Water Conservation
FACTSHEET

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TRICKLE IRRIGATION SCHEDULING USING EVAPOTRANSPIRATION DATA

Evapotranspiration data can be used to schedule trickle irrigation systems using a plant water requirement or water budget method.

➊ The **plant water requirement method** adjusts the trickle system operating time by comparing the actual ET data to the theoretical Peak ET used in system design. This method can be used in situations where the system is designed to irrigate each individual plant with one or more emitters.

➋ The **water budget method** can be used for row crops, such as vegetables, strawberries or any crop that is spaced close enough together so that the system is irrigating the entire field. If the plants or rows are spaced far apart so that portions of the field are not irrigated, then the plant water requirement method will be a better approach. Figure 1 shows the schematics for water budget method.

In both cases, the methodology is to balance the amount of water applied with the amount taken out through evaporation and transpiration.

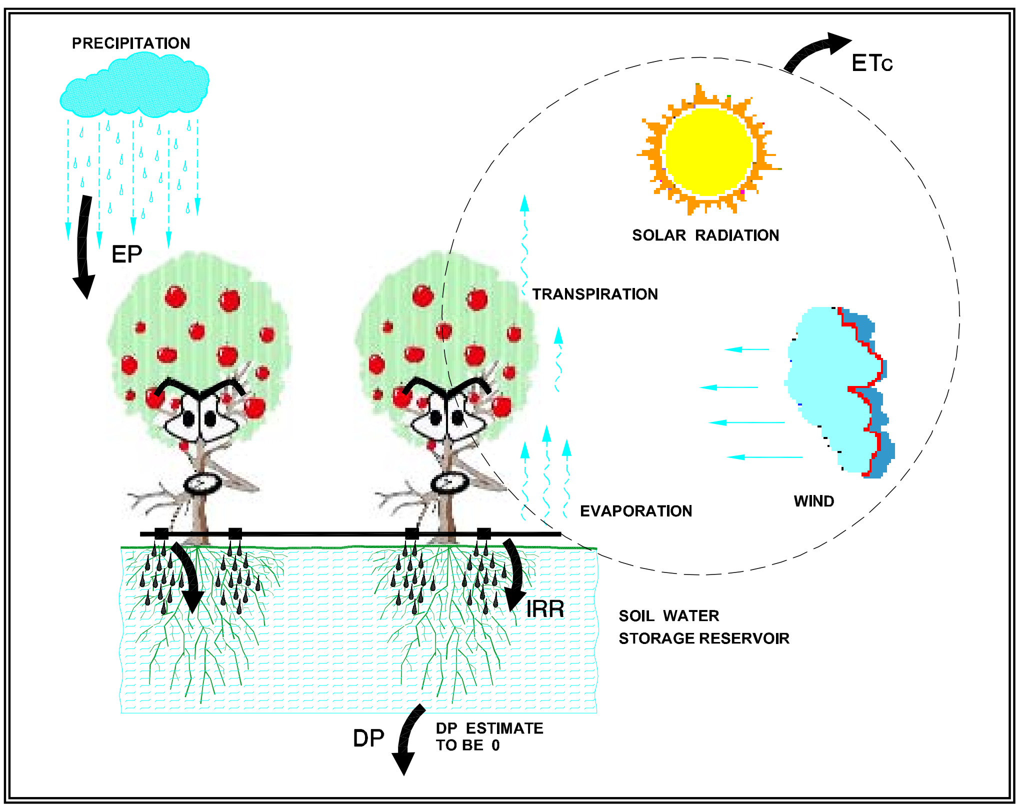

Figure 1 Crop Water Balance

❶ PLANT WATER REQUIREMENT METHOD

It is best to explain this method by using an example. A trickle system is irrigating an apple field in Kelowna on a loam soil. The particulars for this system at a peak design evapotranspiration (ET) rate of 6.1 mm/day are:

Plant Water Requirement	= 40 L/day
Emitters per plant	= 2
Emitter flow rate	= 2 L/hr
Maximum zone operating time	= 10 hr/day

The table below shows the actual daily reference evapotranspiration (ET_o) data from July 20th to July 26th. The crop coefficient (K_c) for July is 0.95.

July	Daily ET_o [mm]	K_c	ET_c [mm]	Operating Time [hr/day]
20th	5.2	0.95	5.0	8.2
21st	6.0	0.95	5.7	9.3
22nd	6.1	0.95	5.8	9.5
23rd	6.5	0.95	6.2	10.2
24th	5.9	0.95	5.6	9.2
25th	5.5	0.95	5.2	8.5
26th	6.0	0.95	5.7	9.3
Weekly Total	41.2		39.2	
Average	5.9		5.6	9.2

The system operating time is determined using a ratio of the peak design ET rate and the actual ET_c rate. If the system needs to operate for 10 hours a day when the peak design ET is 6.1 mm, then the operating time for an ET_c of 5.0 mm will be:

$$\text{For July 20}^{\text{th}}\text{, the zone operating time} = 10 \text{ hr/day} \times \frac{5.0 \text{ mm}}{6.1 \text{ mm}} = 8.2 \text{ hr/day}$$

If the system operating time is to be changed daily, the times shown for each day in the table would be used.

The average operating time for the week would be 9.2 hours.

It is usually more convenient to adjust the irrigation schedule weekly. In this case the average daily ET_o for the week should be calculated and used to adjust the schedule for the following week. In our example, the average daily ET_o is 5.9 mm, and the average ET_c is 5.6 mm. Using the same calculation as above, the irrigation schedule would be altered to irrigate for 9.2 hours per day for the next seven days. The weekly adjustment ensures the soil moisture depleted in the previous week is replaced. While not as effective as altering the schedule daily, a weekly schedule will adjust the irrigation schedule as the climate and crop change throughout the growing season.

When performing a weekly adjustment, visit www.farmwest.com for a five-day forecast on daily ET_o. The forecast information is useful in determining the operating time for the week.

❷ WATER BUDGET METHOD

Using a water budget to schedule trickle irrigation systems is similar to balancing a chequebook. The plant's soil water storage reservoir can be considered as a bank. This reservoir can hold a limited amount of water that is useful for the crop. Adding excessive water to the soil reservoir will mean a loss of water due to deep percolation or runoff. The crop evapotranspiration (ET_c), or the crop water use, is the daily withdrawal from the bank. The bank is replenished with irrigation or rainfall. Figure 1 schematically shows the crop water balance parameters. ***This method should only be used with row crops that are spaced close together.***

The water budget method works well with a computer spreadsheet that allows the daily reference ET (ET_o), precipitation and irrigation amounts to be accounted for irrigation scheduling.

WATER BALANCE EQUATION

Equation 1 can be used to calculate a water balance:

$$CSWC = PSWC + EP + IRR - ET_c - DP \qquad \textbf{[Equation 1]}$$

where
- CSWC = current soil water content (today) [mm]
- PSWC = previous soil water content (yesterday) [mm]
- EP = effective precipitation since yesterday [mm]
- IRR = irrigation since yesterday [mm]
- ET_c = crop evapotranspiration [mm]
- DP = deep percolation, water lost beyond the root zone [mm]

The water budget equation does not provide a factor for runoff as good irrigation management practices should eliminate runoff. Deep percolation (DP) is also assumed to be zero in most cases as it is difficult to measure and should be minimal if good irrigation practices are followed. If leaching is desired in some instances, then the amount of irrigation applied would need to exceed the soil water storage capacity.

The following steps should be used to set up the water budget:

STEP 1 DETERMINE SOIL WATER CONTENT – CSWC AND PSWC

The first step is to determine how much water is in the soil or 'bank'.

See Factsheet 619.000-1 Soil Water Storage Capacity and Available Soil Moisture.

Trickle irrigation systems normally keep the soil moisture at a level higher than sprinkler systems to reduce stress on the plants. The maximum allowable depletion for trickle system scheduling is therefore less. The maximum allowable depletion should not exceed 25% of the maximum soil water storage (SWS) capacity.

What If the Crop Root Zone Changes over the Season ?

It will be necessary to adjust the soil water holding capacity for annual crops that develop larger root systems as the growing season progresses. For example, an annual crop in May might have a 0.15-m rooting depth and would have a smaller reservoir of water to draw upon than later in the season when the rooting depth is 0.40 m.

How Much Water is in the Soil at the Start of the Water Budget ?

Measuring the existing soil moisture can be difficult. It is therefore easier to start the water budget after a thorough irrigation or rainfall that fills the root zone to close to field capacity. The trickle irrigation system is then operated to keep the soil moisture in the range desired, not extracting more than the 25% maximum allowable depletion.

ACTION

• At the top of the worksheet, enter
  o the **Soil Water Storage (SWS) Capacity**
  o the **Maximum Allowable Deficit (MAD)**
  o the **Desired Soil Moisture Range**
• In the table that follows, enter the current amount of soil moisture in the **Previous Soil Water Storage (PSWC)** column.

Tensiometers can be used to ensure that the soil moisture stays within the desired range. See Factsheet 577.100-2 Irrigation Scheduling with Tensiometers for more information on tensiometer use.

STEP 2 DETERMINE EFFECTIVE PRECIPITATION (EP)

Precipitation data can be collected with an on-site rain gauge or obtained from climate stations. Daily climate data in real-time can be obtained from www.farmwest.com for various climate stations throughout British Columbia.

Determining Effective Precipitation

Dry Climate

In dry climate during the irrigation season, rainfall of less than 5 mm does not add any moisture to the soil reservoir as most of it is evaporated before entering the soil. Therefore, if rainfall is less than 5 mm, the effective precipitation (EP) is zero. If rainfall is over 5 mm, only 75% of it will be considered as EP. Refer to Equation 2.

$$EP = (RAIN - 5) \times 0.75 \qquad \textbf{[Equation 2]}$$

where EP = effective precipitation [mm]
RAIN = rainfall [mm]

Wet Climate

In wetter climates or periods of the year when there are many days of rainfall in succession, the summation of the total amount of rainfall can be added without using equation 2. For example:

Day	Rainfall [mm]
1	10
2	5
3	2*
4	7

* Not included in the summation as it is considered as a trace amount (<3 mm)

The total EP for this wet period would be 22 mm, the summation of all the rainfall events except for Day 3. Days with only a trace of rainfall (<3 mm) during a wet period would not be added.

ACTION
• Enter the **Effective Precipitation (EP)** in the table.

STEP 3 DETERMINE RUN TIME OF THE IRRIGATION SYSTEM

The application rate and the length of time the irrigation system runs determine the amount of water applied. The amount of water to be applied should match the maximum allowable depletion determined earlier. This will be equal to IRR.

If the plants and rows are spaced close enough to ensure that the entire area is irrigated, the following formula can be used to determine the operating time for a trickle system.

$$T = \frac{S_1 \times S_2 \times IRR \times 100\%}{Q \times AE}$$ **[Equation 3]**

where
- T = irrigation time [hr]
- IRR = net depth of irrigation water applied [mm]
- Q = emitter flow rate [L/hr]
- S_1 = emitter spacing along line [m]
- S_2 = line spacing [m]
- AE = application efficiency [%]

ACTION

- Enter the **Net Irrigation (IRR)** in the table on the date when irrigation occurs. If the operating time is different from the calculated value in Equation 3, then the IRR value will differ from the maximum allowable depletion.

STEP 4 DETERMINE CROP EVAPOTRANSPIRATION (ET_C)

Finding Reference Evapotranspiration

Daily reference evapotranspiration (ET_o) rates are available at www.farmwest.com for various climate stations throughout British Columbia.

Finding the Right Crop Coefficient

A crop coefficient must be applied to the ET_o value to determine the crop evapotranspiration (ET_c) which is also referred to as crop water use. The crop coefficient depends on the crop type and on the crop's stage of development. This value will change over the growing season as the crop matures. The Factsheet 577.100-5 Crop Coefficients for Use in Irrigation Scheduling provides information on crop coefficients for crops common in B.C..

ACTION

- Enter the **Reference ET (ET_o)** in the table.
- Enter an appropriate **Crop Coefficient (K_c)** for the crop's stage of development in the table.
- Multiply ET_o by K_c to obtain **Crop Water Use (ET_c)**, and enter this value in the appropriate column.

STEP 5 CALCULATE WATER BALANCE

Obtain the Current Soil Water Storage (CSWS) by adding EP and IRR to the PSWS and subtracting ET_c from it.

Date	Previous Soil Water Storage	+	Effective Precipitation	+	Net Irrigation	−	Ref. ET	x	Crop Coefficient	=	Crop Water Use	=	Current Soil Water Storage
	PSWS		EP		IRR		ET_{co}		K_c		ET_c		CSWS

ACTION

- Enter the calculated **Current Soil Water Storage (CSWS)** in the table.
- Enter this CSWS value as the **Previous Soil Water Storage (PSWS)** in the next row to prepare for the calculation in the following day.

The values that are entered can be a daily value or a cumulative value over a specified time period as long as the cumulative values correspond to the same dates.

NOTE: ***Irrigation scheduling using the water balance method is based on estimation and should therefore be checked with soil moisture periodically. It is important to monitor soil water content in the field and compare the calculated soil water content to the actual measured water use once a week or every other week, and correct the calculated water balance when necessary.***

Example – Water Budget Method

(see spreadsheet on next page)

A trickle irrigation system is irrigating vegetables with emitters spaced 0.3 m apart in a row, with the rows being 0.4 m apart. The crop is growing in a loam soil, and has a rooting depth of 0.4 m. The soil water storage (SWS) capacity is therefore 70 mm (See Factsheet 619.000-1 Soil Water Storage Capacity and Available Soil Moisture). The maximum allowable depletion for a trickle system is 25% of the maximum soil water storage (SWS) capacity; therefore, the maximum allowable depletion in this case is:

$$70 \text{ mm} \times 0.25 = 17.5 \text{ mm}$$

Then, irrigation should start when the balance reaches or is close to:

$$(70 - 17.5) \text{ mm} = 52.5 \text{ mm}$$

The trickle irrigation system flow rate from each emission device is 1.0 L/hr. Using Equation 3, the operating hours that the system needs to operate to apply 17.5 mm of irrigation water is:

$$\frac{0.3 \text{ m} \times 0.4 \text{ m} \times 17.5 \text{ mm} \times 100\%}{1.0 \text{ L/hr} \times 92\%} = 2.1 \text{ hr}$$

If the system is operated for 2.3 hours per irrigation, it will apply 17.5 mm of water.

For the month of June, the crop irrigated had a crop coefficient (K_c) of 0.80.

June 24th The soil moisture starts at 70 mm. The ET_o rate was 5 mm. Multiplying this ET_o by the K_c value of 0.80 gives an ET_c of 4.0 mm. At the end of the day, the CSWS is therefore:

$$(70 - 4.0) \text{ mm} = 66 \text{ mm.}$$

June 25th The ET_o rate was 4.8 mm. Multiplying this ET_o by the K_c value of 0.80 gives an ET_c of 3.9 mm. At the end of the day, the CSWS is therefore:

$$(66 - 3.9) \text{ mm} = 62.1 \text{ mm.}$$

June 26th The ET_o rate was 2 mm, and there was 15 mm of effective precipitation (EP). Subtracting 1.6 mm of ET_c ($ET_c = ET_o \times K_c = 2 \text{ mm} \times 0.80$), and adding 15 mm of EP gives a balance of:

$$(62.1 + 15 - 1.6) \text{ mm} = 75.5 \text{ mm.}$$

However, since the maximum soil water storage (SWS) capacity is 70 mm which the balance cannot exceed, the CSWS is equal to 70 mm. The rest of the water is therefore assumed to be lost due to deep percolation and/or runoff. Repeat the same procedures to continue the balance calculation.

For the month of July, K_c is 0.95.

July 1st Irrigation system is operated when the lower soil moisture limit of 52.5 mm is close.

July 4th Irrigation system is operated again as the lower limit of 52.5 mm is again close. The trickle system is operating on a three-day irrigation interval, determined by the parameters that have been chosen.

Related Useful Information:

Factsheet 619.000-1 Soil Storage Capacity and Available Soil Moisture
Factsheet 577.100-5 Crop Coefficients for Use in Irrigation Scheduling
B.C. Trickle Irrigation Manual

TRICKLE IRRIGATION SCHEDULING WATER BUDGET EXAMPLE WORKSHEET

Soil Water Storage (SWS) Capacity: 70 mm
Maximum Allowable Depletion: 17.5 mm
Desired Soil Moisture Range: 55 to 65 mm

Date	Previous Soil Water Storage	+	Effective Precipitation	+	Net Irrigation	–	Reference ET	x	Crop Coefficient	=	Crop Water Use	=	Current Soil Water Storage
	PSWS		EP		IRR		ET_o		K_c		ET_c		CSWS
Example 1: Daily Water Budget Method Start after irrigation when the soil moisture profile is full, monitor daily until the maximum allowable deficit (MAD) is reached.													
June 24	70	+	0	+	0	–	5	x	0.80	=	4.0	=	66
June 25	66	+	0	+	0	–	4.8	x	0.80	=	3.9	=	62.1
June 26	62.1	+	15	+	0	–	2	x	0.80	=	1.6	=	70
June 27	70	+	0	+	0	–	4.2	x	0.80	=	3.4	=	66.6
June 28	66.6	+	0	+	0	–	6.6	x	0.80	=	5.3	=	61.3
June 29	61.3	+	0	+	0	–	5.4	x	0.80	=	4.3	=	57
June 30	57	+	0	+	0	–	5.3	x	0.80	=	4.2	=	52.8
July 1	52.8	+	0	+	17.5	–	5.2	x	0.95	=	5.0	=	65.3
July 2	65.3	+	0	+	0	–	6.0	x	0.95	=	5.7	=	59.6
July 3	59.6	+	0	+	0	–	6.5	x	0.95	=	6.2	=	53.4
July 4	53.4	+	0	+	17.5	–	5.6	x	0.95	=	5.3	=	65.6
July 5	65.6	+	4	+	0	–	4.5	x	0.95	=	4.3	=	65.3

Even though the total water storage would be (62.1 + 15 – 1.6) mm = 75.5 mm, the maximum soil water storage can only be 70 mm. The rest of the water is therefore assumed to be lost due to deep percolation and/or runoff.

TRICKLE IRRIGATION SCHEDULING WATER BUDGET BLANK WORKSHEET

Soil Water Storage (SWS) Capacity: _____ **mm**
Maximum Allowable Depletion: _____ **mm**
Desired Soil Moisture Range: _____ **to** _____ **mm**

Date	Previous Soil Water Storage	+	Effective Precipitation	+	Net Irrigation	–	Reference ET	x	Crop Coefficient	=	Crop Water Use	=	Current Soil Water Storage
	PSWS		EP		IRR		ET_o		K_c		ET_c		CSWS
		+		+		–		x		=		=	
		+		+		–		x		=		=	
		+		+		–		x		=		=	
		+		+		–		x		=		=	
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