Water Conservation
FACTSHEET

BRITISH COLUMBIA
Ministry of Agriculture, Food and Fisheries

Order No. 577.100-5
Revised October 2001
Agdex 561

CROP COEFFICIENTS FOR USE IN IRRIGATION SCHEDULING

Crop water use information can be used to schedule irrigation systems. Crop water use is directly related to evapotranspiration (ET). The ET information must be adjusted to correspond to the crop and climate. This factsheet provides information on selecting the crop coefficient that should be used.

Evapotranspiration

Evapotranspiration (ET) is a combination of the water evaporated from the soil surface and transpired through the plant.

ET can be measured using evaporation pans and atmometers or calculated using climate data. Local climate data for BC can be found on www.farmwest.com.

The following nomenclature is often used for reference ET data:

ETo - ET calculated using grass as the reference crop
ETr - ET calculated using alfalfa as the reference crop
ETp - ET measured from a pan or atmometer

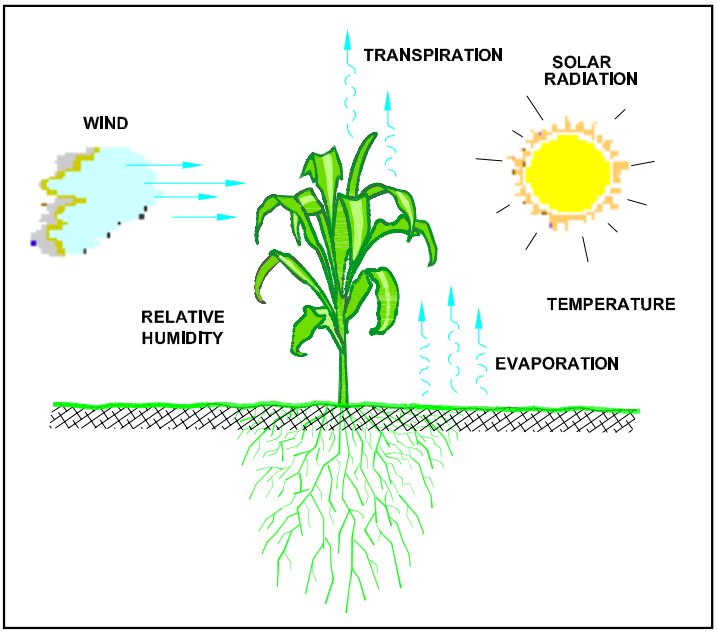

Figure 1 Elements of Evapotranspiration

Once the reference ET has been determined, a crop coefficient must be applied to adjust the reference ET value for local conditions and the type of crop being irrigated. Factsheets 577.100-3 Sprinkler Scheduling Using a Water Budget Method and 577.100-4 Trickle Irrigation Scheduling Using Evapotranspiration Data provide more information on using ET data to schedule irrigation systems.

The tables shown in this factsheet use crop coefficients for use with ET calculated using a grass reference, ETo. These coefficients can be used with ET data from www.farmwest.com.

Crop Water Use

Crop water use is directly related to ET. The crop's water use can be determined by multiplying the reference ETo by a crop coefficient (Kc). The crop coefficient adjusts the calculated reference ETo to obtain the crop evapotranspiration ETc. Different crops will have a different crop coefficient and resulting water use.

$$\mathbf{ETc = ETo \times Kc} \qquad \text{(Equation 1)}$$

Where ETo = calculated reference ET for grass (mm) available from www.farmwest.com

Kc = crop coefficient

ETc = crop evapotranspiration or crop water use (mm)

Crop Coefficients

The reference ET is a measurement of the water use for that reference crop. In the case of ETo grass is used as the reference. However other crops may not use the same amount of water as grass due to changes in rooting depth, crop growth stages and plant physiology. The crop coefficient (Kc) takes into account the crop type and crop development to adjust the ETo for that specific crop. There may be several crop coefficients used for a single crop throughout an irrigation season depending on the crop's stage of development.

Crop coefficients may also vary depending on how the evapotranspiration data has been calculated or obtained.

Figure 2 Weather Station from Davis Instruments

Reference ET

Reference ET is calculated using climatic data obtained from a weather station.

ETo is calculated to simulate a grass reference crop. Alfalfa may also be used as a reference crop in some areas and may be referred to as ETr. As a result there are different types of crop coefficients that may be used in the literature. Crop coefficients developed using grass as the reference crops will be larger than those using alfalfa, because ET from alfalfa is greater. The reference ETo obtained from www.farmwest.com is calculated for a grass reference crop.

If using crop coefficients or reference ET values from other sources make sure the Kc value and ET have been developed for use with the same reference crop.

Pan Evaporation

Atmometers and evaporation pans also provide ET data. If the ET data used is obtained from a pan or atmometer a pan crop coefficient will have to be applied to convert the pan evaporation ETp to a crop water use ETc.

Figure 3 Evaporation Pan and Atmometer

Converting Crop Coefficients

Crop coefficients based on an alfalfa reference or pan reference can be converted for use with a grass reference by using the factors shown in Table 1.

The factors shown are for semi arid, moderately windy conditions. For humid, calm conditions the values will be 10% less and for arid windy conditions the values will be 10% more. For most British Columbia summer conditions the factors in the table can be used.

Table 1 Guide to Converting Crop Coefficients Based on Reference ET Used

Crop Coefficient Conversion	Multiply by:
Kc - grass (ETo) to Kc alfalfa (ETr)	0.83
Kc - grass (ETo) to Kc - pan (ETp)	0.80
Kc - pan (ETp) to Kc – alfalfa (ETr)	1.04

EXAMPLE The Kc value for raspberries in mid season is 1.2 if using a reference ETo for grass. See Table 3.

To convert this Kc value for use with an alfalfa reference ETr multiply the value by 0.83. The crop coefficient for use with an alfalfa reference ETo is:

$$Kc\ (ETr) = 1.2 \times 0.83 = 1.0$$

Crop Water Use and Stages of Growth

Crop growth periods can be divided into four distinct growth stages; initial, crop development, mid season and late season. See Figure 4. The length of each of these stages depends on the climate, latitude, elevation and planting date. Local observations are best for determining the growth stage of the crop and which Kc values to use.

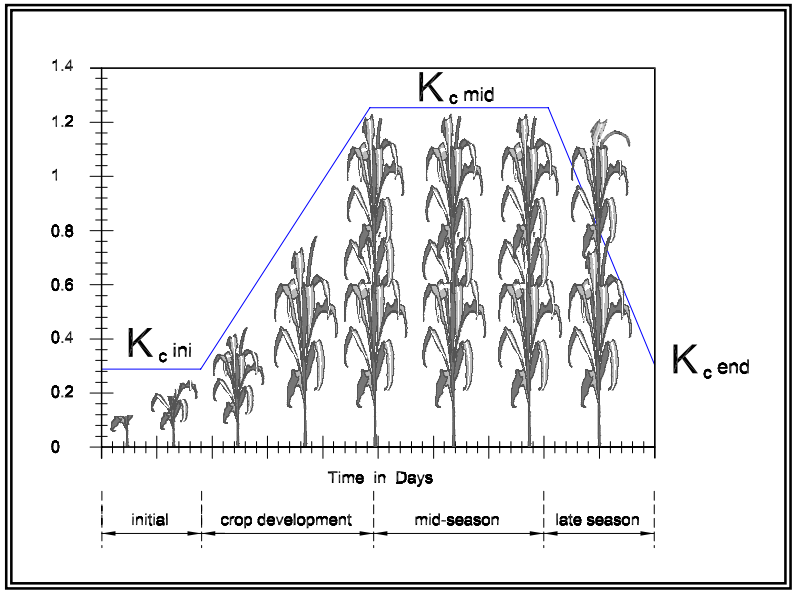

Figure 4 Crop Coefficients and Crop Development Stages

For annual crops, during the crop's germination and establishment, most of the ET occurs as evaporation from the soil surface. As the foliage develops evaporation from the soil surface decreases and transpiration increases. For perennial crops a similar pattern may occur as the plant starts to leaf out, grow new shoots and develop fruit. The percentage of canopy cover will determine the rate of evapotranspiration (ET). Maximum ET occurs when the canopy cover is about 60-70% for tree crops and 70-80% for field and row crops. The maximum canopy cover often coincides with the time of year that sun radiation and air temperature are at their greatest. The maximum ET therefore occurs during mid season.

During the crop development stage there are no set Kc values. If irrigating during this period choose a Kc value that is between Kc_{ini} and Kc_{mid}. A similar approach should be taken for the time period between Kc_{mid} and Kc_{end}. However this time period may be much shorter and a jump directly from Kc_{mid} to Kc_{end} could be taken.

Table 2 provides a description of the various plant growth stages. These stages can be used to select an appropriate crop coefficient from the following Tables.

Table 2	Crop Stage of Development	
Stage	**Indicators**	**Crop Coefficient**
Initial	Planting date (or the start of new leaves for perennials) to 10% ground cover.	Kc_{ini}
Crop development	10% ground cover to effective full cover, about 60-70% coverage for tree crops and 70-80% for field and row crops.	Kc_{ini} - Kc_{mid}
Mid season	Effective full cover to maturity, indicated by yellowing of leave, leaf drop, browning of fruit. This stage is long for perennials but relatively short for vegetables crops that are harvested for their fresh fruit.	Kc_{mid}
Late Season	Maturity to harvest: the Kc value could be high if the crop is irrigated frequently until fresh harvest or low if the crop is allowed to dry out in the field before harvest.	Kc_{mid} - Kc_{end}

Select a Crop Coefficient

The crop coefficients in Tables 3 and 4 can be used as a general guideline for British Columbia. The crop coefficients are to be used for a grass reference ETo. The crops should be of average height, well watered and well managed.

Vegetable and Berry Crops

Table 3 provides crop coefficients for various vegetable and berry crops for different stages of the growing season.

Crop coefficients for many vegetables may not be available. It is possible to estimate the crop coefficient at the peak time of year for some crops using the ratio of bed width to canopy cover. Comparing crop coefficients of other crops that are similar in nature may also be useful.

Kc = Wp/Wb (Equation 2)

Where Kc = crop coefficient
Wp = width of plant canopy
Wb = bed spacing

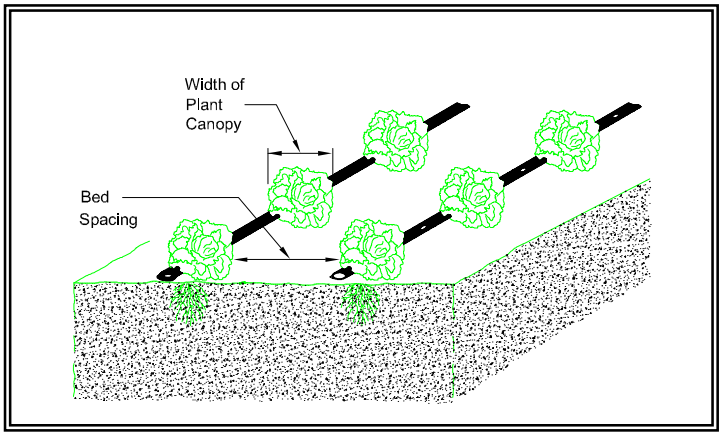

Figure 5 Vegetable Canopy Measurement

Table 3 Crop Coefficients for Forage, Vegetables and Berries

Crop	Kc_{ini}	Kc_{mid}	Kc_{end}
alfalfa	0.4	1.2	1.15
asparagus	0.3	0.95	0.3
beans, green	0.5	1.05	0.9
beets	0.5	1.05	0.95
blueberries	0.4	1.0	0.75
broccoli	0.7	1.05	0.95
cabbage	0.7	1.05	0.95
cabbage -local	0.7	1.05	0.95
carrots	0.7	1.05	0.95
cauliflower	0.7	1.05	0.95
cranberries	0.4	0.9	0.50
celery	0.7	1.05	0.95
cereal	0.3	1.15	0.25
corn	0.3	1.15	0.4
cucumber	0.6	1	0.75
green onions	0.7	1.05	0.95
lettuce	0.7	1	0.95
onions	0.7	1.05	0.95
pasture (grass)	0.4	1.0	0.85
peas	0.5	1.15	1.1
potato	0.5	1.15	0.75
pumpkin	0.5	1	0.8
radish	0.7	0.9	0.85
raspberries	0.4	1.2	0.75
small vegetables	0.70	1.05	0.95
spinach	0.7	1.05	0.95
strawberries	0.4	1.05	0.7
squash	0.5	0.95	0.75
sweet corn	0.3	1.15	0.4
sweet peppers	0.7	1.05	0.85
tomato	0.7	1.05	0.8
tubers	0.5	1.05	0.95
watermelon	0.4	1	0.75

Alfalfa and Other Forage Crops

Many forage or hay crops are harvested several times during the growing season. These crops will therefore have a new growth stage cycle for each cut. Instead of one Kc curve for the entire season as in Figure 4, these crops would have a series of curves to make up the entire growing season. See Figure 6. Immediately after a cutting the crop coefficient would revert to Kc_{ini}, 0.3 and the Kc_{end} would end at the next harvest date.

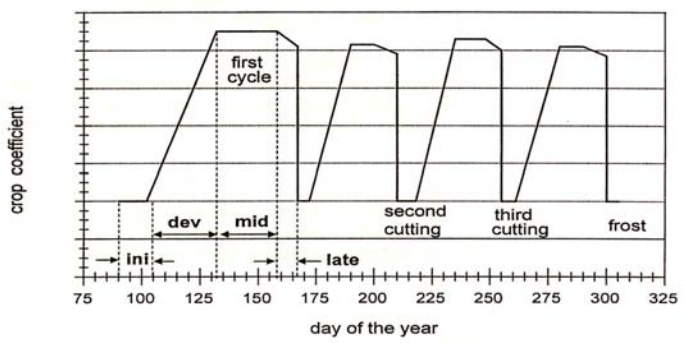

Figure 6 – Growth cycle for forage crops with more than one cut

The growth stages for the second and third cuts may be shorter than the first cut or the fourth cut. This is because the heat units that are available during the warmer summer months would speed up the growth. Growth during the early spring and fall would be shorter. The crop coefficient for forage crops are shown in Table 3.

Apples and Grapes

Crop coefficients for tree fruits and grapes have been segregated into months as shown in Table 4. The absence of a cover crop will lower the crop coefficients shown. The cover crop draws water from the soil storage reservoir and therefore increases water use. If there is no cover crop or grass between the tree or plant rows the crop coefficients will be about 10% lower in May, September and October and 20% lower in June, July and August.

Table 4 Crop Coefficients for Tree Fruit and Grapes

Crop	May	June	July	Aug	Sept.	Oct.
Apples Cherries and Pears with cover crops*						
Lower Mainland / Vancouver Isl.	0.7	0.9	1.00	1.00	0.95	0.75
Okanagan / Thompson	0.85	1.15	1.25	1.25	1.2	.95
Kootenays	0.8	1.10	1.20	1.20	1.15	0.7
Apricots, Peaches and other Stone Fruit with cover crops*						
Lower mainland / Vancouver Isl.	0.9	1.0	1.0	1.0	0.95	0.8
Okanagan / Thompson	0.80	1.10	1.20	1.20	1.15	0.9
Kootenays	0.70	1.00	1.05	1.10	1.00	0.8
Grapes						
Lower mainland / Vancouver Isl.	0.55	0.65	0.65	0.65	0.65	0.50
Okanagan / Thompson	0.50	0.70	0.80	0.85	0.80	0.70
Kootenays	0.45	0.70	0.85	0.90	0.80	0.70
* No Cover crop – reduce values by	10%	20%	20%	20%	10%	10%

Soil moisture monitoring devices can be used to adjust crop coefficients to match local conditions. See Factsheet 577.100-2 Irrigation Scheduling with Tensiometers for additional information.

FOR FURTHER INFORMATION CONTACT

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