PNW 288 • Reprinted October 1994

Irrigation Scheduling

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The main purpose for irrigating is to supply needed water for crops. Plant growth is dependent on photosynthesis. While the plant exchanges gases with the air for photosynthesis, some water evaporates. Water is taken up from the soil by plant roots to replace this water. The water leaving the plant is called *transpiration.*

An illustration of a water balance is shown in Figure 1. The combination of transpiration and evaporation is called *evapotranspiration* (ET) and is considered as the crop water use. The process of water being used by the plant and replaced by irrigation sometimes is compared to a checkbook because of the similarity to withdrawals and deposits. Water taken out of the soil must be made up with either rainfall or irrigation, or the soil reservoir will become dry.

Good irrigation scheduling means applying the right amount of water at the right time—in other words, making sure water is available when the crop needs it. Scheduling maximizes irrigation efficiency by minimizing runoff and percolation losses. This often results in lower energy and water use and optimum crop yields, but it can result in increased energy and water use in situations where water was not being managed properly.

Crop water use

Research has provided information on how much and when a crop needs water. Crop water use can be estimated by a number of methods: evaporation pans, weather data, or soil-moisture monitoring. This information may be available via telephone, radio reports, newspapers, or computers.

Measurements of temperature, wind, solar radiation, and humidity with a weather station can be used to estimate water requirements. A network of automated weather stations is being installed in the Pacific Northwest to make this information available via computer.

An example of crop water use over a season for alfalfa being grown at an elevation of about 3,000 feet is shown in Figure 2. Note that water use is less during the cooler parts of the year and peaks in midsummer. Each cutting temporarily decreases crop water use until the alfalfa grows back enough to completely cover the ground (called full *cover).* Other crops have water use curves with different shapes.

Irrigation amount

An irrigation system usually is designed to deliver a steady flow of water to an irrigated field at a rate sufficient to meet peak irrigation requirements. If the system is operated continuously as shown in Figure 3, excess water will be applied both early and late in the season. Irrigation scheduling is a management tool that can help avoid such overirrigating.

The gross application of water that can be delivered by an irrigation system in a 24-hour day can be determined by:

$$\text{Gross application (in/day)} = \frac{\text{gpm x } 0.053}{\text{acres}}$$

Net irrigation is used to meet crop water needs instead of gross irrigation since not all water applied is available for plant use. Some water may be lost to deep percolation, runoff, wind drift, and evaporation. An estimate or measurement of the efficiency of application of the irrigation system is needed to determine the net application. Table 1 lists representative application efficiency factors to be used in calculating net irrigation. Multiply gross application by these factors to find net application to be used in scheduling.

Make every effort to assure the most uniform irrigation possible. Irrigation systems with distribution problems may have substantially lower efficiencies than those in Table 1.

It is important to measure the flow rate (gpm) of water being delivered for irrigation. Water cannot be well managed without knowing the volume applied.

A good quality rain gauge at each field is important because wide variations in rainfall can occur over relatively short distances. Rainfall that runs off the field should not be counted as useful moisture. In general, about 75 percent of rainfall is stored in the soil.

Soil-water relationships

The texture of soil to be irrigated is very important in determining when and how much to irrigate. Table 2 lists abilities of different soil types to store water.

The plant root zone determines soil depth from which the crop can draw moisture. Table 3 shows the root zones that mature crops depend on for 90 percent of their water needs. Early in the season, annual crops have shadow root zones and approach the values in Table 3 only when they reach full cover.

Plants will show signs of wilting and drought stress before they use all available water stored in the soil. Table 3 shows percent of total available moisture that different crops can withdraw without suffering yield loss.

Soil moisture should be measured initially and monitored regularly to determine the available soil moisture. Soil moisture blocks, neutron probes, tensiometers, or the feel method with soil probing will all work. Some methods work better than others with different soil types.

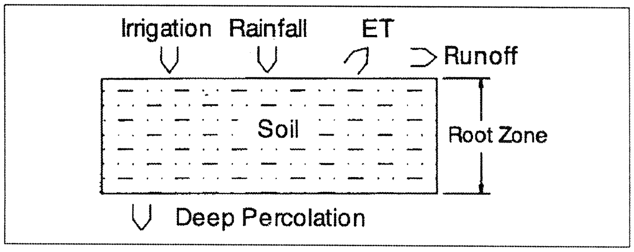

Figure 1.—Schematic representation of the root-zone water-balance components.

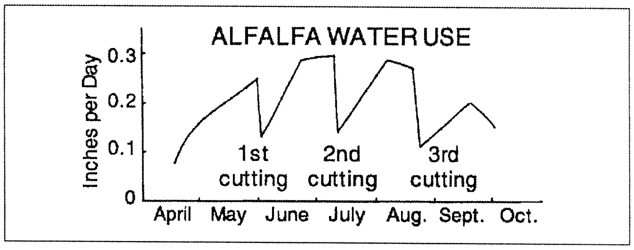

Figure 2.—Typical growing season crop water use by alfalfa.

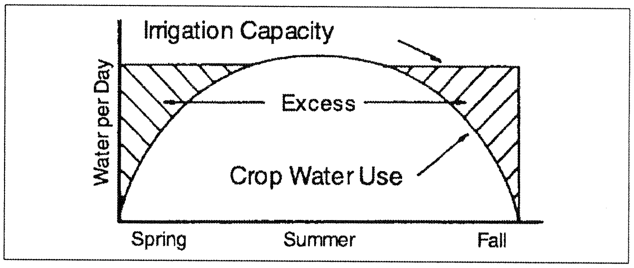

Figure 3.—Comparison of crop water use during growing season and potential overapplication when irrigation system is operated with equal settings every pass.

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Scheduling

Irrigation could be scheduled by continuously monitoring the soil moisture as shown in Figure 4 and starting irrigation when measurements so indicate. Because soil moisture monitoring entails a lot of work and an irrigation cannot be completed instantly, this is not a practical approach. Instead, soil moisture usually is measured infrequently, and the "checkbook" method is used to estimate the soil moisture condition between measurements.

The root zone should be filled with moisture just before the period of peak crop water use. The amount of usable water available in the root zone and the rate at which water is being used determine irrigation timing. When the soil moisture profile is full, multiply depth of root zone (Table 3) by available moisture-holding capacity per foot of soil (Table 2) and that product by the percent allowable depletion (Table 3) to determine available water in storage that can be used by crops between irrigations. The maximum number of days before the next irrigation must be applied is calculated by dividing available soil moisture by the estimated daily crop water use.

Example: Alfalfa on a deep clay loam soil, where root zone is 4.0 ft (Table 3); available moisture is 2.3 in/ft (Table 2); and allowable depletion is 60 percent (Table 3). Our equation is:

Usable moisture = Root zone x Avail. moisture x Allow. deplet.
= 4 x 2.3 x 0.60
= 5.5 inches

Assume the crop water use averages 0.3 inch per day:

$$\frac{\text{5.5 inches of usable soil moisture storage}}{\text{0.3 inch per day}} = 18 \text{ days}$$

The next irrigation must be applied within 18 days. As a full irrigation cycle must be completed in 18 days, irrigation must be started early enough to reach the last set by the 18th day. It is important not to overestimate the number of days between irrigations.

The strategy used to manage irrigation systems varies with type of system. For systems that apply very large amounts of water infrequently (surface systems and some side-roll and hand-line sprinkler systems), the irrigation cycle should be timed so it is completed and refills the soil profile before all usable soil moisture in the root zone is depleted. Do not let the irrigation schedule be determined by the driest portion of the field (for example, the portion with shallowest soil or coarsest texture) unless it represents a significant area.

Often, irrigation systems that must apply heavy applications must begin the irrigation cycle before there is room in the soil profile to store the full irrigation. The irrigation application should be limited when possible so that the root zone is not overfilled. Controlling the amount of irrigation applied and improving application uniformity may be the only possible way to better manage water that is delivered on a fixed calendar schedule. A timer sometimes can be used with hand-line and side-roll sprinklers to limit the application to only the amount that can be stored in the root zone.

For irrigation systems that can apply light irrigations frequently (center pivots, solid set sprinklers, moving sprinkler systems, and drip systems), the system should be started when there is enough room in the soil profile to store the minimum application.

In some cases, it may be desirable to cut back on irrigation late in the season and use most of the available soil moisture by the end of the growing season unless there is a crop on the field that may suffer from fall drought or winter kill. This practice allows the capture of as much off-season precipitation as possible.

Summary

Knowing when crops need water and how much they need are the keys to good water management. With basic knowledge of the soil type and crop water use information, an irrigator can easily learn to schedule more scientifically and to anticipate irrigation demands. County Extension or Natural Resources Conservation Service offices can provide more information on scheduling. Computer programs for irrigation scheduling have been developed to help provide timely and precise scheduling techniques. Irrigation consulting and scheduling services are available in many areas to perform the technical tasks required to schedule irrigations in order to save both water and energy.

Table 1.—Application efficiency factors.

Conditions	Center pivot	Hand move, side roll, solid set	Big gun
Daytime, wind under 10 mph	0.9	0.8	0.7
Daytime, wind over 10 mph	0.8	0.7	0.6

Table 2—Soil water storage capacities*.

Soil General description	 Texture class	Readily available moisture/ft.
Light, Sandy	Coarse Sand	0.7 inches
	Fine Sand	0.9
Medium, Loamy	Fine Sandy Loam	1.5
	Silt Loam	2.0
Heavy, Clay	Clay Loam	2.3
	Clay	2.0
	Peats and Mucks	2.5

*Values given are for deep, uniform soil profiles. Layering and changes in soil texture within the profile may increase or decrease effective available water.

Table 3.—Root-zone depths for selected crops.

Crop	Root zone* (ft)	Time to reach mature root zone	Allowable depletion %
Alfalfa	4.0	0	60
Beans	2.5	50 days after planting	50
Corn	3.0	10 days after tasseling	50
Grapes	3.0	0	65
Orchard	6.0	0	50–65
Potatoes	2.0	80 days after planting	30–40
Pasture/ Turf	2.0	0	60
Small Grains	3.0	heading	50
Sugar Beets	3.0	10 days after planting	50

*The root zone can be limited by shallow soils, compaction layers, and dry soil—all of which reduce amount of water available to the crop, thus requiring more frequent irrigations.

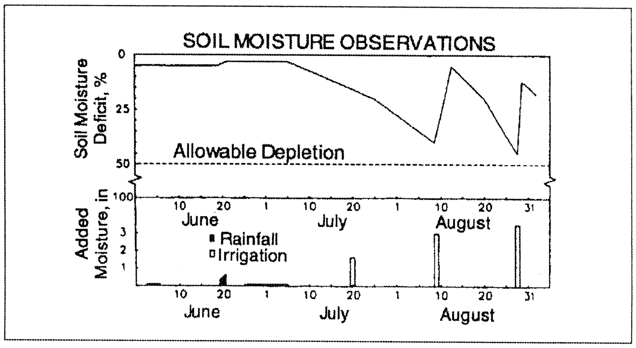

Figure 4.—Typical soil-moisture monitoring chart for a full growing season.

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Published January 1986; Reprinted October 1994. 50¢/50¢/50¢