IRRIGATION SCHEDULING[1]

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Even if an irrigation system is well designed and built of high-quality components, crop yields and profitability will not increase if the system is not properly managed and the irrigation applications skillfully scheduled. In other words, the purchase of an irrigation system does not guarantee success - it won't happen automatically.

Climate in the humid southeastern U. S. is much different from many other areas where irrigation is practiced. Rainfall is one of our greatest assets, but it also complicates the management of irrigation. Rainfall is often adequate when one considersthe total amount for a year or a growing season, but it is extremely variable from year to year or from season to season. Also, rainfall seldom occurs at the frequency needed for optimum crop growth and yield. Soils in the region typically are coarse-textured, particularly in the Coastal Plain, and have a very low water-storage capacity. In some soils, plant-available water is further reduced by compacted layers which restrict root growth to the upper part of the soil profile.

Management Strategy. The first decision to be made with respect to irrigation management is to determine the overall management strategy to be used. Four potential management strategies are maximum yield, maximum profit, minimum risk, and optimum utilization of water resource. The maximum yield strategy was popular at one time, but it will not be the most profitable strategy in most cases. The maximum profit strategy is becoming more popular, particularly in the current agricultural economy. The minimum risk strategy may be desirable in some cases, depending upon the crop, operational costs, source of operational funds, debt level, crop contracts, etc. Finally, it may be necessary to optimize the water resources available, particularly if the resource will not allow irrigation of all crops for the entire season. Therefore, water must be used for crops with the greatest expected return or for the crop that is in a critical growth stage. All strategies can be affected by restrictions placed on irrigation scheduling by practices such as chemigation.

Mode of Operation. Two basic questions must be answered in managing irrigation systems - HOW MUCH WATER TO APPLY and WHEN TO APPLY IT. The type and design of the irrigation system and how it is operated basically determine how much water is applied, but irrigation strategy will also affect this. The system may be operated in a low volume/high frequency mode where it essentially replaces daily crop water use, a common operational mode for trickle systems. Likewise, it may be operated in a medium volume/medium frequency mode, where only a part of the depleted soil water capacity is refilled in order to allow capture of rainfall that may occur on the day of irrigation or immediately following it. This requires more frequent irrigation because of reduced water storage unless rainfall completely refills it, which happens quite often in humid SE. Finally, it may be operated in a high volume/low frequency mode, which is most common for sprinkler systems. Depleted soil storage is completely refilled with each irrigation; consequently, rainfall that occurs 1-2 days following irrigation cannot be stored in the soil profile. This operational mode can lead to saturated soil conditions, poor aeration, leaching of nutrients, and poor utilization of rainfall.

Irrigation scheduling answers the question - WHEN? Many techniques or methods are available, and each has advantages and disadvantages. In some cases, the choice may depend primarily on personal preference. Generally, all techniques can be placed in three groups: (1) Soil and plant measurements, which is basically a reactive method where an instrument is observed and irrigation is performed if the value exceeds a predetermined value; (2) Pan evaporation, which is also basically reactive but can be projected based on average conditions and requires a daily measurement or observation of water level in pan; and (3) Computer-based water balance which uses the accounting method for keeping track of the amount of water stored in the soil profile and water use is calculated from weather measurements and forecast values. This is the only method that has significant capability for planning ahead or predicting future irrigation dates.

Soil and Plant Measurements. Several techniques in this category can be used to indicate the water status of the crop or the soil. Tensiometers measure soil water potential, an important indicator for timing irrigation; however, this measurement must be converted to soil water volume before it can be used to determine irrigation volume or amount. Moisture blocks and matric potential sensors measure soil water content and soil water potential, respectively, but these measurements can be affected by salts and other soil contaminants. An infrared thermometer (IRT) measures the temperature of crop leaves and the difference between this temperature and air temperature can be used to indicate crop stress. This technique is used effectively in arid areas, but should be used with caution in humid areas because of cloud cover. The crop water stress index (CWSI) is used to calculate crop stress based on IRT and weather measurements. Instruments are now being marketed to perform these calculations automatically, but they are new and their accuracy in scheduling irrigation in the humid area is essentially unknown. Measurement of leaf water potential is very complex and requires elaborate instrumentation; therefore, it is used primarily as a research tool. It is important since it can be used to relate crop water potential to soil water potential measurements at a given time. Finally, gravimetric soil water content is one of the most common methods used. It is determined by collecting soil samples, weighing them, drying the samples in an oven for 24 hours, and weighing them again to determine the amount of moisture lost. Soil water content is then calculated from these weights. Most soil water measurements are calibrated with this method, but it is not very useful for direct interpretation in irrigation scheduling because the values must first be converted to a volume basis, it requires a significant amount of labor, and there is a substantial time lag before results are available.

The tensiometer is probably the most popular of these methods. Like any of the methods, it must be used properly and its measurements interpreted accurately for it to be of optimum benefit. The principles of installation, maintenance, operation, and interpretation for the tensiometer generally apply to other methods in this group. Most of these measurements reflect conditions at the point of measurement only (the ceramic tip in the case of the tensiometer); therefore, the instruments must be placed selectively to reflect soil water conditions at locations important to the plant. Location relative to the plant and its root system is most important. It is also important to consider the various soil types in the field. The number of soil depths where tensiometers are installed depends upon the soil, crop, and irrigation strategy. One common method is to place one tensiometer shallow (in the primary root zone), typically 12 inches deep, and one near bottom of root zone (about 18 inches deep). The shallow one is used to determine when to irrigate and the deep one is used to prevent overirrigation and loss of water to deep drainage. The number of tensiometer locations is determined by soil variation, size of the irrigation system, and number of crop types. Frequent maintenance of tensiometers is required if reliable information is expected. Also, daily or three-times-a-week data recording of gauge readings are required for timely irrigation management.

To effectively use tensiometer data in managing irrigation you must decide in advance the value (trigger point) and which tensiometer or combination of tensiometers will be used to initiate irrigation. This trigger point is determined primarily by the soil type and crop sensitivity to stress, and published values are available for many crops. The reason different trigger points are required by different soil types is often a point of confusion. Irrigators deal with water volume (gallons, inches, etc.) when operating systems. Normally an irrigator knows that his soil will store a certain volume of water - say 3"- and that he wants to irrigate when the crop has used one-half (50%) of this water. The tensiometer will not provide this information directly, but it will provide a measure of soil water potential which can be related to available water and water volume through a laboratory-determined curve. However, each soil has a unique curve, but they can be grouped generally by textural classification. The 50% depletion level relates to about 0.25-0.30 bar for loamy sand and about 0.70-0.80 bar for silt loam. Therefore, the tensiometer trigger point would be about 25 cbar for a loamy sand and about 75 cbar for a silt loam in order to irrigate when 50% of the available water has been depleted.

Pan Evaporation. A standard National Weather Service (NWS) class A evaporation pan can be used to estimate daily or weekly ET. Typically, measurements are made manually once each day and the difference in water level after correction for rainfall can be used to estimate potential ET for the period. Unfortunately, birds and animals often drink and bathe in pans which can cause significant error; consequently, pans are often covered with wire screen. This keeps the animals away from the water but also reduces evaporation about 16% so that it is approximately equal to potential ET without further correction. Corrections or coefficients must be applied to pan evaporation data to adjust for crop growth stage and climatic conditions before it can be used for scheduling irrigation. Pans do not have to be the standard NWS size in order to be helpful in scheduling irrigation. Smaller, custom built pans have been used by growers in South Carolina to successfully manage irrigation for tree crops.

Evaporation pans may also be modified to directly simulate the soil water balance. An overflow is installed to allow excess water to escape and an adjustable depth scale is installed to allow measurement of the water level. After soil water storage and allowable depletion have been determined for a given site, the depth scale is set to the level at which irrigation is to be initiated. Rainfall raises the level, simulating the filling of the soil profile. If the pan is located under a sprinkler irrigation system, irrigation refills the pan, as with rainfall; otherwise, an equivalent amount of water must be added to the pan at each irrigation.

Computer-based water balance (CBWB). This method is similar in concept to a bank account because plant-available water stored in the soil profile is computed on a daily basis. At the beginning of the growing season, the soil water content is determined by measurement to establish a beginning balance. Daily withdrawals by the crop (ET) are estimated by pan evaporation values, values calculated by models using measured weather values, or by values published or broadcast by public agencies. Daily deposits include rainfall or any irrigation applied. This method allows the prediction of irrigation requirements for several days into the future if forecast or long-term normal weather information is available. It also computes a daily balance using the information provided. When the balance is depleted to a predetermined level (for example, 50% available water), a special deposit (irrigation) is required to raise the balance to an acceptable level. In the water balance, if the deposit is too large (rainfall and/or irrigation), the soil profile cannot store it and the water is lost either to runoff or deep seepage. The computer makes it easier to make the necessary calculations and to store the information in an orderly manner. This method offers the capability for scheduling irrigation for multiple fields, locations, or farms. It also allows planning into the future for irrigation equipment, water allocation, labor, and energy use.

A CBWB was used to schedule irrigation for corn at five locations in four states for a 3-year period. This CBWB calculated daily ET from daily maximum and minimum temperatures and solar radiation values. It allowed the user to make daily changes in rooting depth and allowable depletion of soil water. Rainfall and irrigation was measured at each site. The CBWB estimated irrigation requirements for five days ahead each time it was operated using weather forecasts provided by the NWS. The CBWB was normally operated twice each week at which time the previous forecast was updated using measured weather values for the past few days and a new forecast for the next five days. The goal in this procedure was to maintain the soil water content within the control zone (50 to 100% available storage) throughout the growing season. The CBWB performed satisfactorily during this 3-year period at all locations and compared favorably with the tensiometer method with respect to corn grain yield and the amount of irrigation water required. Until improvements are made in the CBWB, it is recommended that the procedure be corrected once or twice during the growing season with measured water content values.

Summary. First, select the irrigation strategy to be used. Second, decide upon the operational mode to be used. This may be dictated by the irrigation system design, but some choice may be available. Finally, select some method to indicate when to start the irrigation system. It is possible to overirrigate as well as underirrigate if some rational system is not used for making this decision. Several methods are available and the choice may be determined, to some