, 1985). Hence, delaying the decision to pre-irrigate until spring can allow growers to take advantage of fall and winter precipitation, should it occur.