The Basics of Soybean Irrigation in Tennessee

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Quick Facts

1. The four essential factors for making effective irrigation decisions in soybean are growth stage, water-use rate, soil type and rainfall pattern.
2. On silt loam soils, in most years consider irrigating soybeans at first pod (R3) and full pod (R4) when water use first peaks. Monitor soil water status during first seed (R5), as this is one of the most sensitive growth stages for drought stress in soybean.
3. In high rainfall years, yield reduction in soybean has been observed in silt loam and poorly drained soil when irrigation was added during late vegetative and early reproductive stages (V4 to R3).
4. In sandy soils, soybeans are more likely to require irrigation in late vegetative and early reproductive stages (V4 to R3) with the later reproductive stages (R4 to R6) being even more critical for providing adequate soil moisture.
5. Since variable rainfall can create soil conditions too wet or too dry for optimal soybean yield, a managed depletion irrigation (MDI) approach is recommended. MDI prescribes a significant withdrawal of soil water before initiating irrigation to create storage capacity for capturing rainfall that alleviates crop stress from water logging while maintaining a buffer of easily available soil water to prevent drought stress.

6. Once the MDI level is reached, water should be applied at a rate equal to crop-water use from rainfall and supplemental irrigation (the highest rates will be around 1.5 inches per week).
7. Center pivot application amounts should be set as high as possible without creating significant run-off: 0.3 to 0.5 inches per revolution on sloping fields and 0.5 to 0.8 inches per revolution on flatter river bottoms.
8. Soybean irrigation should be terminated by early to middle full seed (R6.5). Adequate soil moisture and/or rainfall can allow termination before R6.5. Slight but consistent yield loss has been observed when irrigating up to beginning maturity (R7).

9. MDI can be implemented by a water balance method that keeps track of both the water added to the soil by rainfall and irrigation as well the amount used and removed by the crop.
10. MDI also can be implemented by soil sensor methods that are a direct measurement of soil water status at a specific locations and depths.

Soybean irrigation recommendations for Tennessee are based on more than five years of AgResearch and Education Center trials and farm demonstration sites. A more detailed understanding of these recommendations is provided in the remainder of the publication.

Water Use, Soil Type, Rainfall and Irrigation Approach [1]

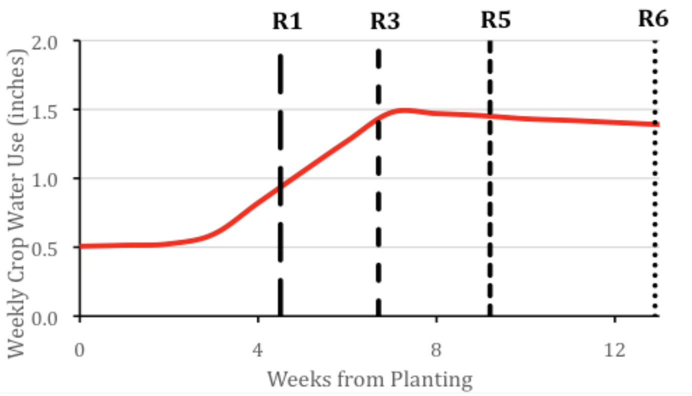


Figure 1: Historic average weekly crop-water use of soybean shown as a solid red line. Crop-water use of any given time period can vary from this line by up to 15 percent, as the weather conditions vary from normal.

Soybean **water use** varies by growth stage and weather conditions. The rate of water use is an important factor for deciding when and how much to irrigate. As shown in Figure 1, water use is 0.5 inches per week during most of the vegetative growth stages, increasing to almost 1.0 inch per week by first flower (R1). From first flower (R1) to first pod (R3), water use increases rapidly from 1.0 to 1.5 inches per week. Thereafter, water-use averages almost 1.5 inches per week through first seed (R5) to full seed (R6). Note that these are historic averages, and a sunny, hot week could require up to 15 percent more water while a cloudy, cool week could require up to 15 percent less water. [2]

Soil type is also an important consideration when making irrigation decisions. A soil profile that is deep silt loam could contain 3 inches of readily available water in a soybean root zone when it is at field capacity (highest amount of water a soil can contain if it drains freely). However, a soil profile that is sandy throughout may only contain around 1.0 inches of readily available water when it is at field capacity. If a deep silt loam and a sandy soil are refilled to field capacity by a large rain event after pod formation (R3), how long would it be before we would need to irrigate each soil? Since water use is averaging 1.5 inches per week at this point, we can expect the sandy soil to need water in five days. On the other hand, the deep silt loam soil can provide enough readily available water to supply that crop for two weeks before the crop starts losing yield potential. The differing abilities of soils to hold water can have implications on irrigation management across fields and even within the same field. [3]

Adjusting to **rainfall** in combination with crop-growth stage and soil type is the key to good irrigation management in soybean. Yet, this can be complex since rain is extremely variable in a humid region like Tennessee. To illustrate the impact of highly variable rainfall patterns, consider this question that is faced by Tennessee irrigators: What is coming next — a four-week drought, a 4 inch rain, or something in between? If we knew a four-week drought was coming, we would irrigate frequently to keep soil moisture close to field capacity to avoid stress and ensure high yield. If we knew a 4-inch rain was coming, we would let the soil dry out in order to utilize that rainfall and avoid overly wet conditions that could harm yield. Since we do not know what weather is on the horizon with a high degree of accuracy, we need to allow soil moisture to deplete to a reasonable level that will facilitate the capture and use of rainfall yet not lose yield potential.

Since center pivots are usually designed to "keep-up" with crop-water use during peak demand periods with no rain, and cannot "catch up" and return the profile to field capacity once significant depletion has occurred, these systems are best managed by maintaining a desired level of soil water depletion. A guiding principle of our **irrigation approach** is to allow a significant but safe soil water depletion to develop according to soil type and crop-growth stage, and then use center pivot irrigation to maintain a "managed depletion" of soil water that facilitates rainfall capture while preserving some readily available water to prevent crop stress. We are calling this approach managed depletion irrigation or MDI.

Initiating Irrigation

Tennessee-based research has verified the importance of irrigating during seed fill (R5 to R6) as consistent yield responses have been noted in silt loam soils (high water holding capacity) even in wet years. In higher than average rainfall years, 1 to 2 inches of irrigation during R5 where able increase yield by 10 percent to 25 percent in silt loam soil. Soybean irrigation will be necessary before R5 and in higher amounts during drier years and in sandier soils with lower water holding capacity. However yield loss has occurred from irrigating during vegetative growth stages and early reproductive stages in silt loam soil during some wet years. Over-irrigation, either too early or too much, can certainly lead to yield loss in poorly drained soils. In most years on silt loam soils, we would recommend beginning to consider irrigation in R3 and R4 when water use first peaks, and especially monitor soil water status during R5. Irrigation will be needed at earlier growth stages in lower water holding soils and we have just initiated soybean irrigation trials in sandier soil to provided better recommendations on when to initiate irrigation under these conditions. [4]

We have discussed the impact of soil textural differences on irrigation initiation, but much of our soybean acres are grown on rolling loess hills where the texture is consistently silt loam. In this case, we expect topography to be the primary driver of irrigation decisions with side slopes requiring earlier irrigation than hilltops and low lying areas due to soil erosion limiting the rooting depth on the side slopes. However, from 2013 to 2017 in several fields across West Tennessee, this pattern has not appeared, and, in fact, the opposite has most often been true with higher soil moisture measured on the sloping ground due to the fragipan impeding drainage of water in wetter years. Yield maps tell us that in a dry year, sloping ground can certainly become water-limited, and in those years the sloping ground could benefit from either earlier irrigation or more irrigation. In wet years, though, there does not appear to be much merit to irrigating sloping grounds differently than level ground on the loess hills of Tennessee. [5]

Irrigation Amounts

Another important part of irrigation decisions is how much water to apply and rates of 1.5, 1.0 and 0.5 inches per week were tested as a combination of rain plus irrigation. In silt loam soils with higher than average rainfall, soybean yield was sometimes optimized with supplemental irrigation lower than the 1.5 inches per week rate during seed fill (R5 to R6) while it should be noted the 1.5 inch per week rated did not diminish yield when irrigation was delayed allowing for a significant but safe depletion of soil water. In drier years and sandier soils, the supplemental irrigation plus rainfall rate of 1.5 inch per week will most likely be required before R5, perhaps requiring water at an R1 or a vegetative growth stage. Therefore, we recommend allowing

soil to dry to the desired "managed depletion" level and then providing water input equal to crop-water use through rainfall and supplemental irrigation in order to maintain soil moisture near the "managed depletion" level. [4]

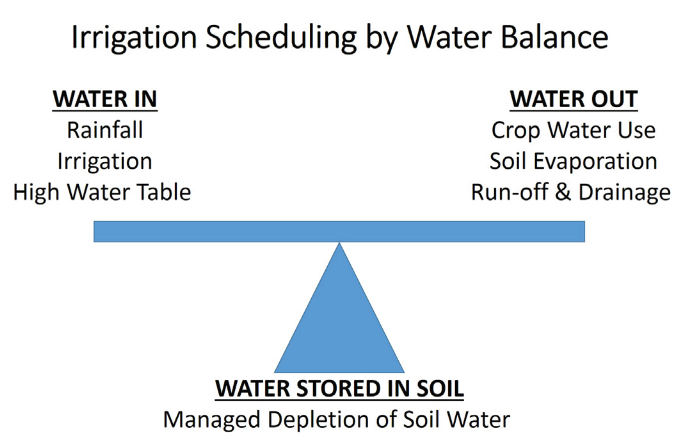
There are also some practical considerations concerning the amount of water applied per irrigation. Most center pivots are designed to be capable of applying 0.3 inches over 24 hours, meaning you potentially could apply just over 2 inches in a week. In flat river bottom ground, where many of our sandy soils are found, it is appropriate to apply higher amounts like 0.5 to 0.8 inches per revolution where runoff is not a substantial concern. However, on sloping fields or fields where infiltration is an issue, limiting irrigation to 0.3 to 0.5 inches per revolution will lead to a more effective irrigation application. We recommend setting pivot application amounts as high as possible without creating significant runoff. [6]

Terminating Irrigation

Soybean irrigation should be terminated in early to mid R6 (full seed). Beans are still filling later developing pods and finalizing seed weight during the early part of R6, therefore irrigation could add to dry weight at harvest if soil moisture or rainfall is insufficient. Irrigating past this point could put unnecessary moisture on plants and could lead to wetter soils and harvest issues. Tennessee trials have shown a slight, yet consistent, yield decrease from irrigating all the way until R7 when pods have turned light green to yellow with some brown pods in the canopy. [4]

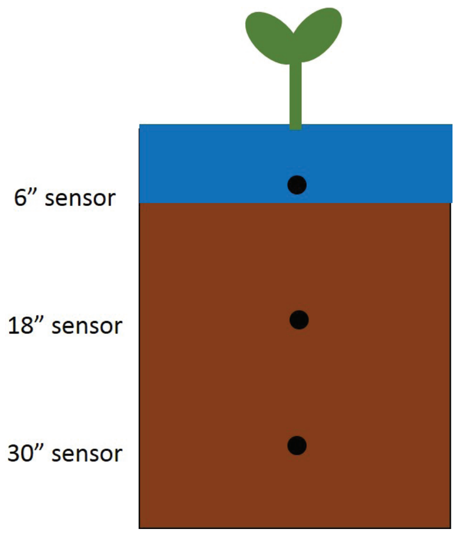
Irrigation Management Tools

Variation in soils, maturity group differences, a wide range of planting dates and unpredictable rainfall make real-time irrigation decisions for soybean challenging. Soil moisture sensors, a water balance or both methods together can be utilized to manage soybean irrigation. The **water balance method** keeps track of both the water added to the soil by rainfall and irrigation as well the amount used and removed by the crop. Table 1 presents MDI (managed depletion irrigation) target values depending on soil type and growth stage for a water balance. Also shown is the Maximum Allowable Depletion (MAD) of 45 percent, beyond which point yield loss is likely. These values are percentages of plant available water that has been removed from the soil profile such that field capacity is 0 percent depletion and permanent wilting is 100 percent. Maintaining soil moisture around the MDI value creates storage space in the soil to capture rainfall while keeping a buffer of easily available soil water to prevent yield



loss. Water balance tools like the **MOIST** (**M**anagement **of** **I**rrigation **S**ystems in **T**ennessee) **spreadsheet** can help you maintain soil-water in a reasonable depletion range, thus increasing the potential of obtaining optimum yield with minimum irrigation. [7]

A water balance approach can be very inexpensive (only requiring a rain gauge) while soil moisture sensors require the purchase and installation of sensor equipment. **Soil moisture sensors** are a direct measurement of soil water status at a specific location. Matric potential sensors (Watermark from Irrometer and MPS-6/TEROS-21 from Meter Group) measure how difficult it will be for a plant to extract moisture from the soil while volumetric sensors (many types and manufacturers) measure the percentage of water in bulk soil. More detailed articles are available to describe the differences between sensor types and how to best use each sensor type. [8]



UT’s recommendations are built around matric potential sensors because their readings are more transferable across soils than volumetric sensors, which require very different trigger points based on soil type compounded by the fact that not all types of volumetric sensors are calibrated the same. Soil moisture sensors should be installed at more than one depth because the soil profile does not dry or rewet uniformly. This means there will be multiple values to consider when making irrigation decisions. A shallow sensor or sensors are needed to detect rainfall and irrigation events while deeper sensors reveal whether water is being used throughout the entire root zone. While soybean needs adequate soil moisture somewhere in the root zone, it does not necessarily need easily available water throughout the soil profile. Soil at some sensor depths should be allowed to dry significantly in an MDI approach as long as water is easily available to the crop at other points in the root zone. Table 2 presents the MDI target values for matric potential sensors. The MPS-6/Terros-21 values have been incorporated into the **MOIST+ APP**. [9]

Water Balance		
Maximum Allowable Depletion of 45%		
Target (% Depletion)		
	Sand	**Silt Loam**
Late Veg (V3) to Begin Seed (R5)	30	35
Begin Seed (R5) to Full Seed (R6.5)	20	25

Table 1: Maximum allowable depletion and managed depletion irrigation (MDI) Levels (as a percent of plant available water depleted for soybean when using the water balance method). The MDI Target Value is not the only soil water depletion target level that can result in optimum yield. It is recommended as a means to balance the effect of unpredictable rainfall patterns by leaving enough water in the soil to prevent drying below the maximum allowable depletion (MAD) and over wetting the soil from excess rainfall; both conditions can lead to yield loss.

Watermark (kpa or cbar)
Easily Available Soil Water Range

	Sand	Silt Loam
Late Veg (V3) to Begin Seed (R5)	8 to 55	8 to 100
Begin Seed (R5) to Full Seed (R6.5)	8 to 40	8 to 60

MPS-6/TEROS-21 (kpa or cbar)
Easily Available Soil Water Range

	Sand	Silt Loam
Late Veg (V3) to Begin Seed (R5)	11 to 70	11 to 150
Begin Seed (R5) to Full Seed (R6.5)	11 to 40	11 to 70

Table 2: Guideline matric potential values for Watermark and MPS-2 sensors in soybean to maintain a managed depletion irrigation (MDI) strategy by growth stage and soil type.

1. Saturated conditions occur at values less than the range minimums.
2. Easily available water is not required or recommended in the entire soil profile. Only one sensor needs to be within the recommended range.
3. Yield loss may occur if all parts of the crop root zone are greater than the range maximums.

UT Extension provides several resources to assist producers in implementing soybean irrigation scheduling (see links below). Additionally, several crop consultants in Tennessee are offering irrigation management as part of their services. [10]

Supplemental Publications

1. Irrigation Water Management – A Simple Analogy.
2. How Much Water Is Your Crop Using?
3. How Soils Hold Water, a Home Experiment.
4. Summary of Soybean Irrigation Studies in Tennessee.
5. Determining Irrigation Management Zones for Center Pivots.
6. What Is Your Center Pivots Application Rate?
7. Using a Water Balance to Make Irrigation Decisions: MOIST spreadsheet.
8. Using Soil Moisture Sensors for Irrigation Management in Tennessee.
9. Automating and Combining Water Balance and Sensor Based Irrigation Scheduling: MOIST+ APP.
10. List of Irrigation Consultants in Tennessee.

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