NebGuide

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Irrigating Soybean

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Proper irrigation management is critical to optimize both yields and irrigation water resources. Irrigated soybean production in Nebraska encompasses a region with diverse soils and climate and different irrigation management strategies. This NebGuide details irrigation water management recommendations that accommodate Nebraska's soil, climate and precipitation variability.

Soybean acreage in Nebraska has increased from 43,000 acres of irrigated production in 1972 to 2.55 million acres of irrigated production in 2003. About 45 percent of Nebraska's total soybean acreage is irrigated. The interest in soybean is due to favorable economic returns, varieties with better yield potential, the value of soybean in rotation with other crops such as corn, and changes in U.S. farm legislation.

Soybean Plant Growth and Development

Soybean plant development can be separated into two phases — vegetative and reproductive. The vegetative stage begins with seed germination and seedling emergence. The reproductive stage begins with the appearance of the first flower on the plant. Vegetative development is typically monitored by counting the number of main stem nodes. The node where the two cotyledons are attached is counted as node 0, whereas the node where the two unifoliolate leaflets are attached is counted as node 1. All other nodes above the unifoliolate leaflets bear trifoliolate leaflets and are counted in sequence as 2, 3, etc. Reproductive development is a bit more complicated and details are provided in *Table I*. Knowing these soybean stages is important when using the stage-of-growth method of scheduling irrigations.

Soybean Varieties and Stem Growth Habit Types

For irrigated soybean production, variety selection is an important management factor. Most of the soybean varieties available in Nebraska are of the ***indeterminate*** type, in which the later stages of vegetative growth overlap with the early stages of reproductive development. In these varieties, the main stem apex retains vegetative activity (i.e., produces new nodes) after the first flower appears (typically on node six of the main stem). Though vegetative activity continues, it gradually slows until it ceases just after the onset of the seed enlargement stage (i.e., no more nodes produced). Such varieties often will have more than 20 main stem nodes at maturity.

Table I. Reproductive stages of soybean plant development (Ritchie et al. 1994).

Stage		*Description*
Beginning Flower	R1	**At least one open flower is present at any main stem node.** The first flower generally occurs on node six in indeterminate varieties, but nearly all nodes flower simultaneously in determinate varieties.
Full Flower	R2	**At least one open flower is present at any one of the two uppermost main stem nodes that have fully developed leaves.** A node with a fully developed leaf will be just below a node whose leaflets have unrolled to the extent that the leaflet edges are no longer touching.
Beginning Pod Elongation	R3	**At least one pod of 3/16-inch length is present at any one of the four upper most main stem nodes that have a fully developed leaf.** It is not uncommon to see pods of greater length at the lower nodes, plus withering flowers, open flowers, and flower buds on a plant at the R3 stage.
End of Pod Elongation	R4	**At least one pod of 3/4-inch length is present at one of the four uppermost nodes that have fully developed leaves.**
Beginning Seed Enlargement	R5	**At least one pod containing small seeds is present at one of the four uppermost nodes that have fully developed leaves.** You can hold a pod up to the bright sky to see the small developing seeds in the pod cavities.
End of Seed Enlargement	R6	**At least one pod whose cavities are completely filled with green seeds is present at one of the four uppermost nodes that have fully developed leaves.** The pod, when backlighted by a bright sky, will have its cavities completely occupied by dark green seeds. Seed growth slows after R6, but does not entirely cease until the seed attains physiological maturity.
Beginning Maturity	R7	**At least one (normal) pod that has attained its final mature color (tan or brown, depending on variety) is present on any main stem node.**
Full Maturity	R8	**Ninety-five percent of the pods have reached their mature pod color.**

In contrast, the main stem apex of ***determinate*** varieties abruptly ceases vegetative activity upon floral induction. This leads to the main stem apex conversion into a terminal cluster of flowers. Such varieties generally have only about 10-14 main stem nodes at maturity, but their short stature can be an advantage when used with high plant densities in irrigated bottomlands where indeterminate varieties often lodge.

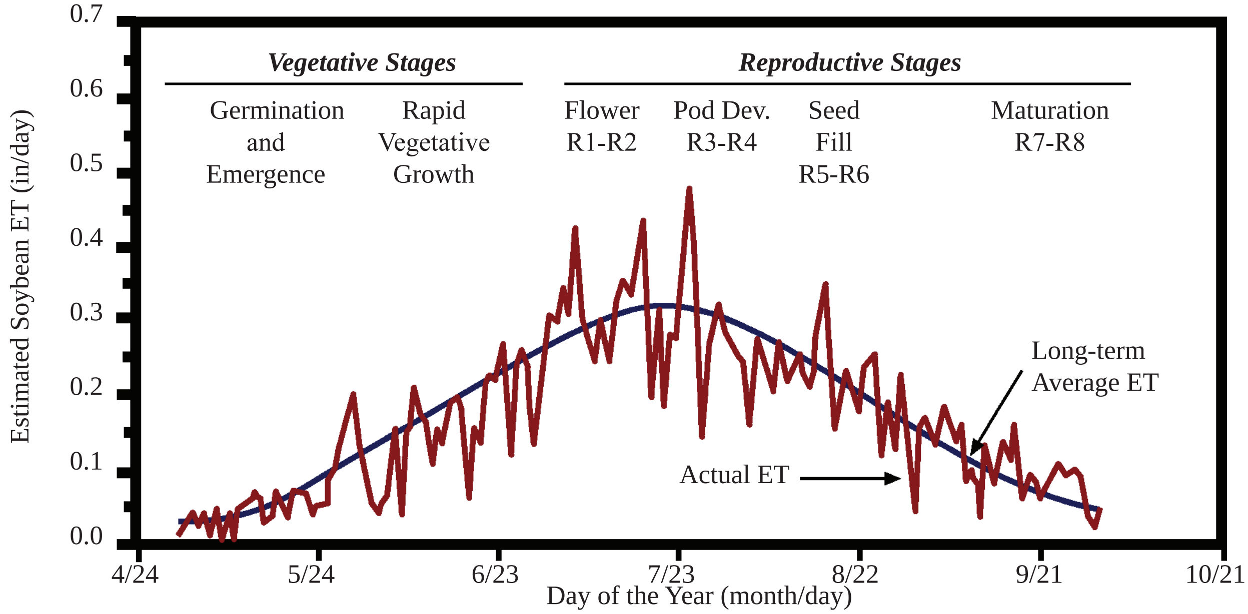

Figure 1. Soybean crop water use or daily evapotranspiration (ET) from a well-watered crop. The blue line depicts the expected ET based on historical data, whereas the red line depicts the daily ET for a specific growing season. Source: High Plains Regional Climate Center Data Archives

Varieties of ***semi-determinate*** type are becoming available in Nebraska. (Nebraska variety NE3001 is an example.) The main stem apex in these varieties is not converted as quickly from a vegetative to reproductive state and generally will have about 16-18 main stem nodes at maturity. Research conducted by the University of Nebraska–Lincoln suggests that semi-determinate varieties may be needed to better exploit the yield potential of intensely managed irrigated soybean production systems.

Plant-Water Relationships

Irrigation applications, or high amounts of rainfall that occur during vegetative growth, are normally not beneficial unless soil water levels are extremely low. In fact, excessive water during the early growth stages may stimulate vegetative growth without leading to a yield increase. If lodging occurs, vegetative stage irrigation can substantially depress yields.

The seasonal pattern of soybean water use, in conjunction with the vegetative growth and reproductive development stages, is shown as a curved blue line in *Figure 1*. The total water used (evaporation plus transpiration) by a fully irrigated soybean crop may vary from 20 to 26 inches during the growing season. About 65 percent of total water use occurs during the **R1** to **R6+** reproductive stages. In an average season, the water-use rate will reach a peak of about 0.32 inches per day during the late flowering and early pod development stages, but during the mid to late reproductive stages it may average 0.25 inches per day. As shown by the jagged red line in *Figure 1*, the actual ET amount in any given year will vary daily. Note that a well-watered soybean crop may transpire up to 0.5 inches of water on a hot, windy day in late-July or August.

The most important times for soybean plants to have adequate water are during pod development **(R3-R4)** and seed fill **(R5-R6)**. These are the stages when water stress can lead to a significant decrease in yield. Irrigation also may be required prior to these stages on sandy soils (insufficient water-holding capacity) or during very low rainfall years on medium- and fine-textured soils. However, if water is applied during flowering, it is important to follow with adequate water during seed fill. Irrigation at flowering typically increases the number of seeds produced per plant, but any subsequent water stress will reduce the size of those seeds such that the yield response to an irrigation at flowering may be no more or even less than not irrigating at flowering. Irrigation at flowering also may increase the potential for a white mold infection due to the humid in-canopy conditions after the irrigation.

Though soybean roots can reach depths of 5 to 6 feet, the largest concentration of roots and the majority of soil water extraction occur in the top 2 to 3 feet of the soil profile. Irrigation water should thus be limited to a 3-foot penetration depth to avoid leaching nitrates into the local aquifer. Producers should be able to achieve soybean yields of 60 to 80 bushels per acre on soils with good internal and surface drainage if irrigation events are properly applied during the growing season.

Soybean Irrigation Water Management Research

A convenient means of scheduling soybean irrigation is to match applications with the most water-sensitive crop growth stages. Stage-of-growth irrigation scheduling can work well for a crop like soybean that responds well to water supplied during the later growth stages. However, delaying irrigation until after the R3 stage can be problematic if the irrigation system does not have sufficient capacity to meet crop water demands. Precipitation during the growing season, stored soil water prior to the growing season, and irrigation system capacity are all important when it comes to deciding when to start irrigating. Research in eastern Nebraska has shown that soybean can respond well to delayed irrigation; however, if stored soil water is not optimal at planting and/or if rainfall is severely deficient prior to beginning pod development, delayed irrigation may reduce yields when compared to full-season irrigation scheduling.

In Nebraska research, full-season irrigation scheduling (i.e., irrigation was applied any time during the season when crop water use led to a 50 percent or more depletion of the avail-

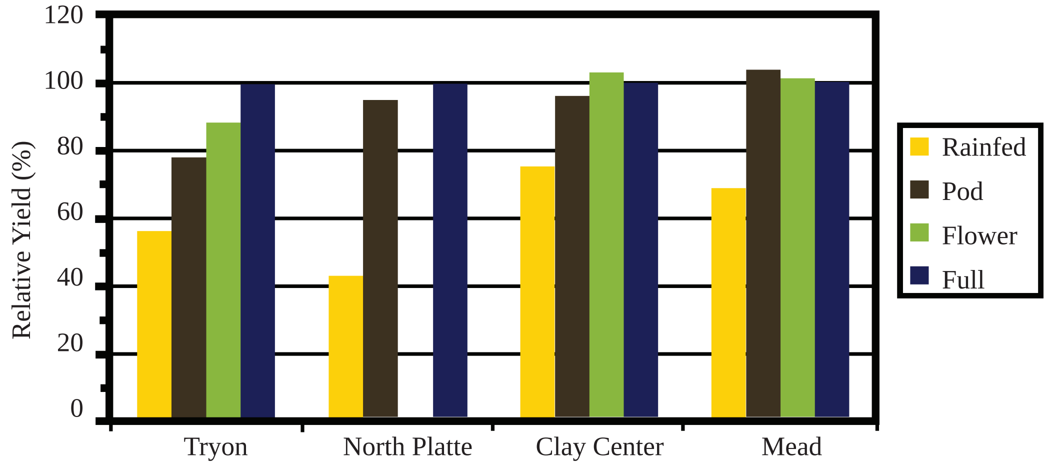

Figure 2. Soybean yields obtained at four Nebraska locations when raised under four conditions: rainfed; delayed irrigation until pod development (R3-R4) or flowering (R2); or full-season irrigation scheduling.

able soil water in the crop root zone) was compared with two growth-stage irrigation scheduling methods (i.e., no irrigation until the crop reached the **R2** stage or the **R3-R3.5** stage, after which irrigation was commenced and continued). All irrigation water was applied using sprinkler systems. The results of this comparison were used to evaluate the effects of delayed irrigation on grain yield and water use efficiency. Four irrigation treatments were evaluated across Nebraska at Tryon, North Platte, Clay Center and Mead and are described below:

1. **Rainfed.** Irrigation water applied only if needed to achieve germination.
2. **Pod Elongation (Pod/7.5 inches).** Irrigation was delayed until a pod 3/16- to 3/4-inch in length was evident at one of the four uppermost main stem nodes that had a fully developed leaf **(R3-R3.5)**. Irrigations totaling 3 inches were applied within a two-week period. Irrigations totaling 4.5 inches of water were applied during the three-week period of seed fill **(R5-R6).** Total seasonal effective irrigation was 7.5 inches in this treatment, with irrigation amounts adjusted for rainfall.
3. **Full Flower (Flower/10.5 inches).** Irrigation was delayed until a flower opened at a node immediately below the uppermost main stem node that had a fully developed leaf **(R2).** Irrigations totaling 3 inches were applied within a week, followed by irrigations totaling 3 inches during the next week's pod elongation stage **(R3-R4).** Irrigations totaling 4.5 inches were applied during the three week period of seed fill **(R5-R6).** Total seasonal effective irrigation was 10.5 inches in this treatment, with irrigation amounts adjusted for rainfall.
4. **Full-season (Full/12.5 inches).** Irrigations were scheduled to maintain the available soil water above the 50 percent available level. Irrigation began prior to flowering if needed to supply water according to the water use of soybean. Total seasonal effective irrigation was 12.5 inches in this treatment, with irrigation amounts adjusted for rainfall.

The yields obtained in the four treatments at the four locations are shown in *Figure 2.* Non-irrigated yields were greater at Mead and Clay Center than at the two west-central locations due to greater off-season precipitation (more soil water storage) and greater in-season precipitation at the eastern Nebraska sites. Yield of the treatment in which irrigation was not commenced until the pod elongation stage was not significantly different from the full season treatment at most locations, despite receiving the lowest total seasonal irrigation (i.e., only 7.5 inches). However, soil water storage and rainfall during the vegetative stage often cannot be sufficient to produce maximum yields when the irrigation is delayed until the pod-elongation treatment. This scenario may occur too frequently at the west-central locations to permit irrigation to be delayed that long; however, from a yield perspective, the data does support withholding irrigation during the vegetative stage and perhaps during the flowering stage as well in most seasons in eastern Nebraska.

Recommendations for Irrigation Water Management

Coarse-textured Soils

Water management for coarse-textured soils is more difficult than for medium-textured soils. Soils in this classification include fine sands, loamy sands and fine sandy loams. Generally, these soils have a low (less than 1.5 inches per foot) available water capacity. In addition, some sandy soils in Nebraska have root-restricting layers at shallow depths. The combination of low available water capacity and shallow rooting results in a small soil water reservoir. The available water-holding capacity in a 3-foot active root zone will be 3.0 to 4.5 inches. This low available water-holding capacity means light (0.75 to 1.0 inches) frequent water applications are necessary to recharge the limited soil water reservoir. Further, there is less room for error in timing irrigations so irrigations should begin in time to ensure that the soil water content does not drop below 50 percent of the available water holding capacity.

The general recommendation for water management on coarse-textured soil is to allow no more than 50 percent depletion of the available soil water in the top 2 feet during vegetative growth and flowering **(R1-R2),** and then no more than 50 percent depletion in the top 3 feet during pod elongation **(R3-R4)** and seed fill **(R5-R6)**. Soil water levels can be determined by combining the appearance and feel method with soil water-balance calculations using reliable evapotranspiration (ET) estimates. Estimated daily soybean ET data can be obtained on-line from the High Plains Regional Climate Center at *hprcc.unl.edu.*

Deep Medium- and Fine-textured Soils

These soils (silt loams, silty clay loams, silty clay) generally have an available water capacity of more than 2.0 inches per foot or 6.0 inches in the top 3 feet. Using irrigation scheduling to maintain 50 percent available water in the top three feet of the root zone after the full flower stage **(R2)** generally will result in maximum yields.

An alternative scheduling approach on deep- and fine-textured soils is stage-of-growth scheduling, as discussed in the last section. This method works if the water reservoir in the top 5 feet of soil is at or near field capacity at planting time. In the eastern half of Nebraska, this usually occurs if the soils were irrigated during the previous season and/or if there was sufficient off-season precipitation to refill the profile.

For soybean, between 10 and 11 inches of water may be required during the soybean reproductive period. Ordinarily, this would translate into effective irrigation (adjusted for rainfall) totaling about 3 inches during the flowering stage **(R1-R2),** 3 inches during pod development **(R3-R4)** and 4.5 inches during seed fill **(R5-R6),** which sums to 10.5 inches. With adequate rainfall, optimum yields will be obtained with two effective furrow irrigations of 3 inches each, one applied at full flowering or beginning pod development and the other at beginning seed fill. Where white mold is a real or potential problem, it would be wise to avoid irrigating at (or just before) full flowering. With systems, such as center pivots that have limited irrigation capacities (e.g., 0.5 to 0.75 inches per revolution), several revolutions may be necessary within a short time frame to apply the desired 3 inches during a particular growth stage. In abnormally dry years, an additional 3 to 5 inches of effective irrigation may be required to overcome the rainfall deficit.

If irrigation must begin at the full flower stage **(R2)** or if significant rainfall occurs at the beginning flower stage **(R1),** it is especially important to ensure that adequate soil water (50 percent available soil water or greater) is maintained during the remainder of the growing season. This is because late season water stress seems to have a larger impact on final yield if the soybean was irrigated during flowering.

If you are limited in the amount of irrigation water you can apply during the season, you will get the maximum benefit of this water if it is applied during the pod development **(R3-R4)** and seed fill **(R5-R6)** growth stages. However, delaying irrigation may not work if there is a severe rainfall deficit prior to flowering. In dry years, limited water may be needed as a "rescue" application earlier in the season.

With furrow irrigation systems, delaying irrigation until pod development **(R3)** in those low-rainfall Julys can be problematic. This is because soil in the furrows may crack, making it difficult to apply the desired 1.0 to 1.5 inches. An earlier irrigation date, designed to at least seal the furrow, may be advisable in such cases.

Summary

When irrigating soybean in Nebraska, the producer has two irrigation scheduling options:

1. Scheduling irrigation to coincide with critical reproductive stages can be used on deep medium- to fine-textured soils. If soil water is at field capacity at planting, and precipitation is not severely deficient during the vegetative stage, irrigation can be delayed until the full flower stage **(R2 or R3)** if no water stress is allowed thereafter and white mold is not a potential or real problem. The growth-stage irrigation scheduling system is not effective if:
   a. the soil texture is sandy loam or coarser;
   b. the soil water reservoir size is limited (e.g., rooting depth impeded); or
   c. the capacity of the irrigation system is less than 1.5 inches per week.

2. Scheduling irrigation on the basis of crop water use is an ideal method, particularly if the soil texture is sandy loam or coarser. The producer must track the soil water use and be able to apply irrigation in a timely manner. With center pivot irrigation, water applications can be closely matched to crop ET after adjusting for rainfall. This method of scheduling will, however, mean that the producer must:
   a. allocate time to track soil water amounts;
   b. use caution when irrigating at flowering if white mold is a potential problem; and
   c. recognize that a soybean crop watered frequently early in the season will be more sensitive to water stress later in the season.

Soil water can be monitored by hand-feel methods or by mechanical and electronic devices. Alternatively, daily and weekly sums of soil water use can be estimated using ET data calculated from a nearby weather station.

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