CONCEPTS OF IRRIGATION SCHEDULING

Danny H. Rogers
Extension Agricultural Engineering
Kansas State University
Manhattan, KS 66506

Irrigation scheduling is a decision-making process through which a determination of when and how much irrigation water will be applied to a growing crop to meet specific management objectives. Factors affecting this process include crop considerations, such as seasonal water requirements, peak use rates, and critical stages of growth; equipment considerations, such as pumping plant and irrigation system distribution capabilities; and labor, management, weather and cost considerations.

Crop irrigation requirements can be quite variable. Figure 1 shows the calculated potential evapotranspiration (PET), actual ET, and growing season rainfall for seven growing seasons at Colby, Kansas. Potential ET can be thought of as the environmental demand placed on a crop and is influenced by climatological factors such as temperature, relative humidity and solar radiation. Actual ET is the amount of water used by the crop which is controlled by many factors, including the crop type and stage of growth and the soil water available to the crop. Figure 1 demonstrates the seasonal variability of these values. PET ranges from 30 to 40 inches. Actual ET values have varied by nearly ten inches. Rainfall is also variable and during this span of time some of the wettest and driest months and years on record have occurred. The difference between actual ET and rainfall represents the irrigation demand. This demand, of course, is variable and is enhanced since high PET years generally coincide with low rainfall years. Daily fluctuations in ET are also normal, and can range from nearly zero to one-half inch per day at peak crop use rates and high environmental demand periods.

A method of irrigation scheduling will help irrigators cope with these widely fluctuating demands and reach desired yield goals while minimizing water and irrigation fuel requirements.

Irrigation scheduling can be accomplished using the following procedures:

1. Determine the active crop root zone of the crop.

2. Determine the amount of soil water storage capacity in the root zone.

3. Determine the amount of allowable soil water depletion

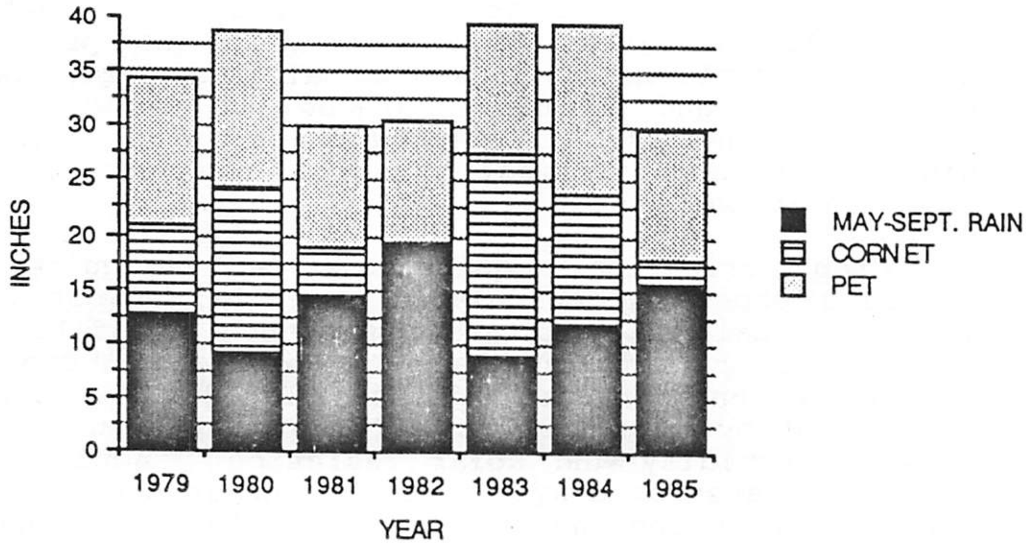

Figure 1. Calculated Potential Evapotranspiration Calculated Actual Evapotranspiration for Corn, and Growing Season Rainfall at Colby, Kansas.

before irrigation is started.

4. Determine the total crop water use since the completion of the last irrigation, using ET reports or soil water depletion observations.

5. Determine the total effective rainfall since the completion of the first set of the last irrigation.

6. Begin the irrigation when the total crop water use minus the effective rainfall equals the allowable soil water depletion or when the soil depletion amount equals or exceeds the net irrigation application amount.

This procedure will maintain the soil water levels at and above the allowable soil water depletion if the irrigation system has the capacity to supply the water requirements of the crop at its peak rate of water use. If your system capacity is less than this, the crop will gradually reduce the soil water reserves unless natural rainfall replaces the deficiency. It is recommended that periodic soil water sampling be done to insure that adequate water reserves are being maintained.

CROP ROOT ZONE

The active root zone of the crop is dependent on crop type, stage of maturity, and soil conditions. All common Kansas crops have similar rooting depths, generally taken as a three foot depth. Soil conditions, such as hard pans, may restrict root development. The root zone of the crop may exceed three feet, but the majority of the roots and therefore the majority of the water withdrawn will be from this zone. Any root development beyond three feet can be considered a safety factor. If the entire root zone is divided into quarters about 40% of the water is taken from the top quarter, 30% is taken from the second quarter, 20% in the third quarter and only 10% in the bottom quarter. This pattern is true for all our normal annual plants and many of the perennial ones. The uptake of nutrients, in general, follows a pattern similar to water so the upper half of the root zone is the most important zone.

Scheduling requires an estimate of the root growth. Early irrigations should be based on a lessor depth. Root growth parallels plant growth until the reproductive stage of growth.

SOIL WATER HOLDING CAPACITIES

The soil texture influences the water holding capacity of the soil; the coarser the texture, the less the holding capacity. Holding capacities of some common Kansas soils are shown below.

Average Available Water
Holding Capacity for Kansas Soils*
(inches per foot)

Sand	0.8
Sandy Loam	1.9
Fine Sandy Loam	1.7
Silt Loam	2.3
Clay Loam	2.1
Clay	2.0

* Selected soil types from 1977 SCS Irrigation Guide

The water used by plants is soil water. Soil texture (soil particle size) controls the availability of soil water. Heavy soils (clays) hold the most water, but silt loams or medium textured soils contain the most available soil water. Sands hold the least water and the smallest available amount.

ALLOWABLE SOIL WATER DEPLETION

Crops have differing levels of water depletion tolerance. Too much depletion stresses the crop and depresses yields; too frequent watering wastes water, fuel, and fertilizer and could also depress yields. General irrigation guidelines from research has shown a 50% depletion of available soil water to be a good management guideline for most crops.

The total available soil water is dependent upon the soil texture and the plant rooting depth. Multiply the rooting depth by the available holding capacity of the soil to obtain total available water. If the available water capacity of the root zone is 4 inches, then using the allowable depletion guideline, only 2 inches of depletion are allowed before soil water is replaced with irrigation. To do this, a method to measure or estimate the amount of water used or the amount of water remaining in the soil must be used. Plant symptoms of water stress are normally too slow to prevent yield reduction or damage to the plants to be used as an effective scheduling tool.

CROP WATER USE

ET estimates of crop water use have been briefly described previously. Scheduling, using ET information, is a method that is becoming more available to irrigators today.

Formerly, this method was difficult to use because of the weather data input required and the calculation involved. However, better collection and exchange of weather data, increasing accuracy of crop water use models, and increased availability of computers have made this method of scheduling more easily incorporated into an on-farm management program. Some ET data is now available through radio broadcasts, weather service telephone lines and newspaper. Hopefully its availability will continue to increase.

Crop water use can be indirectly estimated by making soil water observations. There are several different methods that can be used. Using a soil probe to remove a soil core and physically feeling the soil core is one way. Using instrumentation such as gypsum blocks or tensiometers which are buried in the soil during the growing season is another. Soil water observations used to estimate soil water status will automatically take into account rainfall and irrigation applications.

EFFECTIVE RAINFALL

The amount of rainfall that actually enters the root zone is the effective rainfall. Effective rainfall is based on the intensity and duration of the rainfall event. High intensity rainfall events exceed the soils infiltration capacity and increase runoff. High intensity rainfall, coupled with long duration, would indicate large runoff volumes. Low intensity rainfalls are desirable since the soil infiltration capacity would be more closely matched. Long duration rainfall events have increased runoff potential since the soil's intake capacity will decrease as water content increases.

The irrigator should measure rainfall in a location near the field or fields where scheduling is being used. Simple, inexpensive rain gages will do. Reported rainfall from a nearby weather station can be used but summer rains, as everyone knows, are quite variable and frequently do not cover a large area. Thus, locally reported rainfall may be in serious error when used for a particular field.

BEGIN IRRIGATION

Begin irrigation when the allowable soil water depletion is estimated or observed. The irrigation amount that is important to the crop is the net irrigation amount. This is the part available for the crop. With sprinkler systems, this is assumed to be about 75% of the water pumped. With surface systems, this is 50 to 80% depending upon the system. Measuring the soil water before and after an irrigation is a way to determine the net irrigation amount. Of coarse, another complication is that the irrigation efficiency may be variable, particularly for flood irrigation systems.

This example assumes that the irrigation amount can be added in one day and that the amount of irrigation water is flexible. Neither of these conditions are the usual situation. A surface system designed to apply a 4 inch application does not work as well when only 2 inches are applied and a center pivot system may add about one inch per application. In addition, it may take several days to apply the water, so the irrigator must anticipate when to start in order to complete the irrigation before the last part of the field to be irrigated is stressed.

The crop water use information can be used as an indication of future water needs as well. Combining future water need prediction with allowable depletion and system capacity information allows the irrigator to determine when to start irrigation on the first set to avoid stress on the last set.

If the irrigator wishes to use the principles of limited irrigation, the method of scheduling outlined above is still helpful. The principle of limited irrigation is that many crops can stand much greater stress than the 50% of available soil water normally used for full irrigation if soil water is readily available at certain key times. Plant growth may be affected but 80 to 90% of the full irrigation grain yields may be obtained with half the amount of irrigation water used with full irrigation. Other limited irrigation programs combine allowable depletion and stage of growth criteria. Full irrigation may be practiced only during critical growth stages and limited at others.

Summary

Irrigation scheduling is a method of determining both the time of irrigation application that should help make the most efficient use of water resources. Irrigation scheduling may not result in water savings, but helps assure whatever water is applied is most likely to be available for use effectively.