Table 18. Average daily corn water use (ET) in Colorado. Corn water use changes dramatically across the growing season. Water use increases rapidly from six leaf (V6) to tassel, peaks around blister (R2), and rapidly declines after early dent (R4). Estimate ET for stages not given by extrapolating between stages. Evapotranspiration data for many areas of Colorado is available on the web at www.coagmet.com.

	Location					
Growth Stage	**Delta/ Olathe**	**Grand Valley**	**Front Range**	**Northeast/ Lower S. Platte**	**Central High Plains**	**Ark Valley**
	Average ET (Inches/day)					
Emergence (VE)	0.04	0.06	0.04	0.04	0.04	0.05
3-leaf (V3)	0.06	0.08	0.05	0.06	0.06	0.06
6-leaf (V6)	0.13	0.15	0.08	0.12	0.10	0.12
9-leaf (V9)	0.15	0.18	0.14	0.15	0.17	0.18
12-leaf (V12)	0.28	0.30	0.22	0.25	0.28	0.30
15-leaf (V15)	0.31	0.35	0.27	0.32	0.34	0.36
Tassle (VT)	0.29	0.35	0.26	0.29	0.32	0.35
Silk (R1)	0.28	0.34	0.25	0.27	0.31	0.34
Blister (R2)	0.28	0.31	0.24	0.26	0.30	0.34
Milk (R3)	0.25	0.30	0.23	0.26	0.28	0.30
Dough (R4)	0.22	0.26	0.20	0.26	0.28	0.28
Dent (R5)	0.18	0.20	0.15	0.18	0.20	0.20
Maturity (R6)	0.09	0.09	0.08	0.10	0.12	0.12

*Calculated using Ref-ET computer program with Standardized ASCE Standard Penman-Monteith equation. Weather data averaged from CoAgMet stations using a minimum of 7 years of data.

Curling leaves by midmorning and darkening color on days that do not reach 85^{0}F are symptoms of water stress at all stages. Curling and wilting on hot days can indicate temperature stress or moisture stress, which a soil moisture test can determine.

Critical growth stages

The most sensitive growth stages for water stress are during the growth stages of tassel emergence (VT) to dough (R3). Also, at V4 growth stage corn initiates ear shoots and determines ear size, and water stress can significally reduce grain yield. Colorado research in the late 1970’s found that corn had the highest grain yield response when irrigated during the late vegetative and pollination period. Irrigating during pollination produced the most yield response compared to any other growth stage.

BMP
Apply only enough irrigation water to fill the effective crop root zone.

Table 19. Allowable soil moisture depletion for corn at various growth stages.

Growth Stage	**Allowable depletion of available water (%)**	**Water use & notes on water stress**
Emergence to V4	50	V4 is critical (50%) - because of shallow rooting depth
V4 to V16	60-70	Can tolerate more water stress
V16 to Dough	50	Tasseling and silking until grain is fully formed are critical growth stages and yield will be reduced if water is short
Dough to Maturity	60-70	Water use is rapidly declining

Growth Stages and Water Stress

Some water stress during vegetative growth stages helps save soil water without significantly reducing grain yields. During vegetative growth the root zone is rapidly expanding to meet its water needs, but if corn is well watered, with frequent irrigations, the root system may not fully develop into the subsoil.

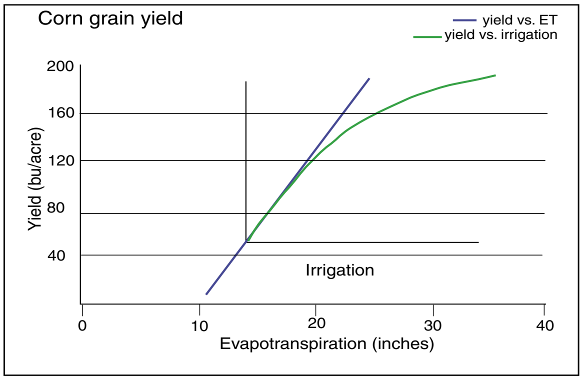


Figure 27. Grain yield vs. ET and irrigation. As maximum ET is approached, each inch of irrigation water responds with less grain yield than the previous inch. Deep percolation increases and rain water use decreases because there is less room to store and utilize water.

Water stressed corn (left) and irrigated corn (right) in late June at V6 - V10. Both treatments had similar yields, the corn on the left had a 3 inch water savings.

Limited Water Management

In below normal precipitation years fields with low well capacity or limited allocation often have insufficient water to meet corn ET demand, causing a reduction in yields. Planting an entire field with a single crop may increase water use beyond what the system can apply, necessitating early irrigation. While irrigating early increases soil moisture storage for the critical time period, possible deep percolation during the early portion of the growing season can waste water. Producers are left with few choices:

- Leave a field fallow or plant dryland crops on some fields to allow full irrigation on others - resulting in reduced yields in the dryland portion.
- Split fields into two or more sections and plant crops with different water use patterns and critical time periods that takes advantage each crop's peak ET.

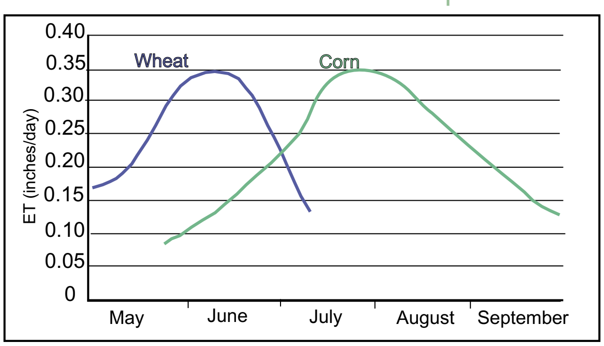


Figure 28. When wheat ET demand is high, corn has a lower ET allowing water to be concentrated on the wheat crop. Once wheat has matured, ET for corn is increasing and water can be moved to corn. Splitting a field into two or more crops allows more flexibility with limited water supplies. Soybeans and sunflowers are crops with peak ET later than corn.

With low capacity systems, splitting the system with different crops allows growers to irrigate fewer acres at a single time (Figure 28). With less irrigated acres, the system can better meet crop water use and better use stored soil moisture and precipitation. Meeting crop water needs during critical periods by improving management may result in higher yields with less water.

Using ET for Irrigation Scheduling

Weather station sources

Corn water use information helps producers understand how quickly available soil water is being depleted and for estimating the next irrigation event. In most cases, growers should use ET from the nearest weather station or a nearby station that has similar location characteristics, like topography and percentage of irrigated crops in the area. If a farm lies between two stations use the average of the two.

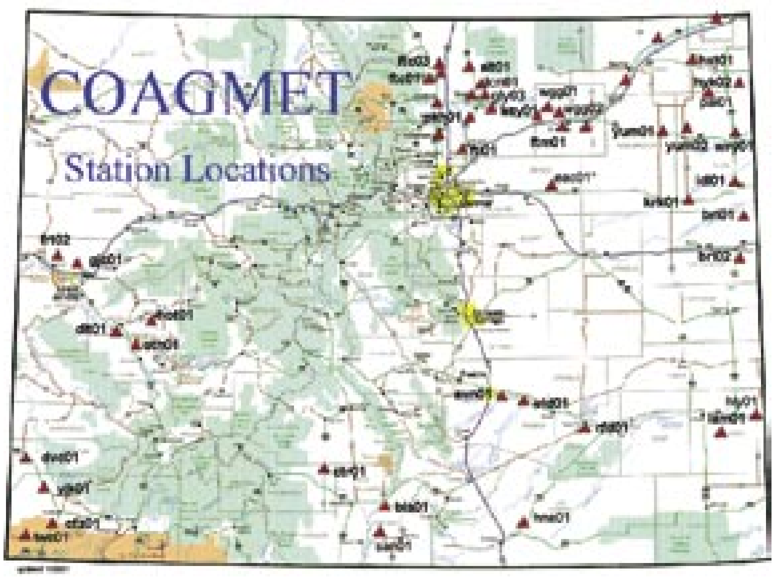


Figure 29. In Colorado, a network of weather stations can provide ET information. This information is available by calling (in Northern Colorado) 888-662-6426, on the internet, DTN satellite systems, or in some areas, on local radio.

Using atmometers for irrigation scheduling

Another source for ET is an atmometer. An atmometer acts as mini-weather station that, when properly installed, provides reference ET (ETr) at a reasonable cost and with little effort. Studies show that an atmometer will provide ETr values that closely match ETr calculated from weather station data. The ability to provide reliable ET makes atmometers especially useful for areas that do not have nearby weather stations or for people that do not have access to this information. A consultant or grower can install an atmometer to help schedule irrigations for fields within a several mile radius.

Why schedule irrigation?

Avoid over-watering costs from:

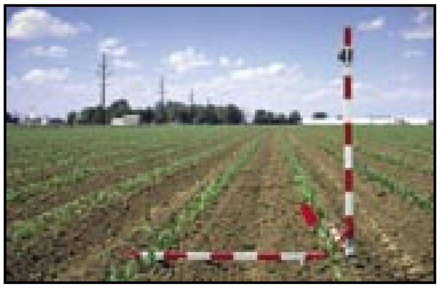
- leached nitrogen resulting in extra fertilizer inputs.
- pumping and labor.
- salinity and water logging impacts that include yield loss and long-term productivity.
- local aquifer depletion.

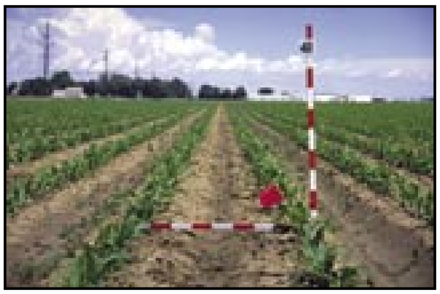
Under-irrigation can result in yield loss.

Atmometer advantages:

- simple to use
- low maintenance
- provide visual estimate of crop water use
- relatively inexpensive

Atmometers can complement other scheduling methods such as soil moisture monitoring and checkbook methods. Atmometers provide reference ET at field locations where they are installed. Like a rain gauge, the information is displayed on a sight tube mounted in front of a ruler on the instrument.


15% of ETr (K_c = 0.15)


20% of ETr (K_c = 0.20)


40% of ETr (K_c = 0.40)


65% of ETr (K_c = 0.65)

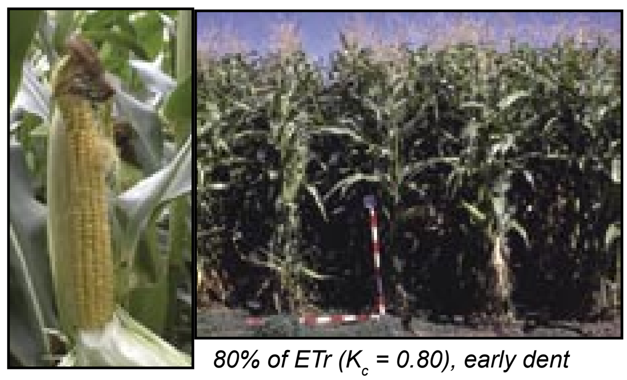

100% of ETr (K_c = 1.0)

Crop coefficient guide

Reported ET rates are sometimes given as reference ET (ETr). Atmometers also provide ETr. Reference ET is water use of well-watered alfalfa and needs to be adjusted to get actual corn water use by multiplying it by a coefficient (K_c). The following photographs can be used to estimate the crop coefficient (K_c) to determine ET used by corn for various stages of development.

Photos H. Duke, USDA-ARS


100% of ETr (K_c = 1.0)


80% of ETr (K_c = 0.80), early dent


70% of ETr (K_c = 0.70), late dent


45% of ETr, mature cob (K_c = 0.45)

The staff in all photos is 3.3' (1 m) high.

Irrigation Timing

Three watering events that require special consideration are preseason, the first and the last irrigation.

Preseason Irrigation

Determining if preseason irrigation is needed and how much water to apply is necessary to conserve water and for ensuring that a crop will not fail due to lack of water. Preseason irrigation has advantages for low capacity systems that "get behind" later in the year and to replace depleted subsoil moisture during periods of low crop water use. However, during an average year, some corn-growing areas of Colorado will receive enough precipitation during the off-season (Table 20) to bring the soil profile water content close to field capacity (Table 16, page 64, soil AWC) by June 1 and preseason irrigation is unnecessary for most soils. Filling the profile earlier in the year does not allow for subsequent rainfall storage in wetter months, but does increase pumping costs and the potential for leaching. A better strategy is to determine if pre-irrigation is needed near planting time rather than earlier in the year. If soil moisture is close to, or near field capacity, then pre-irrigating is not recommended.

Table 20. Average annual growing season precipitation.

	Growing season precipitation*								
	Off-season precipitation	Apr	May	Jun	Jul	Aug	Sep	Total Growing Season	Total Annual
	inches								
Sterling	3.1	1.4	2.8	2.8	2.4	1.7	1.2	12.2	15.3
Greeley	3.5	1.6	2.5	1.8	1.4	1.0	1.1	9.3	12.9
Central High Plains	3.5	1.7	2.9	2.7	2.8	2.0	1.3	13.3	16.8
SE High Plains**	4.6	1.4	2.5	2.2	2.4	2.1	1.2	11.8	16.3
Rocky Ford	2.8	1.4	1.9	1.4	2.0	1.6	0.9	9.1	11.9
Fruita	4.4	0.8	0.7	0.5	0.7	0.9	0.9	4.5	8.8
Olathe	3.4	0.6	0.7	0.5	0.7	1.0	1.0	4.4	7.8

* Average of minimum

** Springfield/Walsh

First Irrigation

The first irrigation is recommended when the soil moisture reaches 50% of plant available in the active root zone in the last portion of the irrigated field. As shown in Table 17 (page 65), the root zone is small early in the year and less water is required to bring it to field capacity. However, applying smaller amounts of water is more practical with center pivot than surface irrigation systems.

Estimating the first irrigation

	Example	
Corn growth stage:		V3
Current soil moisture in sandy loam:	80% of available (1.3")	= 1.0"
Allowable depletion:	40% available x 1.3"	= 0.5"
Plant available water:		1.0" - 0.5" = 0.5"
Forcasted ET:		0.1"/day
Days to irrigate:	0.5" available water / 0.1"/day	5 days

Using the known soil moisture, estimate the crop ET for the number of days that it takes to complete irrigating a field and subtract that from the amount of moisture in the soil. If that amount is less than 50% available, it is time to irrigate. If it is above 50% available, then you can wait with the first irrigation. Keep in mind that the root zone is rapidly expanding during vegetative growth, but roots will not grow through dry subsoil. Available soil moisture for various growth stages and soils are provided in Table 16 and average ET rates are found in Table 18.

Symptoms of drought stress with increasing levels of severity:

- minor leaf rolling during the heat of the day
- leaf rolling for many hours of the day
- leaf rolling from sunup to sundown plus a grayish cast to the leaves
- leaf death (bleached straw color leaves)
- dead corn plants that directly affects yield potential as it affects harvestable plant population

Last Irrigation

The final irrigation should be properly timed for several reasons. Over-irrigating results in unused soil moisture that causes harvest difficulties and increases soil compaction potential. Under-irrigating may reduce test weight and yield. The tables below are provided to help growers time the last irrigation event. The amount of ET required to reach maturity for several crop growth stages is provided in Table 21. Producers can estimate the final irrigation by comparing the water use to maturity in Table 21 to the allowable water balance in Table 22. If soil moisture equals or exceeds the water requirement to maturity, then additional irrigation is not required.

Table 21. Average water use for given growth stages to maturity.

Growth Stage	Approximate Days to Maturity	Approximate GDUs to Maturity	Approximate ET to Maturity*
			--inches--
Blister (R2)	45	1050	11.5
Dough (R4)	35	700	8.5
Beginning Dent	24	600	5.5
Full Dent (R5)	14	400	3.0
Maturity (R6)	0	0	0.0

* Varies according to areas of state. See Table 18 for areas with higher and lower ET.

Estimating the final irrigation

------------------Example------------------

Corn growth stage:	full dent (R5)
Current soil moisture in 4' root zone in silt loam, 80% of available (2.25" x 4 x .80)	= 7.2"
Minimum allowable soil water balance (Table 22):	3.6'
Usable available water:	7.2" - 3.6" = 3.6"
ET, full dent to maturity (Table 21)	3.0"

No additional irrigation needed

Table 22. Allowable soil water depletion for corn at maturity.

Soil Texture	Available water capacity Low	Available water capacity High	Minimum allowable soil water balance
	inches per foot		inches water per root zone
Fine sands	0.8	1.0	1.4
Loamy sands	0.8	1.2	1.6
Sandy loams	1.2	1.5	2.2
Loam	1.7	2.5	3.4
Silty loams	2.0	2.5	3.6
Clay loam	1.6	2.0	2.9