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Cotton Irrigation Scheduling

Kater Hake, Van Ayers, Bob Hutchinson, Bill Lyle, Lyle Pringle and Jim Thomas

The use of irrigation to enhance yield, quality and profit stability has exploded across the rainbelt in the last 5 years. If cotton returns to the profitable column, we will see this expansion continue. Whether you are considering purchasing an irrigation system or need to optimize return on existing investments, a season-long strategy to irrigation scheduling is essential.

Objectives in Water Management

Water is a production tool just like fertilizer or tillage that provides a lifeline in the arid West and a supplement to rainfall in other regions. Regardless of the region, the goal of water management is to meet crop demand and optimize yield with the resources available. Success at reaching this goal depends on the irrigation system uniformity and capacity along with a conviction to use the system properly. Poor system uniformity will limit the benefits that can be extracted from water compared to controlled systems such as LEPA, sprinklers or surface irrigation of precision leveled land. The following are some specific objectives in applying water that extend beyond the simplified objective, to meet crop water needs.

- **Seedbed Moisture for Germination**. Since cotton is sensitive to chilling injury, irrigating up or applying water to seedlings when temperatures remain below 80°F is ill-advised. Seedling disease and chilling injury are more severe if cool weather is combined with wet soils. In the cold spring of 1992, stand loss in the Mid-South and Southeast was less than expected primarily because of the early drought that allowed seedlings to develop under drying conditions. Since the ideal regime for germination includes plenty of moisture prior to the planting season followed by sunny days to warm the soil for healthy seedling growth, it is preferred to water prior to planting than trying to irrigate up.
- **Herbicide activation** is necessary for pre-emerge herbicides. When herbicides remain on the soil surface, their concentration and weed control is diminished through volatility, decomposition and reduced weed root uptake. Typically, 0.25 to 0.75 inches of rain or sprinkler irrigation is sufficient to activate most herbicides, depending of soil type and region. Excessive amounts of rain or irrigation may move some materials deeper in the soil resulting in crop injury or weed control failure.
- **Nutrient Uptake**. Surface-soil moisture is also necessary for uptake of surface-applied nutrients. Rainbelt cotton petiole P and K levels are higher when frequent rain or irrigation keeps the surface-soil moist. Irrigation or frequent showers maintains root activity in the more fertile top soil, allowing sustained uptake of nutrients.
- **The cooling effect of rain or irrigation** on soil and plants can be beneficial in July and August. Most of the water absorbed by the plant (99.9%) is transpired out of the leaves, taking with it heat energy thus cooling the plant. Where temperatures are very hot (100°F or hotter) keeping soil moisture levels high with frequent (7 days or less) light irrigations can cool the plant more effectively than less frequent irrigations where the surface-soil is allowed to dry.
- **Control Growth and Optimize Lint Yield.** Because of the strong control water and nitrogen hold over leaf and stem growth, these two inputs can be used to either push plant height or limit it. Excess water and nitrogen prior to bloom, during squaring, results in rapid mainstem growth because photosynthates are usually in abundant supply from the healthy young leaves and the lack of strong sinks (developing bolls). Excess water and nitrogen after this period has less effect on plant height unless boll retention is abnormally low.
- **Prepare the Crop for Harvest**. The challenge in adequately irrigating and fertilizing cotton, compared to other field crops, arises from the need to deplete the soil of available nitrogen and water during boll opening. Mid-season water stress results in tough, waxy, resistant-to-defoliant leaves; while water and nitrogen stress at the end of the season senesces the leaves and bolls and leads to early leaf drop and boll opening.

Irrigation Scheduling in Desert Climates

In the greenhouse environment of the desert climates, irrigation scheduling is the dominant influence on yield. Top yielding ranches, that's what a farm is called out West, have the capacity to irrigate their entire acreage over a short time period (7 to 10 days), to allow surgically precise applications of water. The lack of untimely rainfall during the growing season allows this degree of control and maximizes the benefits derived from water. The irrigation season in a desert climate is divided into distinct parts, each with different objectives and criteria for rate and timing.

Preirrigation

The soil moisture objective at planting is: a soil profile full of moisture to the depth of rooting, drained of excess water near the surface and rewarmed by the sun. This full soil profile delays the need for irrigation and avoids the problems associated with spring irrigation: evaporation loss of valuable water, plant cooling, nitrate leaching, and soilborne disease infection. The optimum timing and amount of the preirrigation is dependent on soil texture and residual moisture. Auguring and coring are the standard methods to determine residual moisture and soil texture.

Summer Irrigations

Across the Cotton Belt, the timing of the first post-plant irrigation is the most critical irrigation decision. Start too early and the root system will be shallow, weeds germinated, plant bugs attracted and rank growth promoted. Start too late and the crop will be stunted, cutout early, and suffer reduced yields. Optimum timing in the West occurs when the plant has just started to slow mainstem growth (-15 bars mid-day leaf water potential) but before obvious leaf color changes.

Once irrigations are initiated in the summer, few producers have the option of temporarily shutting the system down. Objectives during the bloom period are to maintain a sufficient reservoir of soil moisture such that water stress does not occur even when the temperature spikes over 100°F. Timing and amount is often determined by the limits of the irrigation system or by recent cotton ET estimates.

Terminating Irrigation

Terminating irrigation is another difficult decision: too early and top set bolls shed or fail to mature; too late and water is wasted, defoliation is more difficult and quality suffers. Optimum timing would allow sufficient moisture for the plant to fill the last set boll that could be matured given the limitations of fall weather. Cutout date and soil water reserve are the prime determinants of optimum water cutoff dates. Coarse textured or shallow moisture fields need irrigations later in the season. Fields with clay loam soils that have maintained some reserve moisture in the 3rd and 4th foot, especially if the crop cuts out early, can receive their final irrigation a month earlier. In the Far West, approximately 9 inches of soil moisture is necessary to fully mature a late set boll from bloom. Using plant monitoring to determine when that boll is set can permit early termination of irrigation if the crop is early.

Irrigation Scheduling in the Rainbelt

Supplemental irrigation can be a very useful tool for increasing profitability even in areas with 50 inches of annual rainfall. Favorable responses in these areas are usually a result of the producer's ability to precisely time irrigations to those few weeks when soil moisture is less than optimum due to poor rainfall distribution and/or soils with low water holding capacity or shallow root zones. Due to the variability in rainfall amount and frequency, strategies for irrigation scheduling in the rainbelt do not change significantly from the wet areas of Louisiana to the drier areas of West Texas and Missouri. As recent weather demonstrates, long term average rainfall is a poor predictor of rainfall in any given year.

Strategies do change depending on water supply. Where the irrigation system and rainfall can not keep up with peak water demand during the summer, irrigation must be started early, to avoid depleting the soil moisture profile prior to bloom. Under these low capacity conditions, producers start the water as soon as the soil can hold the moisture. This strategy may overwater cotton in the spring, possible requiring more Pix to keep plant height under control, but it will lessen the water stress during peak bloom. On the other hand, where system capacity can meet the need for supplemental water during the summer, producers can deplete the subsoil moisture prior to the initiation of irrigation.

The most efficient irrigation strategy in the rainbelt would be to irrigate before severe plant water stress occurs, with an amount of water that even with subsequent rainfall would not waterlog the soil reducing yield. This is a tall order and one that requires both close crop monitoring and the ability to timely apply controlled amounts of water.

How Much Water to Apply

In the rainbelt, it is preferred to apply small amounts of water with each irrigation: approximately 2 inches with surface irrigation and 1 inch or less with sprinklers to lessen runoff and plant damage if subsequent rainfall is heavy. Surface irrigators generally use the higher rate, because amounts of 1 inch or less become difficult to apply uniformly and increase labor costs. Rates can be higher in fields with good drainage, because the threat of soil saturation is less. Where drainage is adequate, producers often begin and end the season with small amounts of water, but during the peak use period of June and July, apply as much water as the infiltration rate and soil water holding capacity will allow (up to 2 inches with sprinklers and 3 with furrows). This strategy closely regulates the soil water in the spring and fall while minimizing cost during the summer.

Another condition that justifies higher application rates is low humidity, here 1 to 1.5 inches each sprinkler irrigation are preferred to minimize spray and soil evaporative loss that would occur with lesser rates.

Initiating Irrigation

In the rainbelt, optimum irrigation initiation varies due to soil type, weather, cultural practices, plant status and irrigation system capabilities. Soil variation within a field further complicates irrigation initiation. One method to time the first irrigation requires determination of soil moisture at 6 or 12 inch intervals in and below the anticipated rooting profile. Follow early season moisture extraction to determine that year's rooting depth and initiate irrigations when moisture extraction in the observed root zone has essentially ceased (ie. tensiometer reading near 90 centibars). Timing the first irrigation when 50% of the available moisture has been extracted from the root zone will insure the greatest depth of rooting and minimize the risk of early season soil saturation at a time when the plant is most vulnerable. If the crop blooms before irrigation is initiated, do not further delay needed irrigations. Under these conditions, water can be safely applied without promoting rank growth or restricting rooting.

Subsequent Irrigations

Once irrigation is started, irrigation plus rainfall should meet cotton ET requirements and avoid plant stress. Cotton ET estimates along with soil moisture sensors in the root zone provide good indications if irrigation is staying ahead or falling behind soil drying.

Where the water supply in combination with rainfall does not supply cotton's water needs, it will be necessary to spread the water out to receive the greatest benefit. This strategy contrasts with the California/Arizona approach, where when water supply is limited, after improving system efficiency, planted acres are reduced. If controlled irrigation systems, such as Low Energy Precision Application (LEPA), are available, deficit irrigation with 30 to 50% of cotton ET on a frequent (4 to 7 day) cycle has made excellent yields in the Texas High Plains with minimal water inputs. LEPA is a modified center pivot using low pressure nozzles on drop tubes to place small amounts of water in alternate rows. This system, in combination with furrow diking, allows a high uniformity at low rates and lower evaporative losses. Even with sprinkler irrigation, rainbelt producers can successfully deficit irrigate by increasing the frequency of application to 4 to 7 days and cutting back on the application rate to 60 to 80% of cotton ET. If this regime is adopted during a prolonged dry spell, do not shut the system down, because the limited volume of soil moisture can allow the plant to stress rapidly if an irrigation is missed.

Terminating Irrigation

Optimum timing of the last irrigation in high rainfall areas requires a difficult balancing act between maturing the last set bolls (those with time to mature) without delaying harvest or increasing chances of boll rot. In general, surface irrigations are terminated prior to boll opening due to their larger application rates; sprinkler irrigation in amounts of 1 inch or less may need to be continued 1 or 2 weeks after first open boll, if soil moisture reserves and warm sunny weather exists for bolls with a chance to mature. Adequate moisture will allow small bolls to safely develop past the most sensitive shedding stage (2 weeks after bloom). Excess soil moisture from rainfall or irrigation at this time will delay maturity, be more difficult to defoliate, and extend the period needed to protect the crop from insects. This also results in a delay in harvest which can be extremelly important in high rainfall areas because days fit for harvest diminish as the harvest season progresses.

Rank growth and a heavy top crop often occur together; both are promoted by early season boll shed and excess rainfall and/or irrigation. This combination is especially difficult to manage in the rainbelt because of the need to avoid prolonged cool, damp conditions to minimize boll rot, and the need to have adequate moisture to mature late set bolls. Under these conditions, checking the soil moisture profile, can provide some guidance. If deep soil moisture is ample, avoiding late irrigations (after bolls begin to open) will be the best strategy to reduce boll rot and retain small bolls.

Tools to Measure Moisture

Infrared Thermometers and Pressure Chambers

Plant-based measurements, such as infrared thermometers and pressure chambers, are ideally suited to the Desert West because they directly sense the plant status. Plant health is the prime objective, not maintaining a certain soil water status. For example, under cool and cloudy weather plants can withstand drier soil. However, in the rainbelt sporadic cloudy conditions exist during most of the summer. When clouds pass overhead, the atmospheric demand drops and plant stress is altered, making stable readings impossible. Even if plant based measurements were restricted to sunlit periods between clouds, the plant lags in its response to changing solar radiation caused by intermittent cloud cover.

Soil Moisture Measurements

Many irrigation scheduling recommendations rely on determining the available moisture holding capacity of the soil, and irrigating when the soil has been depleted to a certain point, often 50% of the available capacity. This strategy is limited by the variability in soil types, compaction, root density and other restrictions to root activity. Available moisture holding capacity is not nearly as precise a quantity as older soil text books led us to believe. However, this concept still can be used to schedule irrigations if on-site measurements of soil moisture extraction can be made in multiple locations of the field. One of the easier and least quantitative measurements of soil moisture is the "soil feel technique".

Soil Moisture Feel. This method in the hands of an experienced producer or consultant can be precise and reliable. Utilize an experienced soils person from the Extension Service, SCS or University to initially "educate" your fingers as to what moisture is available. Tables of soil moisture content and "feel" are available from these same sources. Use a soil core to rapidly sample the top 18 inches in 6 or 9 inch increments. Soil cores will not easily penetrate dry soil, but for scheduling purposes this may not be necessary. After an irrigation, this technique can also determine the depth of wetting, an important consideration for irrigation and fertilization management.

Tensiometers. Tensiometers measure the pull that the soil exerts to retain water. Because water develops air embolisms under high tension, these instruments break suction near 90 centibars and are only useful in the wet range. Thus, they have limited use in Western cotton, where deeper rooting dries the surface soil. In the rainbelt, they are generally placed at two soil depths, with the deep tensiometer used to initiate irrigations and the shallow used to time subsequent irrigations. The disadvantages of tensiometers are the installation time, limited moisture range and maintenance. An advantage is the ability to rapidly take readings.

Gypsum Blocks. By measuring the electrical resistance is a block of gypsum, soil moisture can be indicated over a drier range than tensiometers. When the gypsum block is placed in the soil, its moisture content equilabrates to the soil moisture. If the block is wet, resistance is low; if the block is dry, resistance is high. The low cost and maintenance of gypsum blocks provide advantages for use in cotton. Placement and use is similar to tensiometers, but the lower cost allows placement at greater number of depths.

Soil Moisture Probes. Neutron probes provide very precise indications of relative water content, from extremely wet to extremely dry. These probes use radioactive metal to emit fast neutrons, which are reflected back by the soil water resulting in slow moving neutrons. The reflected slow neutrons are then counted by a sensor in the probe. Because neutron probes directly read "counts" of slow neutrons, they detect slight changes in soil water content. To determine actual moisture content, neutron probes require calibration with the soil type, a tedious and exacting process. The advantages of neutron probes include their precision and ease of reading multiple depths. Non-nuclear soil moisture probes, that rely on changes in the soil dielectric constant, are also available. Limited information indicates that their utility may be similar to neutron probes, but without the regulatory requirements for use of radioactive materials.

Water Budget Programs

Water budget programs have the potential of being excellent tools to aid in irrigation scheduling. Simplified versions have been used successfully in the Mid-South where producers track rainfall and cumulative crop water use (cotton ET) and then replace 90 to 100% of the difference with center pivot irrigation. If a producer applies 0.5 inches with each irrigation, he would add up the daily cotton ET from the previous irrigation, subtract the daily rainfall, and irrigate when this total reached 0.5 inches. In West Texas, producers prefer to set the frequency of irrigation and apply the correct amount of water to match crop use and rainfall. More complex water budget programs require estimates of rooting depth, available water and crop development stage, all of which adds complexity to the arithmetic.

Regardless of rainfall pattern, the "art" of irrigation scheduling can be greatly enhanced by an understanding of plant water relations, a season-long gameplan, and frequent inspections of the soil profile. But even with the most sophisticated irrigation system, getting water to the plant at the right time in the right amount still requires a tremendous amount of management ability.

Cotton Map Available

A poster map of the U.S. Cotton Belt with each county, color-coded based on their bale production level, is available to members of the National Cotton Council. Supplies are limited of this poster; for a free copy, please contact your local NCC Field Service Representative or send $5 for postage to Betty Thorne at NCC, P.O. Box 12285, Memphis TN 38182.

Module Cover Guide Available

A pamphlet on selecting module covers has been prepared for the 1992 harvest season. This publication, authored by Doug Herber of the NCC Technical Staff, covers many aspects of module cover selection and evaluation. Call Pat Yearwood at NCC Memphis 901-274-9030 for free copies.

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