NATIONAL CORN HANDBOOK

Irrigation Scheduling for Corn—Why and How

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Irrigation scheduling is a planning and decision-making process, the primary decision being: *how much water to apply and when to apply it.*

How much water to apply depends on (1) the soil's available moisture storage capacity and (2) the amount of available water depleted from the soil profile by crop water use. (Soil moisture storage capacity, as explained later, is determined by available-water holding capacity of the soil and crop rooting depth.) When to apply irrigation water depends on rate of water use by the crop and the total available soil moisture.

This publication deals with the why's and how's of corn irrigation scheduling. Discussed are the potential benefits of proper scheduling; the crop, soil, and climatic factors involved and their relationships; methods of determining irrigation timing; and scheduling considerations unique to different climatic regions.

VALUE OF IRRIGATION SCHEDULING

The main objective of irrigation scheduling is to manage irrigations for greatest effectiveness. Proper scheduling will minimize yield loss due to crop water stress, maximize yield response to other management practices, and optimize yield per unit of water applied (irrigation efficiency)—all of which contribute to profitability.

Scheduling that results in either excessive or inadequate water application can significantly reduce the potential for profitability. For instance, over-irrigation during the growing season may eliminate crop water stress, but it will also lessen irrigation efficiency and yield response to other management practices, such as fertilization, planting date, population and weed control. Inadequate irrigation, on the other hand, results in crop water stress and less yield response to other management factors, even though irrigation efficiency remains high because runoff and deep percolation are reduced.

FACTORS AFFECTING IRRIGATION SCHEDULING

Knowing when and how much to irrigate is determined primarily by four factors—availability of the water in the soil, water needs of the crop, value of any rainfall and actual output of the irrigation system. The effect of each factor and how to assess it are discussed in the following paragraphs.

Soil, Water and Plant Relationships

Soils are diverse and require different water management techniques. For instance, their textural characteristics dictate the water holding capacity, intake rate, and drainage rate. Table 1 gives the available-water holding capacities of ten different soil types. Soils also differ as to depth adequate for active root development; some have underlying layers of gravel or had pan that would restrict root growth.

Soil is like a sponge in that "squeezing" water from it is easy at first but becomes more difficult as water is removed. That's just what the corn plant experiences as it grows. When the soil profile is full, the plant expends little effort to obtain water; but as soil moisture becomes depleted, more effort is required to meet the plant's water demands.

The water content of a soil after being saturated by rainfall or irrigation and allowed to drain is called *field capacity.* The point at which a crop can no longer take water up from the soil is called the *permanent wilting point.* The water held by the soil between field capacity and the permanent wilting point is considered *available water.* Corn is capable of using 50 percent of the available water stored in the soil before plant stress begins.

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Table 1. Available-Water Holding Capacity of Ten Soil Types.

Soil Type	Textural characteristics	Storage capacity
		in./ft.
0	Sandy clay loam	2.0
1	Silty clay loam	1.8
2	Clay loam	1.8
3	Loam	
Low (2%)	Very fine sandy loam	2.0
O.M.	Silt loam	
4	Loam	
High (3%)	Very fine sandy loam	2.5
O.M.	Silt loam	
5	Fine sandy loam	1.8
6	Sandy loam	1.4
7	Loamy sand	1.1
8	Fine sands	1.0
9	Silty clay	
	Clay	1.6

Soil can be viewed as a reservoir that holds moisture for plant use. The capacity of the reservoir for a particular soil type is determined by multiplying that soil's available-water holding capacity (Table 1) by the crop rooting depth.

Maximum allowable depletion of the soil reservoir is reached when water must be added to prevent crop stress (which for corn is when it has used half the stored water). The allowable depletion point increases during the season as roots grow deeper, thus enlarging the soil reservoir. Table 2 presents the estimated maximum moisture deficiency levels for the ten soil types in Table 1 at various crop rooting depths.

Although corn root depth early in the season is shallow, moisture must nevertheless be available in the eventual root profile to assure good root development. When actively growing, corn obtains 90 percent of the water it uses from the top 3 feet of the soil profile.

The normal root depth of corn at various stages of growth is shown in Table 3. By knowing both corn growth stage and soil type, an irrigator can determine from Tables 1 and 3 the soil's total water holding capacity and, from that, the maximum amount of water to apply at one time if the soil moisture level is depleted.

For example, a sandy loam (see Table 1) when corn is at silking (see Table 3) has a total water holding capacity of 4.2 inches (1.4 in water/ft. soil depth x 3.0 ft root depth). Since only 50 percent of that capacity can be used by the corn before stress will begin, the maximum allowable depletion would be 2.1 inches of water (4.2 in. x .5).

Crop Water Demand

Water is absorbed from the soil, transported through the plant, then lost to the atmosphere by a process called *transpiration.* Evaporation from the soil surface combined with transpiration is called *evapotranspiration.*

The evapotranspiration rate depends on temperature, humidity, wind, solar radiation, and total leaf area of the crop. When temperature is relatively low and humidity is high as on a calm, cloudy day, the evapotranspiration rate will be low. If temperature is high and humidity low as on a sunny, windy day, the rate will be high.

Under similar environmental conditions, a small, young plant with little leaf area and limited root system would require much less water than a mature plant with its large leaf area and dense root system, 75 percent of which is in the top 12 inches of soil. The effect of plant size on crop water demand is illustrated in Figure 1.

Rainfall Value

Rainfall usually reduces the requirement for irrigation. However, not all rainfall can be considered effective; thus, estimates are needed to determine its value.

Table 2. Maximum Allowable Moisture Depletion of Ten Soil Types at Various Root Depths.

Root depth	Soil type (see Table 1) 0	1	2	3	4	5	6	7	8	9
feet	inches									
1.5	1.5	1.4	1.4	1.5	1.9	1.4	1.0	0.8	0.8	1.2
2.0	2.0	1.8	1.8	2.0	2.5	1.8	1.4	1.1	1.0	1.6
2.5	2.5	2.2	2.2	2.5	3.1	2.2	1.8	1.4	1.2	2.0
3.0*	3.0	2.7	2.7	3.0	3.8	2.7	2.1	1.6	1.5	2.4

* For corn, 75 percent of available soil moisture may be removed after dough stage of growth when monitoring a 3-foot depth.

Table 3. Average Root Depth of Corn at Various Stage of Growth

Stage of corn development	Assumed root depth*
	feet
12-leaf	2.0
Early tassel (16-leaf)	2.5
Silking	3.0
Blister	3.5
Beginning dent	4.0

*Root development may be restricted to a depth less than that shown due to compaction or limiting layers.

Rainfall can be lost from the soil in two ways—runoff and deep percolation. Runoff occurs when the rainfall rate exceeds the soil's infiltration rate. Low rates of rainfall over an extended period of time will often replenish the soil without runoff. Water is lost by deep percolation when rainfall exceeds the soil's total water holding capacity. Because rainfall is highly variable, measurements should be taken near the fields scheduled for irrigation.

A small amount of precipitation has little effect on irrigation water management. However, rainfall sufficient to fill much of the root zone will place an irrigation schedule in a start-over mode; and unless the schedule is reestablished, over-irrigation of a portion of the field(s) scheduled may result. With a center-pivot irrigation system, this problem can be successfully dealt with by varying the amount of water applied around the field.

Gravity irrigation systems, unfortunately, do not allow this flexibility; and irrigation must be started based on the last portion of the field(s) to be irrigated. Thus, during high water-use periods, when crop water demand equals system capacity, precipitation will likely result in over-irrigation. Delaying irrigation to avoid this, however, could lead to crop stress later in the season.

The best guide for determining the effectiveness of precipitation is to consider soil type together with rainfall intensity. For example, there will be runoff from a high-intensity rain much sooner on a fine-textured soil than on a coarse-textured soil. Rainfall, like soil type, can vary greatly in short distances, making them both very site-specific factors. Thus, precipitation should be measured in the immediate location of the field scheduled and estimates made of the efficiency of *each* rainfall.

The irrigator should take advantage of rainfall when possible, and remember that accurate measurement is the primary way to determine its value.

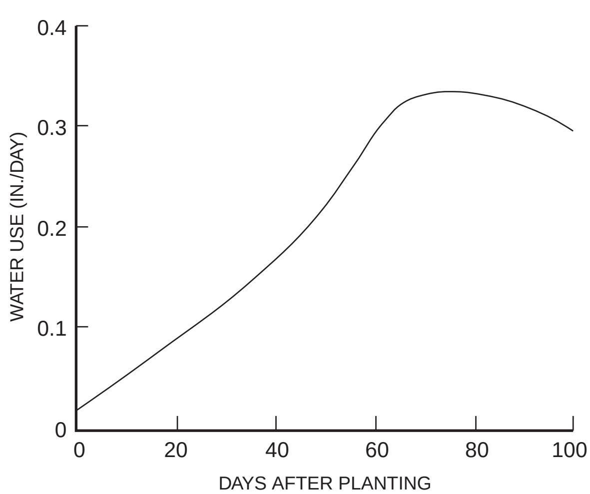

Figure 1. Water use by the corn plant in the first 100 days after planting calculated from rainfall and irrigation.

Measurement of Irrigation Water

Periodic calibration with flow-measuring devices is important to ensure that desired irrigation water application rates are being realized. The output rate of an irrigation system is a critical factor for scheduling and must be known because it determines how long the system has to operate to apply the desired amount of water.

For sprinkler-type irrigation systems, flow meters or rain gauges should be used to measure water applied. Straight-sided cans make inexpensive rain gauges and, if set out in sufficient numbers, will also help determine sprinkler uniformity. For furrow irrigation systems, flow meters at the pump or weirs in the delivery canal should be used.

METHODS OF TIMING IRRIGATION

As already discussed, a soil's water holding capacity indicates both amount of water available for plant use and maximum allowable depletion. Thus, to determine when irrigation is needed (i.e., when maximum allowable depletion would be reached), one must know how much water is in the soil reservoir at any given point in time.

There are a number of ways to make this estimate. The most common ones are discussed here and can be used regardless of soil type.

Feel Method

The feel method is one of the oldest ways to determine amount of soil moisture. As water content changes, the "feel" of soil changes. With experience, some people can calibrate their sense of touch to estimate available soil water. Table 4 describes the appearance and feel of sandy, loamy, and clayey soils at various moisture content levels.

The only instrument needed for employing this technique is an inexpensive hand probe long enough to reach down through the full root profile. However, although simple to use, the probe-feel method allows for only approximate soil moisture values. (When using any stationary soil moisture measurement device, a soil probe is recommended for double checking equipment operation and confirming moisture values in other areas of the field.)

Table 4. Visual and Textural Characteristics of Three Soil Classifications at Various Moisture Contents.

Pct. available water	Soil classification: Sandy	Loamy	Clayey
0	Dry, loose, flows through fingers	Powdery, dry	Hard, baked, cracked
50 or less	Appears dry, will not form a ball under pressure	Crumbly, but will hold together from pressure	Pliable, will ball under pressure
50 to 75	Tends to ball under pressure but does not hold together	Forms ball, slightly plastic, will slick slightly with pressure	Forms ball, pliable, slicks readily
75 to 100	Forms weak ball, breaks easily, will not slick	Forms ball, will ribbon out between thumb and forefinger	Easily ribbons out between fingers, has slick feeling

Electrical Conductivity

Electrical resistance blocks measure soil water more precisely than the feel method. Small blocks made from plaster of paris (gypsum), nylon, fiberglass, or other material containing electrodes are buried in the soil with wires extending to the surface. An electrical meter touching the wires measures the change in electrical resistance during wetting and drying cycles.

The blocks, which can be used only one season, are placed at four locations or stations in a field. At each station, three blocks are buried at 0.5-, 1.5-, and 2.0-foot depths.

With a gravity irrigation system, one station should be at the top and one at the bottom of the field in both the first and last irrigation sets. With a center-pivot system, there should be two stations on each side of the normal stop position, all accessible from the pivot roadway. Of the two on each side of the road, one should be near the center and other near the outer edge of the pivot. Flag the location of any instruments used in fields so they can be found easily.

The electrical conductivity method is recommended on the finer-textured soils.

Tensiometers

Tensiometers are mechanical instruments that measure soil water suction, as shown in Figure 2. They can be used successfully for scheduling irrigations if the relationship between soil water suction and available water for a particular soil is known.

Tensiometers are recommended for use on loamy sands and fine sands. Their placement and the number of stations in a field are the same as for electrical resistance blocks.

Neutron Moisture Probe

A neutron probe measures soil water content using a radioactive source. The instrument itself and the access tubes (which require installation) are quite expensive. Therefore, the neutron probe method is used mostly for research and by some irrigation consulting firms that measure large numbers of fields. It is not recommended for small-scale irrigation scheduling.

Evaporation Pans

Evapoation pans may be used to calculate the amount of water utilized by the crop. The pans can

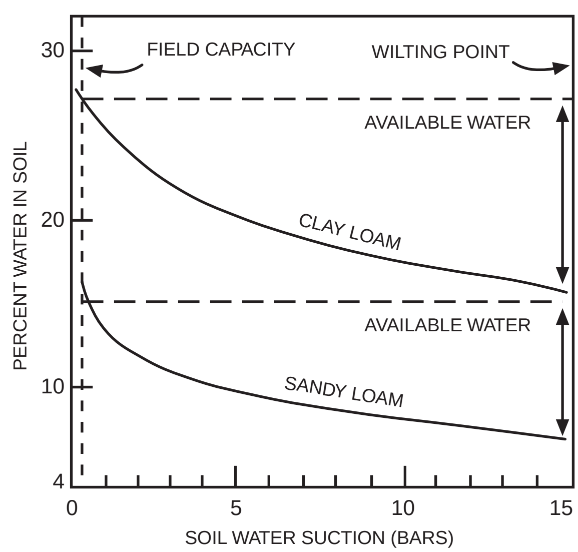

Figure 2. Relationship between soil water suction and percent water for clay loam and sandy loam soil types.

serve wide areas, but calibration is required based on a crop coefficient to relate evaporation rate to actual water use. The coefficient is the ratio of potential evapotranspiration (water loss from both crop and soil surface) to pan evaporation.

During the early part of the growing season, the crop coefficient is less than 0.5 but approaches 1.0 as the crop canopy closes. For example, if the crop coefficient is 0.3 and 1 inch of water evaporates from the pan, crop water use would be 0.3 inch.

Computer Programs

Computer programs have been developed for scheduling irrigation, and they use meteorological data to calculate water use. The computer forecasts the timing and amount of irrigation water necessary for optimum crop production.

Computer irrigation scheduling is available from computer networks that provide scheduling programs for a service fee. There are also similar programs for personal computers and hand-held calculators that may be purchased.

Water Budgeting

Water budgeting is a method used to balance the available soil moisture. Rainfall and irrigation amounts represent credit entries, whereas evapotranspiration is a debit entry. Rainfall and irrigation should be measured as previously discussed. Evapotranspiration can be estimated from evaporation pan data, from weather data obtained at a nearby weather station, or from information available through local agencies that calculate crop water use.

The critical value in water budgeting is soil water holding capacity. Fifty percent of this value is the maximum allowable depletion level, and 50 percent is the maximum application amount.

A good starting point for a water budget system is when the soil water level is at field capacity. This allows the center-pivot irrigator to follow a replacement schedule whereby any water used by the plant is replaced through irrigation or rainfall.

Water budget scheduling also provides water management for the gravity irrigator. Plant water use can be estimated from any of the sources noted above. Since the soil profile is normally filled with each irrigation, soil water holding capacity can serve as a guide to determine amount of water available. When water used equals the maximum allowable depletion, irrigation is needed.

An example water budget balance sheet for corn is presented in Figure 3.

IRRIGATION SCHEDULING IN DIFFERENT CLIMATIC REGIONS

Humid and Subhumid Region Scheduling

The high probability of precipitation makes scheduling irrigation in humid regions difficult. Chances of over-irrigation are high because of the greater likelihood of summer rains. Rainfall usually supplies the major part of a crop's water requirement in these regions and should be used to the full extent.

Since the chances are good of rainfall occurring shortly after irrigation, it is advisable to not recharge the complete root zone. This not only reduces irrigation costs, but also minimizes nutrient leaching. Research on a variety of soil types has shown that corn yields of 150-200 bushels per acre can be obtained by recharging just the top 8-12 inches of the soil profile.

Mobile sprinkler systems, such as traveling guns and center pivots, require an extended period of time to cover the irrigated area. This poses no problem as long as the irrigation cycle is not interrupted by rainfall. Sufficient amounts of rain uniformly recharge the soil to field capacity over the entire irrigated area simultaneously.

If the available soil water is permitted to reach the maximum allowable depetion level following rain, a portion of the field will likely experience considerable water stress before the irrigation cycle is completed. This problem can be minimized by (1) starting the system when half of allowable depletion occurs and (2) applying half the normal water rate (which should allow the abbreviated cycle to be completed in half the normal time). Such a procedure re-establishes the irrigation cycle without subjecting part of the crop to excessive stress.

Arid and Semiarid Scheduling

Depending on soil type, expected early precipitation or irrigation at planting normally meets the corn crop's water demand during the spring in arid and semiarid regions. Then as reserve moisture is used, irrigation becomes the primary means for plant growth.

Scheduling irrigation for corn during high water-use periods may seem unnecessary if an irrigator is at best marginally capable of keeping up with crop demands due to either low system capacity or water supply and/or cost restrictions. In such cases, a logical schedule during peak water use is probably to irrigate continually, unless there are rainstorms of sufficient number or intensity for the soil profile to "catch up." Scheduling will then determine if continued irrigation is needed should that precipitation occur.

In most cases, scheduling in the arid areas provides the greatest return during spring and fall.

As the name implies, arid and semiarid regions have low probabilities of precipitation. Therefore, irrigators should plan to fill the soil profile during irrigation rather than leave room for possible rain. Water use can average above .25 inch a day during the summer, which means over 1 inch of soil moisture depletion in only 4 days.

It is important to keep ahead of crop demand rather than to risk falling behind trying to leave room for low-probability rainfall. The exception to this occurs in the fall when crop water demand is on its downward trend.

Field soil type: Fine sand.

Soil available-water holding capacity: 1.0 inch per foot (from Table 1).

Maximum available profile moisture: 2.0 inches from seedling to 12-leaf stage; 3.0 inches from 12-leaf stage to maturity.[a]

Week	Growth stage	Weekly[b] evapotran-spiration	Weekly rain-fall	Weekly irri-gation	Weekly[c] moisture balance	Actual[d] profile moisture
				inches/acre		
1	Seedling	0.4	1.5	0	+1.1	2.0
2	2 to 4 leaf	0.4	0	0	-0.4	1.6
3	4 to 6 leaf	0.6	0	0	-0.6	1.0
4	6 to 8 leaf	0.8	1.2	0	+0.4	1.4
5	8 to 10 leaf	1.1	0	1.0	-0.1	1.3*
6	10 to 12 leaf	1.4	0	1.5	+0.1	1.4
7	12 to 14 leaf	1.4	0	1.4	0	2.4[e]
8	14 to 16 leaf	1.5	2.3	0	+0.8	3.0[f]
9	Pollination	2.3	3.0	0	+0.7	3.0
10	Pollination	2.3	0	1.0	-1.3	1.7*
11	Grainfilling	1.8	0	2.0	+0.2	1.9
12	Grainfilling	1.8	0	2.0	+0.2	2.1
13	Grainfilling	1.8	0	2.0	+0.2	2.3
14	Grainfilling	1.7	1.5	0	-0.2	2.1
15	Grainfilling	1.7	1.0	1.0	+0.3	2.4*
16	Maturity	1.6	0	1.5	-0.1	2.3
17	Maturity	1.6	0	1.0	-0.6	1.7

a Maximum available profile moisture = soil available-water holding capacity (from Table 1) x approximate plant root depth at various growth stages (from Table 3).

b Evapotranspiration = water used by the plant (see Figure 1) + water lost to the atmosphere (estimated). Values will vary with location and year.

c Moisture balance = (rainfall + irrigation) - evapotranspiration.

d Profile moisture = Previous week's profile moisture + present week's moisture balance.

e This 1 inch increase in profile moisture from the previous week is due to the additional foot of root depth as corn passes the 12-leaf stage.

f The week's +0.8 inch moisture balance added to 2.4 inches already in the profile totals 3.2 inches. However, 3.0 inches is the profile maximum, which means the excess water drained below the root zone.

***** Usually, irrigation of corn should begin when profile moisture falls below the soil's maximum allowable moisture depletion (from Table 2) and there has been no significant rainfall. In this example, that point is 1.0 inch up to the 12-leaf stage and 1.5 inches after the 12-leaf stage.

Figure 3. Example of a water budgeting balance sheet for corn.

SUMMARY

Corn adapts well to furrow, sprinkler, and traveling-gun irrigation; and all three systems are equally adaptable to irrigation scheduling. Center pivot is an excellent system for applying different amounts of water during the growing season uniformly across a field.

When scheduling sprinkler, traveling-gun, or center-pivot irrigations, the potentially high rate of evaporation should be taken into account to determine sprinkler efficiency. The easiest way to measure total water applied is catch cans placed at several locations in the field. Flow meters will provide data on total water pumped but not on application efficiency.

Properly managed furrow irrigation can apply a relatively uniform amount of water. However, application of small amounts may not be feasible with this system because of the labor input required for each irrigation. Thus, furrow irrigations are normally made with the intent of filling the soil profile, using set times of 8-12 hours. Under these conditions, the soil profile should be near the 50 percent depletion level when irrigation begins.

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