EVAPOTRANSPIRATION AND CROP COEFFICIENTS FOR MIDSOUTH SOYBEANS

Irrigating crops is or should be a scientific endeavor. Gone are the days when producers can afford to just "water" crops without regard for how much water they are using or how much they may be wasting by unnecessary irrigation or overwatering without regard to the plant's need.

Midsouth soybean producers are cognizant of conserving their major source of irrigation water, the Mississippi River Valley Alluvial Aquifer (MRVAA). Producers are increasingly using soil moisture sensors to schedule irrigations and Pipe Planner to properly meter surface-applied water through polypipe onto each field according to its shape. Some are even using surge valves in an attempt to furrow irrigate more efficiently. Using these tools is a necessary and vital first step to more efficient surface irrigation. However, there are other tools that producers can use to become even more efficient irrigators.

Many of the terms used in this narrative are referred to by their abbreviations. These are given here.

- ***Transpiration [T]***. *The process by which water that enters plant roots is carried to stems and leaves and then passes through the leaves to the atmosphere in the form of water vapor.*
- ***Evaporation [E]***. *The process of water leaving a surface–i.e. soil, water, and plant leaves–and being absorbed into the drier surrounding air. In a crop environment, water lost through soil evaporation is of no benefit since it does not contribute to crop growth, development, and yield. Thus, cropping practices that reduce E from the soil should benefit a developing crop.*
- ***Pan Evaporation [PE]***. *A measure of the amount of water that evaporates from a water surface. It usually is obtained from a Class A evaporation pan that holds water for the determination of the amount of evaporation at a given location.*
- ***Potential Evapotranspiration [PET].*** *The amount of water that can be moved from a surface to the surrounding air through the processes of evaporation and transpiration assuming the availability of unlimited water. It is usually obtained from pan evaporation or atmometer data. Solar radiation, wind, and air temperature are the factors that most influence PET.*
- ***Evapotranspiration [ET].*** *A dynamic variable that defines the transfer of water in the form of water vapor from the surface of soil and plants [leaves] to the surrounding atmosphere–i.e. crop water use. It is a combination of water that is evaporated [E] from the soil surface and water that moves from the soil through plant leaves to the atmosphere via transpiration [T]. It is generally the largest component of the hydrologic cycle. ET increases with increasing air temperature and solar radiation, the two main drivers of ET. ET will be highest from irrigated plants, or plants that experience minimal water-deficit stress by accessing adequate, readily available soil water. E comprises the greatest proportion of ET from young crops, but decreases with increasing T as the crop grows. In general, most ET early in the season of any crop occurs as evaporation from the soil. As the crop canopy develops and covers the soil surface, E from the soil decreases and T increases. Thus, factors such as row spacing will affect how the ratio of E to T will change during crop development.*
- ***Vapor Pressure Deficit [VPD].*** *An indication of the dryness of the air. VPD is the difference between the amount of water in the air and how much water the air can hold when it is saturated at a given temperature. As the VPD increases, root extraction of water from the soil must increase to meet the increased demand of air for water from the plant. A reduction in relative humidity [drier air] increases the VPD, which results in a corresponding increase in ET. Higher ET will always need to occur to meet the demand of the air for moisture when VPD increases. The VPD is a function of both relative humidity and air temperature.*
- ***Relative Humidity [RH].*** *RH is the ratio of water in the air to the amount of water that air will hold at a given temperature. In essence, it is the amount of water in an air-water mixture and is usually expressed as a percentage. High RH reduces ET, and conversely, low RH increases ET because low*

RH increases the VPD of the air surrounding leaves.

CROP COEFFICIENTS [CC's]

The following narrative briefly describes CC's, and provides background information for understanding them, how they can be determined, and how they can be used with atmometer data to estimate crop water use over a defined time period.

Crop Coefficients account for the difference between PET and actual ET. CC is the coefficient for a given crop and its stage of development, and is usually obtained experimentally. Crop coefficients are used in conjunction with PET to estimate ET at a given growth or developmental stage of the crop in question so that water deficits or crop water use for defined periods of soybean development can be determined.

Presently, there are no calculated CC's for Midsouth soybeans. Estimates of CC's that have been calculated or used previously in Midsouth soybeans are 0.5, 0.7, and 0.95 for the periods planting to R1, R1 to R3, and R3 to R6, respectively [click here to access Table 1 in White Paper], and 0.21, 0.67, and 0.94 for pre-R1, R1 to R3, and R3 to R6, respectively.

A University of Nebraska publication [NebGuide G1994] provides CC estimates based on specific vegetative and reproductive growth stages of soybeans. They are 0.20, 0.40, and 0.60 for first, second, and third node stages, 0.90 for R1, 1.00 for full bloom (R2), 1.10 for R3 to R6, and 0.90 for R7. These values were obtained from the High Plains Regional Climate Center, and are alfalfa-reference crop coefficients. Click here for CC's that have been developed for soybean in West Texas.

Results from irrigation research conducted in Miss. indicate that soybeans will rarely require irrigation prior to bloom. Thus, CC's for the bloom to R6.5 period are the ones that are most important for Midsouth soybeans. Until these are developed, a good CC estimate for the R1 to R7 reproductive period is 1.00±0.10. However, it is likely that this CC estimate will be different between early and late soybean plantings that will be in reproductive phases at significantly different times of the season. For example, it is not unreasonable to assume that the CC for the R1 to R6.5 period of ESPS plantings of MG IV varieties might be 0.90, while the CC for the same period of late-May/early-June plantings of MG IV and/or MG V varieties might be 1.10. Such a difference, if in fact it does exist at this magnitude, is significant in terms of water requirement for the two soybean cropping systems.

Quantification of ET is necessary for determining crop productivity response to units of water applied and/or received. Atmometer data combined with crop-specific coefficients can be used for estimating this crop water use [actual crop ET] during a defined period of crop development. These data may prove invaluable if deficit irrigation [less than that to replace full ET] vs. full irrigation is necessary to conserve water in the region.

MEASURING ET

ET can be estimated using various methods. Some of these are described below.

Crop Coefficient [CC] Approach. The two-step CC approach is the most common equation [Nebraska Farmer, Nov. 2018]. It uses a CC [Kc] multiplied by a reference ET [ETo] to derive the equation ETc = Kc x ETo. Reference ET is best calculated by the Penman-Monteith method, which uses a combination of radiation, temperature, relative humidity, and wind speed to arrive at the reference ET. The calculated ET [ETc] thus uses the Kc [the difference in water use between a reference crop and the crop of interest] and the reference ET to estimate the actual ET of the crop of interest.

Soil Water Balance [SWB] Approach. This indirect method accounts for the difference between water inputs [rainfall, irrigation] into the system and the outputs [change in stored water over time]. Some of the output components [e.g. runoff] may be difficult to estimate, and will require using models.

Atmometer. Another tool for estimating ET is the atmometer [called an ETgage or Evapotranspiration Simulator by the Nebraska Agriculture Water Management Network], which is an instrument that simulates ET from a growing crop. Atmometers consist of a wet, porous ceramic cup mounted on top of a cylindrical water reservoir. The ceramic cup is covered with a green canvas that simulates the crop canopy. The reservoir is filled with distilled water that evaporates from the ceramic cup and is pulled through a suction tube that extends to the bottom of the reservoir. Underneath the fabric, there is a special membrane that keeps rainwater from seeping into the cup.

Atmometers are typically mounted on posts near irrigated fields so that they can be easily read. Information is displayed on a sight tube mounted in front of a ruler on the instrument. Reading the sight tube is akin to reading a rain gauge in reverse–i.e. the water level drops over time vs. increases with rainfall. Crop water use can be estimated by recording the drop in water level in the atmometer over the desired timeframe–e.g. daily or weekly.

Data from atmometers is most useful when used in coordination with crop coefficients. Using atmometer data with crop coefficients is addressed in NebGuide G1579. Crop coefficients for Midsouth soybeans have not been developed.

Fortunately, soybean water use or ET during the normal irrigation period of R1-R6 in the Midsouth when the crop is or should be at full canopy will roughly equal the water loss measured by the atmometer. In fact, this is probably the case regardless of the geographic location of the field–e.g. see the Crop Coefficients for Nebraska soybeans here.

Pan evaporation (PE). Daily PE for many Mississippi locations can be found on the Delta Research and Extension Center website. Care should be taken when using offsite PE data to ensure that weather [rainfall, temperature, and sunlight] at both locations [data collection site and irrigation site] are the same. University of Georgia scientists have devised a home-made pan evaporation device that can be placed on-site. This can be a valuable irrigation tool when maintained properly. For best results, PE data should be used in conjunction with CC's to accurately estimate actual ET at a given stage of a soybean crop.

***Caveat**. Data from PE's and Atmometers will theoretically be different for a given set of conditions because of the different surfaces from which evaporation is measured. Also, atmometers should be easier to maintain to ensure accuracy of obtained data. The important point to remember is that CC's developed using data from the two different sources will be different by some amount, so it is important that CC's that might be developed in the future give the reference source for those calculations.*

Eddy Covariance. This technique measures ET using flux towers such as those described by Runkle et al., Agric. Environ. Lett., Vol. 2, 2017. Data from these towers gives a direct measurement of the "flux" of water vapor and carbon dioxide leaving and returning to the earth's surface from the atmosphere, thus providing a direct net measurement of water that is evaporated and transpired. The above linked article provides details about the setup and use of a network of these towers to provide site-level measurements to quantify carbon and water fluxes in the Lower Mississippi River Basin [LMRB]. The overall goal of the network is to integrate site-level findings about carbon and water fluxes into cohesive data sets that can be used for determining coordinated regional needs [e.g. irrigation requirement].

One of the goals of this Delta-flux network is to create a high-quality, consistent dataset from these tower-based carbon and water flux measurements that can be used to accurately estimate ET from a given area. The network will improve the efficiency of data collection, storage, and analysis through cross-site collaboration that supports uniformity/standardization of data collection and labeling, reduced duplication of effort, and use of a consistent working vocabulary.

Caveat: Data from all tools and instruments used to increase irrigation efficiency will be accurate and useful only if the instruments are properly calibrated, installed, and maintained so that data that are generated from their application/use will accurately *estimate what has happened or what needs to be done. That is why producers and their crop consultants and/or advisors must be certain that they understand the correct use and function of all of the instruments that are used to schedule/apply irrigation more efficiently so that they can recognize their proper/improper functioning and make adjustments when necessary.*

TAKE HOME MESSAGE

The Midsouth has over 4 million acres of irrigated soybeans. This justifies a substantial commitment of resources to support the most efficient use of irrigation water on this sizeable acreage. With time, these resources can be allocated to support a network that uses data from any of the above methods coupled with accurate CC's throughout the Midsouth where significant soybean irrigation occurs. Once such a network and a central data collection point can be established and maintained, producers will have another tool they can access to determine how much water the crop has used in a given time period so that irrigation can be scheduled to replenish this water use or a fraction thereof.

There are noteworthy points to consider from the above narrative.

- The surface irrigation that is predominantly used for irrigating soybeans growing on the shrink-swell clay soils in the Midsouth is likely best scheduled with soil moisture sensors as shown by results from MSPB-funded research (click here). This is because these soils that are irrigated by surface methods absorb the amount of water used by the crop since the last irrigation–i.e. the amount of water applied with each irrigation is controlled by the amount of water these cracking soils will hold.
- Use of the PET/CC scheduling system seems made to order for overhead irrigation of soybeans, especially those grown on silty [non-clayey] soils. This is because 1) overhead irrigation systems can be set to apply a known amount of water to a given area and thus can be set to apply what the PET/CC methodology determines is the amount needed to replace what has been used since the last irrigation, and, 2) many of these soils have a low infiltration rate, and thus can only handle small amounts of irrigation water that should be applied frequently. Thus, soil moisture sensors placed at the recommended 6, 12, and 24 in. depths likely will not be effective for scheduling overhead irrigation on these soils because irrigation water or rainfall may not infiltrate to those depths.
- Use of the PET/CC scheduling system will only become usable when CC's for Midsouth soybeans are developed.
- Data from the PET/CC methodology can be invaluable for accurately estimating how much water an irrigated soybean crop actually uses regardless of how it was irrigated or what soil it was grown on.
- PET/CC data can be used to accurately estimate how much a known water deficit reduces productivity of nonirrigated soybeans. This will enable nonirrigated producers to adopt practices that will allow their soybean crop to be grown in periods with the least water deficit during the growing season so the crop can be managed to produce the highest, most consistent dryland yields.
- The establishment of strategically-located towers to measure water "flux" throughout the Midsouth crop production region will simplify ET determination and subsequent irrigation scheduling.

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