

## CO652.0308 State Supplement

### (a) Irrigating with limited water supplies

Irrigation managers can do something other than purchase additional equipment or reduce irrigated acreage to accommodate limited water supplies. Well-timed irrigations may help managers irrigate more acres without lowering crop yields.

By making the best use of water, irrigation managers can free up both water and equipment for use on other crops or other land. Seed-producing crops respond more to irrigations during one particular stage of development than during other stages. Some of those crops include corn, barley, sunflowers, wheat, and beans. Yields of storage and forage crops (sugar beets, potatoes, alfalfa, and grasses) are more directly related to climatic demand and cumulative water use during the season than to stress during any particular growth stage.

Sugar beets are quite drought-tolerant. They can withstand extended periods without rainfall or irrigation water by using water stored in the soil. Limited water can even increase the efficiency of sucrose production. Sucrose yield per unit of water use can be increased above that where maximum water use is allowed simply by cutting off irrigations three to four weeks before harvest operations. Sugarbeets are only moderately sensitive to plant stress, except during the early growth stages. Afternoon leaf wilting during hot, dry, windy conditions has negligible effects on total sugar production. Water can be used more efficiently on sugarbeets by applying the last major irrigation to recharge the entire soil profile at the onset of the major stress period. Sugarbeets adapt to limited irrigations by using deeply stored soil water and quickly recovering when water is made available following major stress periods. Normal irrigations of sugarbeets can be reduced after the middle of July. Sucrose yield is likely to be reduced very little when such a practice is used and a final heavy irrigation is applied in early August.

Corn is very sensitive to drought stress, especially during the flowering and reproductive stages. Stress during the early vegetative stage is not nearly as serious as stress during flowering, pollination, and early seed filling. Grain corn is most sensitive to drought stress between the three and four leaf stage when the ear size is set, and is then fairly tolerant until the 12-leaf and blister kernel stages; this period includes flowering, pollination, and initial seed filling. Stress during any part of the cropping season limits grain corn production. To maximize water use efficiency in grain corn, it is best to limit irrigations during the vegetative stage.

Barley responds to drought stress much like corn and other cereal crops. Considering drought stress before, during, and after heading, yield is reduced the most by stress before heading. Yield is likely to be reduced very little when drought stress occurs during the vegetative period. However, a major disadvantage of early drought stress is the tendency for plants to tiller more than usual. Although the increased tillering is desirable, often the tillers never produce grain-yielding heads. Barley is most sensitive to stress during jointing, booting, and initial grain filling. Flowering and pollination appear to be the most sensitive periods when soil moisture in the rooting zone should be maintained above 40% MAD. 50% MAD should be planned during grain filling. After soft dough stage, very little yield change occurs from increased stress up to 60 percent MAD.

Several studies have been conducted with spring wheat and winter wheat to evaluate the effect of limited irrigation on crop quality and production. Stress was most critical during and after heading; allow a MAD of 50% AWC in the actual root zone. This response is similar to that for barley. There is little or no measurable benefit from irrigating spring grains before the boot stage, unless moisture stress is evident. Stress is evident when the plants appear wilted and the leaves curl. The period between grain filling and maturity is critical. Yield is reduced the most when stress starts during soft

dough or during or following heading. Stress during the maturing process results in about a 10 percent lower yield. Moderate stress (60% MAD in root zone) during the early vegetative period has essentially no effect on yield. Irrigation managers can use water most efficiently on spring-planted grains by reducing early-season irrigations and minimizing crop stress during flowering, pollination, and seed filling.

Drought stress on winter wheat production during early spring regrowth results in premature heading approximately seven to 10 days. The consequence of early heading is early maturity and a shortened growth period; thus, yield is reduced. Early stress results in development of more heads than usual; however, many of the heads fail to produce grain. Winter wheat is most sensitive to drought stress during shooting and booting. It is essential to avoid even slight water stress at jointing. Withholding water to increase tillering may lead to premature heading and grain maturity.

High-quality potato yields can be achieved only by maintaining a uniformly high level of available water throughout the crop season. Potato production is directly related to crop water use between emergence and defoliation. Mild stress (MAD 50% in top 18" of the root zone) during the early vegetative stage and during the skin ripening stage at the end of potato bulking is not detrimental. Maintaining high available water (MAD 30 – 40% in top 18" of the root zone) during tuber set through bulking is critical for tuber quality and yield—Soil saturation for long periods leads to pathogen infections and serious tuber quality problems. Applying too much irrigation water or surface movement of applied water to lower areas in the field should be avoided.

Alfalfa forage yield is directly related to available water and actual plant water use. Alfalfa is not nearly as sensitive to plant water stress at different times of the season as are most of the grain-producing crops. Forage increases have been obtained from one-sixth to one-fifth ton per acre per

year for each inch of applied water. Maximum water use by alfalfa is not likely to exceed 24 inches between late April and the latter part of August. Excessive water application or too frequent light irrigations, however will reduce yield, and promote saturated conditions that permit pathogen infections and increases of grassy weeds. Stand life will be decreased. Ideally, established alfalfa should be allowed to withdraw 50% of AWC in the top 36 inches prior to successive irrigations

When subjected to plant water stress, most alfalfa varieties will go into dormancy, thus dramatically reducing both water use and production. When irrigation reduces stress, the crop resumes growth. Alfalfa is much less sensitive to plant water stress, regardless of when it occurs during the growing season.

Essentially two types of responses occur when irrigated crops are subjected to drought stress. Determinate crops, which are grown primarily for the harvest of mature seed and depend upon day length and season length, are most sensitive to drought stress during the seed formation period. This period includes heading, flowering, and pollination. Crops most affected by stress during this period include small grains, other cereal crops, and oilseed crops. Drought stress that occurs between seed development and maturity also limits yield, but to a lesser degree. These same crops are relatively insensitive to drought stress during the early vegetative period.

Indeterminate crops, such as root crops that are grown primarily for the harvest of storage organisms, are relatively insensitive to moderate drought stress for short intervals throughout the entire crop growing season. Crops like sugar beets, alfalfa, and pasture quickly recover from short stress periods and little reduction in yield occurs. Indeterminate potato varieties are less sensitive to mild stress (up to 50% MAD in actual root zone) while determinate varieties are extremely sensitive in tuber set through bulking stage. Both yield and tuber quality can be reduced.

Irrigation managers confronted with limited irrigation water should consider making the most efficient use of water by their crops. For seed crops, this means cutting back on early-season irrigations and ensuring minimum stress conditions between seed development and maturity. For root and forage crops, irrigation managers should minimize the number of early-season irrigations and eliminate late-season irrigations.

Further information on deficit irrigation is located at: <http://www.montana.edu/wwwpb/ag/baudr298.html>

For additional information or to receive a regular email distribution of agronomy notes such as the one above, Jim Bauder can be contacted by email at "jbauder@montana.edu" or by calling 406-994-5685 at Montana State University.

The Colorado State University Cooperative Extension Service has prepared a fact sheet addressing crop water use at different growth stages for crops. This fact sheet can be found at: <http://www.ext.colostate.edu/PUBS/crops/04715.html>

### (b) CROP NUTRIENT CONTENT

A tool on the web has been developed by NRCS to approximate the amount of nitrogen, phosphorus, and potassium that is removed by the harvest of agricultural crops.

This site can be found at:

[http://npk.nrcs.usda.gov/nutrient\\_body.html](http://npk.nrcs.usda.gov/nutrient_body.html)

Additional information on nutrient management can be found in the Colorado NRCS Standard (Code 590) in the Electronic Field Office Technical Guide (eFOTG). A link to this standard can be found at:

<http://efotg.nrcs.usda.gov/references/public/CO/CO590.pdf>

Other technical information on nutrient management such as job sheets, nitrogen leaching index, and phosphorus runoff index can be found at:

Job Sheets:

[http://efotg.nrcs.usda.gov/references/public/CO/CO590\\_JS.xls](http://efotg.nrcs.usda.gov/references/public/CO/CO590_JS.xls)

Nitrogen Leaching Index:

[http://efotg.nrcs.usda.gov/references/public/CO/COATN\\_97v2.pdf](http://efotg.nrcs.usda.gov/references/public/CO/COATN_97v2.pdf)

Phosphorus Runoff Index:

[http://efotg.nrcs.usda.gov/references/public/CO/COATN\\_95.pdf](http://efotg.nrcs.usda.gov/references/public/CO/COATN_95.pdf)

The Colorado State University Cooperative Extension Service has prepared a fact sheet addressing nitrogen and irrigation water. A link to the fact sheet can be found at:

<http://www.ext.colostate.edu/PUBS/crops/00514.html>

### (c) SALINITY

Salinity is defined as the concentration of dissolved mineral salts in water and soil. The concentration can be expressed on a mass, volume, or chemical basis. Expressed on a mass basis, the most familiar units are parts per million (ppm), while on a volume basis, the typical units are milligrams per liter (mg/l). Another useful way of expressing the dissolved mineral concentration is on an equivalent basis, since many chemical composition calculations involve equivalence calculations. The common unit is milliequivalents per liter (meq/l) or millimoles of charge per liter (mmol<sub>c</sub>/l). These two units are equivalent and interchangeable. For any reported value, the chemical equivalent is equal to the reported value either divided by the ion's equivalent weight, or multiplied by the reciprocal of the equivalent weight. The equivalent weight of any given ion is the atomic mass divided by its valence. For example, calcium, which has a valence of +2 and an atomic mass of 40.078, has an equivalent weight of 20.039. Today most laboratories report each constituent in both mg/l and meq/l. The major solutes comprising dissolved salts are the cations (sodium, calcium, magnesium, and potassium) and the anions (sulfate, chloride, carbonate, bicarbonate, and nitrate). On occasion, the term hypersalinity may be encountered. Use of this term indicates a reference to the minerals listed above plus other constituents that may include manganese, boron, lithium, fluoride, barium, strontium, uranium, aluminum, rubidium, and silica; and specifically describes land salt sources found in enclosed, inland water bodies that have solute concentrations well in excess of sea water.

The primary source of salts in irrigated agricultural systems is the chemical weathering of geological materials and anthropogenic processes. Dissolution and redox reactions are responsible for salt accumulation in soils and water by chemical weathering. Anthropogenic salinization processes are driven by evapotranspiration processes. The concentrations of soluble salts increases in soils as the soil water is removed to meet atmospheric demand through evaporation and transpiration. The

salts, which are left behind, will concentrate in the shrinking soil-water volume after each successive irrigation passes through the soil profile. Soils with shallow, saline water tables can become salinity affected as the result of upward flux of water and salts into the root zone. If these salts are not managed, they will eventually build up in irrigated soils to the point that crop yield is adversely affected. **Table CO 3-2** lists salt tolerance values for some common crops in Colorado.

The Agriculture Research Service has developed a web site for salt, boron, and chloride tolerance in crops. The sites are:

Salt Tolerance (Fiber and Grain Crops):

[http://www.ussl.ars.usda.gov/pls/caliche/SALT\\_T42A](http://www.ussl.ars.usda.gov/pls/caliche/SALT_T42A)

Salt Tolerance (Grass and Forage Crops):

[http://www.ussl.ars.usda.gov/pls/caliche/SALT\\_T42B](http://www.ussl.ars.usda.gov/pls/caliche/SALT_T42B)

Salt Tolerance (Vegetable and Fruit Crops):

[http://www.ussl.ars.usda.gov/pls/caliche/SALT\\_T42C](http://www.ussl.ars.usda.gov/pls/caliche/SALT_T42C)

Salt Tolerance (Woody Crops):

[http://www.ussl.ars.usda.gov/pls/caliche/SALT\\_T43](http://www.ussl.ars.usda.gov/pls/caliche/SALT_T43)

Boron Tolerance:

[http://www.ussl.ars.usda.gov/pls/caliche/BORO\\_T46](http://www.ussl.ars.usda.gov/pls/caliche/BORO_T46)

Chloride Tolerance:

<http://www.ussl.ars.usda.gov/pls/caliche/CLTT49>

An older, but still very useful guide to management and improvement of saline soils is the [USDA Salinity Handbook 60](#). This

publication is no longer in print, but can be accessed electronically at the following link:

<http://www.ars.usda.gov/Services/docs.htm?docid=10158&page=2>

Colorado State University Cooperative Extension Service has prepared several fact sheets relating to the management of saline and sodic soils. These fact sheets can be accessed at the following links:

Managing Saline Soils:

<http://www.ext.colostate.edu/PUBS/crops/00503.html>

Managing Sodic Soils:

<http://www.ext.colostate.edu/PUBS/crops/00504.html>

Diagnosing Saline and Sodic Soil Problems:

<http://www.ext.colostate.edu/PUBS/crops/00521.html>

### **(d) Wetland/water body $K_c$ (crop coefficient)**

Evaporation from the open water areas of a wetland can be much different than that of the vegetated area and should be calculated separately. This is especially true in a temperate climate. In a temperate climate there may be portions of the fall, winter, and spring months, in which the vegetation is dead and therefore becomes "protective" mulch above the wet soil or water, and thereby reduces the  $K_c$  dramatically. Researchers have measured a  $K_c$  of less than 0.2 for dead cattail vegetation in northern Utah. During the summer, the tall, lush cattail or bulrush vegetation can approach a  $K_c$  of even 1.4 in an arid climate based on grass reference due to the tall roughness and general "oasis" effect of transport of sensible heat and dry air from outside of the wetland.

It is correct to presume that the " $K_c$  end" (end season) value can be used until the "greenup" of the

following year. However, in a freezing climate, the  $K_c$  can go even lower than a typical  $K_c$  end (not a problem in California). The value of the  $K_c$  during non-growing season will of course change with precipitation frequency, and is best estimated using a daily calculation time step and a  $K_c$  procedure that separately includes the evaporation of water from the soil and vegetation surface (interception).

Evaporation from water can be very different and is a strong function of the water depth, turbidity, and variation in temperature during the year. Shallow (less than 1 m) or turbid water will intercept solar radiation near the water surface and will facilitate the conversion of radiation to evaporation at the surface in near real time but will be impacted by night-time evaporation and carry over of heat from hot to cool days. In deep water, however, the radiation from the sun is transmitted deeply into the water and is converted directly into heat which can only be transported to the water surface to supply evaporation by convection within the water body. This can be an extremely slow process for deep, cold water bodies such as in the Rocky Mountain area of the USA. A simple calculation using specific heat of water multiplied by the depth of water will indicate the tremendous storage capacity for heat in deep lakes. Researchers have measured  $K_c$  values for evaporation from Bear Lake, Utah of less than 0.40 in the summer months due to the heat storage effect. Bear Lake is quite deep, extremely clear, and has cold winter temperatures.

Much of the stored heat in Bear Lake returns to the surface in the fall months as the lake cools. During this later period, the vapor pressure deficit of the air is less, so less of the energy is converted into evaporation than would during summer, and more stored heat warms the cooler air. Therefore over the course of a year, a smaller ratio of total solar radiation is converted to evaporation in a clear, deep lake as opposed to a shallow or turbid lake. Therefore the  $K_c$  is lower than for a shallow lake.

The [FAO 56](#), a revision of the FAO 24 publication on Crop Evapotranspiration, suggests two different

$K_c$  values. The first one is for shallow water bodies near wetlands. The other set of  $K_c$  values is for deep lakes. For open water less than 2m deep, or for all water bodies in tropical climates having little change in water temperature, [FAO 56](#) suggests using a  $K_c$  of 1.05 for all months. This coefficient is based on the grass reference. For deep-water bodies (greater than 2m deep) in temperate climates with winters, the [FAO 56](#) suggests using a  $K_c = 1.25$  for the fall and winter and .65 for spring and summer. Of course, these average values will vary, as previously discussed, with actual depth, turbidity, and variation in climate during the year.

The  $K_c$  for wetland varies substantially with the "clothesline" effect caused by occurrences of limited stands of wetland vegetation that are surrounded by vegetation or other cover that is evaporating at a lower rate. This is common for wetland vegetation that occurs along roadways or canals. In this instance the  $K_c$  can go as high as 1.8.

The [FAO 56](#) publication suggests an average  $K_c$  during midseason of 1.2 for large areas (greater than 2 acres) for cattails and bulrushes in subhumid climates. For semi-arid and arid climates the mid-season  $K_c$  increases to 1.3 to 1.4. For an average  $K_c$  at the beginning and end of the growing season 0.3 is suggested for cattails and bulrushes in a killing frost climate, and 0.6 without a killing frost. An average  $K_c$  for wetlands with short vegetation is 1.05 to 1.10.

### **Conversion between alfalfa and pasture reference crop coefficients ( $K_c$ values).**

The revised [FAO 56](#) suggests that the ratio of alfalfa reference to grass reference ( $E_{Tr}/E_{To}$ ) varies from about 1.05 for humid, calm conditions, to 1.2 for semi-arid, moderately windy conditions, and to 1.35 for arid, windy conditions. The first condition is dominated by net radiation, which is similar between the references. The latter two values are influenced more by the differences in aerodynamic roughness and bulk surface resistance.

An equation for predicting the conversion between the two references that is in the revision is the following:

$$ET_o/ET_r = 1.2 + [0.04 (u_2 - 2) - 0.004 (RH_{min} - 45)] (h/3)^{0.3}$$

Where  $u_2$  is average wind speed at 2m in m/s,  $RH_{min}$  is daily minimum relative humidity percentage, and  $h$  is height of the alfalfa (generally 0.5 m is used for the alfalfa reference and 0.12 m is used for grass). The "0.3" exponent is used on the  $h/3$  term to indicate the effect of roughness (height) on the impact of dryness and windiness on the ratio. This same "adjustment" expression is used in the revision to adjust  $K_c$  values for all crops for climate for use with the grass reference  $ET_o$ .

The above equation happens to predict a ratio  $ET_o/ET_r = 1.24$  at Kimberly, Idaho, where  $u_2 = 2.2$  m/s during the summer period and  $RH_{min}$  averages 30 percent. This is similar to values of  $ET_R/ET_O$  that have been measured by Dr. Jim Wright at Kimberly using weighing lysimeters.

$RH_{min}$  can be predicted from daily or monthly dewpoint temperature as

$$RH_{min} = 100 e^{\circ}(T_{dew})/e^{\circ}(T_{max})$$

where  $e^{\circ}()$  is the saturation vapor function. If no  $T_{dew}$  data are available,

$$RH_{min} = 100 e^{\circ}(T_{min})/e^{\circ}(T_{max})$$

where  $T_{min}$  and  $T_{max}$  are average daily minimum and maximum air temperatures.

$$e^{\circ} = \exp\left(\frac{16.78T - 116.9}{T + 237.3}\right) \quad T \text{ in } ^{\circ}\text{C}$$

Prepared by Dr. Rick Allen, Utah State University, 5/12/98, in response to a question raised by Dr. Dean Reynolds on SOWACS and Irrigation-L discussion groups.

### (e) Chemigation and Fertigation

Chemigation and fertigation are methods for applying chemicals and nutrients to a crop through the irrigation water. While these methods have had limited use for years in surface flood irrigation systems with anhydrous ammonia and certain other chemicals, chemigation and fertigation are primarily used under sprinkler and microirrigation systems. Chemigation or fertigation is not simply putting chemicals into the irrigation water or injecting nutrients into a pressurized delivery system. There are advantages and drawbacks to these methods. Some of the advantages to chemigation are the uniformity of application, timeliness of application, reduction of soil compaction, and the economics of the application. Disadvantages include higher management levels for the irrigation system, additional equipment, possible environmental impacts, and the requirements for permitting. Under the *Colorado Chemigation Act*, permitting is required for the majority of chemical applications through irrigation systems. Additionally, not all chemicals or nutrients can be applied by chemigation techniques due to the nature of the chemical or improper labeling for legal application. A link to the Colorado Department of Agriculture website is:

<http://www.colorado.gov/ag>

Additional information about the *Colorado Chemigation Act*, copies of the Act, information about permit fees, permit applications, and information about inspections can also be obtained from the Colorado Department of Agriculture at the following address:

Colorado Department of Agriculture  
Division of Plant Industry  
700 Kipling Street, Suite 4000  
Lakewood, Colorado 80215-5894  
Tel:(303) 239-4149

The Colorado State University Cooperative Extension Service has prepared a fact sheet discussing fertigation. A link to the fact sheet can be found at:

<http://www.ext.colostate.edu/pubs/crops/00512.html>

The Mississippi State University has prepared a fact sheet discussing the advantages and disadvantages of chemigation systems and some of the related safety concerns and equipment. A link to this fact sheet can be found at:

<http://msucares.com/pubs/publications/p1551.htm>.

### **(f) Crop Planting**

Seeding rates will generally vary due to the presence or absence of an irrigation system, cultural factors, or other variables. Underseeding can adversely affect yields. Overseeding can reduce crop yields or potentially lead to a crop failure if irrigation and soil moisture are severely limited. To maximize yields, it is imperative to accurately apply seed to the field. A fact sheet has been prepared by the Colorado State University Extension Service that discusses seeder calibration and typical seeding rates for common Colorado crops. A link to this fact sheet can be found at:

<http://www.ext.colostate.edu/pubs/crops/00103.html>

### **(g) Crop Growth Curves**

Further information on crop  $K_c$  values can be found in the fact sheet [Irrigation Scheduling: The Water Balance Approach](#) from the Colorado State University Extension Service.

### **(h) Crop Water Stress**

### **(i) Crop Fact Sheets**

Several fact sheets and informational publications exist for a variety of crops commonly grown in Colorado. The fact sheets presented in this section are from the Colorado State University Extension unless otherwise noted.

#### General

[Best Management Practices for Colorado Agriculture: An Overview](#)

#### Alfalfa

[Alfalfa: Production and Management](#)

[Alfalfa: Weeds, Diseases, and Insects](#)

[Hay Preservation Systems](#)

[Fertilizing Alfalfa and Grasses](#)

#### Canola

[Rapeseed / canola production](#)

#### Corn

Colorado State University Extension Water Quality Programs:

[Best Management Practices for Colorado Corn](#)

Colorado State University Extension:

[Fertilizing Corn](#)

#### Dry Beans

[Fertilizing Dry Beans](#)

[VegNet for Dry Beans](#)

#### Onions

[VegNet for Onions](#)

#### Potatoes

[Fertilizing Potatoes](#)

[VegNet for Potatoes](#)

#### Safflower

[Safflower Production](#)

#### Sorghum

[Fertilizing Grain and Forage Sorghums](#)

#### Spring Wheat

[Fertilizing Spring-Seeded Small Grains](#)

[Vegetable Fertilizer Guide](#)

[Sugar Beet](#)

[Colorado VegNet](#)

[Fertilizing Sugar Beets](#)

[Winter Wheat](#)

[Sunflower](#)

[Fertilizing Winter Wheat](#)

[Fertilizing Sunflowers](#)

[Irrigation of Winter Wheat](#)

[Vegetable Crops](#)

**(j) Example Management Allowable Depletion (MAD) and Irrigation Frequency**

Following is an example of how to select a Management Allowable Depletion (MAD) and use it to calculate net irrigation water requirement and irrigation frequency.

Given: The operator is growing potatoes on a sandy loam soil. The crop ET rate is .34 in./day.

Solution: Select an appropriate MAD value and determine the net irrigation requirement and the irrigation frequency.

Step 1. Using procedures mentioned in Chapter 2, the available water capacity for a potato crop with 18" rooting depth on a loam soil with 30% coarse fragments is estimated at 2.16 inches.

Table 3-4 shows typical rooting depths. For the purpose of this example, a rooting depth of 2 feet (24") is selected from the table, and corrected to 18". (In an actual situation, never assume a plant root zone for management purposes; rather, check actual root development pattern and depth.) From Table 3-3 select a MAD of 35%. Net irrigation can be calculated the following way:

$$\text{Net Irrigation} = \text{Available Water Capacity (AWC, in/in)} \times \text{Root Depth} \times \frac{\text{MAD}\%}{100}$$

$$\text{Net Irrigation} = 2.6 \text{ in.} \times \frac{35\%}{100} = 0.91 \text{ in.}$$

Step 2. The Irrigation Frequency can be calculated as follows:

$$\text{Irrigation Frequency} = \frac{\text{MAD}}{\text{Crop ET rate}} = \frac{0.91 \text{ in}}{0.34 \text{ in/day}} = 2.6 \text{ days}$$

**Table CO 3-1: Critical Growth Periods for Major Crops**

<b>Crop</b>	<b>Moisture Stress</b>	<b>Critical Period</b>	<b>Other Considerations</b>
<b>Alfalfa</b>	<b>Darkening color, then wilting</b>	<b>Early spring and immediately after cuttings</b>	<b>Normally 3-4 inches of water is needed between cuttings. Fall irrigation is desirable.</b>
<b>Corn</b>	<b>Curling of leaves by mid-morning</b>	<b>Three to four leaf stage, tasseling, silk stage until grain is fully formed</b>	<b>Needs adequate moisture from germination to dent stage for maximum production.</b>
<b>Sorghum</b>	<b>Curling of leaves by mid-morning</b>	<b>Boot, bloom, and dough stages</b>	<b>Yields are reduced if water is short during seed development.</b>
<b>Sugar Beets</b>	<b>Leaves wilting during the heat of the day.</b>	<b>Post thinning</b>	<b>Excessive fall irrigation lowers sugar content.</b>
<b>Beans</b>	<b>Wilting</b>	<b>Bloom and fruit set</b>	<b>Yields are reduced if water is short at bloom or fruit set.</b>
<b>Small Grains</b>	<b>Dull green color followed by firing of the lower leaves</b>	<b>Boot and bloom stage</b>	<b>Last irrigation at milk stage.</b>
<b>Potatoes</b>	<b>Wilting during the heat of the day</b>	<b>Tuber formation to harvest</b>	<b>Moisture stress during critical period may cause cracking of tubers.</b>
<b>Onions</b>	<b>Wilting</b>	<b>Bulb formation</b>	<b>Keep wet during bulb formation, let soil dry near harvest.</b>
<b>Tomatoes</b>	<b>Wilting</b>	<b>After fruit set</b>	<b>Wilt and leaf rolling can be caused by disease.</b>
<b>Cool Season Grass</b>	<b>Dull Green color, then wilting</b>	<b>Early spring, Early fall</b>	<b>Critical period for seed production is boot to head formation.</b>
<b>Fruit Trees</b>	<b>Dulling of leaf color and drooping of growing points</b>	<b>Any point during the growing season</b>	<b>Stone fruits are sensitive to moisture stress during the last two weeks prior to harvest.</b>

**Table CO 3-2: Approximate Yield Decrease for Selected Crops due to Salinity**

Crop	0% ECe <sup>(1)</sup>	10% ECe	25% ECe	50% ECe	Maximum ECe <sup>(2)</sup>
Apples	1.7	2.3	3.3	4.8	8
Alfalfa	2	3.4	5.4	8.8	15.5
Barley <sup>(3)</sup>	8	10	13	18	28
Cabbage	1.8	2.8	4.4	7	12
Cantaloupe	2.2	3.6	6.7	9.1	16
Corn	1.7	2.5	3.8	5.9	10
Dry Beans	1.0	1.5	2.3	3.6	6.5
Onions	1.2	1.8	2.8	4.3	7.5
Peaches	1.7	2.2	2.9	4.1	6.5
Potatoes	1.7	2.5	3.8	5.9	10
Sorghum	4.0	5.1	7.2	11	18
Sweet Corn	1.7	2.5	3.8	5.9	10
Sugar Beets	7.0	8.7	11	15	24
Wheat <sup>(3)</sup>	6.0	7.4	9.5	13	20

(1) EC means the electrical conductivity of the saturation extract of the soil reported in decisiemens per meter at 25°C.

(2) Maximum ECe means the maximum electrical conductivity of the soil saturation extract that can develop due to the listed crop withdrawing soil water to meet its evapotranspiration demand. At this salinity, crop growth ceases (100% crop decrement) due to the osmotic effect and reduction in crop water availability to zero.

(3) Barley and wheat are less tolerant during germination and seedling stage. ECe should not exceed 4 or 5 decisiemens per meter during these growth stages.

**Source:** Bernstein (1964), University of California Committee of Consultants (1974).