# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

To irrigate effectively, you need to know how much water your crop needs, and when it needs it.

The goal of irrigation is to provide a crop with the right amount of water, when the crop needs it for maximum crop response, at the lowest cost and with least impact on the environment.

To do this effectively, it's worth looking at some basic principles, such as:

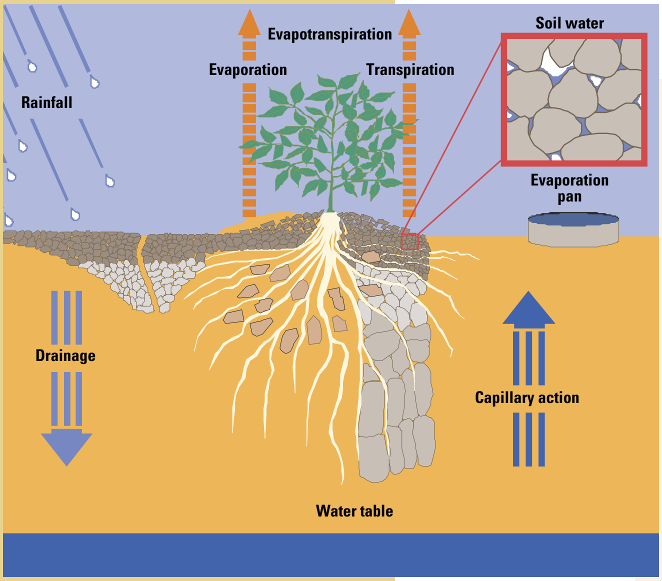
- how water flows through, over, and around your cropland
- how soils provide moisture to crops
- how much water crops require and when they need it
- how to estimate and schedule crop water requirements practically and at low cost.

This chapter explains:

- when to irrigate
- how much water your crop requires, using practical and accurate methods
- how to change the amount of water applied if soil types change across your farm
- how to account for rainfall when you estimate crop water needs.

## WATER CYCLE

Knowing how water moves through cropland can help you use irrigation water more effectively and with less risk to water sources.




Water is added to cropland as snow, snowmelt and rain. In a typical field, most of this water will eventually be evaporated back to the atmosphere (66% from April to October). About 25% of it will run off the soil surface to streams, creeks, drains, lakes and ponds.

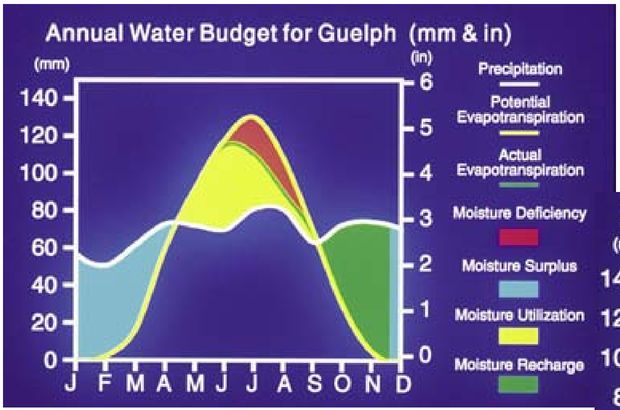
The remaining 9% of this will enter ("infiltrate") the soil. This soil water can flow through the soil to ground water, be stored as soil moisture, or is transpired by plants back to the atmosphere. The ground water will replenish the soil water table (shallow aquifers), percolate to deep aquifers, or flow back to surface waters such as streams and creeks.

Irrigation is applied to meet crop requirements just before the combination of evaporation and transpiration (evapotranspiration) exceeds the available soil moisture supplies. The fate of irrigation water, particularly with overhead sprinkler systems, is similar to that of falling precipitation (as described above). The fundamental difference is that water is taken from local surface or ground water sources. The risk to these resources is taking or wasting too much water when supplies are low.

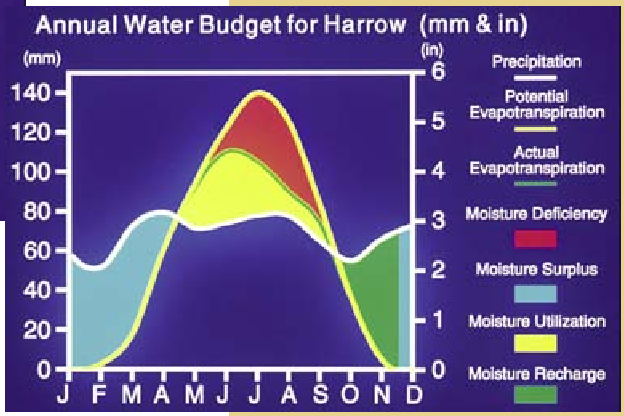
# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## WATER BALANCES: RAINFALL AND CROP REQUIREMENTS

Most of the province's irrigation occurs in Southern Ontario, where average annual precipitation ranges from about 26.0–40.2 inches (660–1020 mm). In Southwestern Ontario, crop water requirements may be 20–24 inches (500–600 mm) during the growing season, but precipitation during the same period averages only 12–16 inches (300–400 mm). This results in a water deficit for the crop in an average year. Unfortunately, years of below-average rainfall also occur, causing even greater moisture deficits.




**The annual water budget for Guelph shows how water is supplied and used throughout the year. Guelph experiences a moisture deficit of up to 2 inches (50 mm) each year in July and August.**




**Note the extent of the moisture deficit: over 3 inches (75 mm) monthly each year for most of Harrow's growing season.**

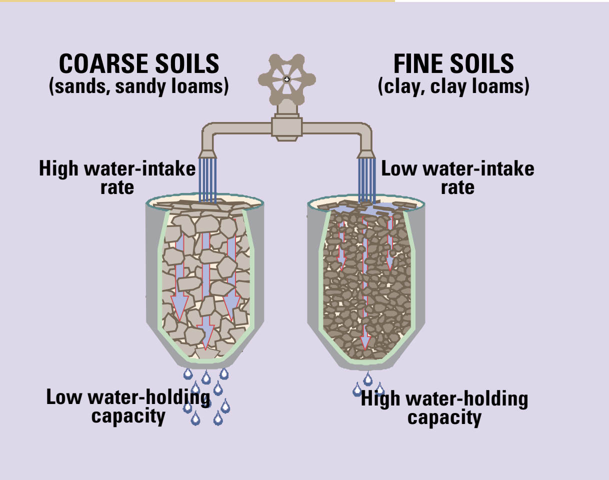
## SOIL WATER

Each soil type and field have unique moisture characteristics that determine how much water is held and how available the water is for plant growth. Based on this information, you can determine how much and how frequently water should be applied. The two main characteristics explored here are **water intake rate** and **available water capacity.**

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

**Water Intake Rate** (or **infiltration rate**) – how fast the soil can absorb water

- the larger the soil particles, the faster the soil can absorb water
- water infiltrates coarse-textured soils faster than fine-textured ones
- good soil structure improves infiltration – soil aggregate formation and stability are key, especially in loams, silt loams and clays
- cover crops or crop residues can protect soil and slow runoff, increasing water intake rate and maintaining soil structure at the same time
- slope, soil compaction and tillage practices also affect speed of water movement into the soil
  - in heavier soils, some growers may chisel the trough between tilled rows to improve water infiltration
- the presence of macropores, such as those formed by earthworms, can have a very beneficial effect on water infiltration rates
- water applied faster than a soil's intake rate can result in ponding, leading to runoff, erosion and wasted irrigation water




Coarse-textured soils such as sands and gravels have high infiltration rates and contain the least amount of available water for plants when at field capacity. Fine-textured soils (clays) have low infiltration rates and have more available water for plants when at field capacity. However, medium-textured soils (loams) have the most available water for plants when at field capacity.

**Available Water Capacity** – the amount of water a soil can hold that is available to the crop

- soil texture determines how much water a soil can hold – what the crop can use is called **available soil water***, and the water bound to the soil but unavailable to the crop is called **bound water**
- coarse-textured soils hold less water, so that watering must be more frequent
- **field capacity** is the amount of water held in a soil after the excess has drained following a saturating rainfall
- the **permanent wilting point** is the amount of water held in the soil, below which plants wilt beyond recovery

For more information on soil water and the water cycle, see the Best Management Practices books, *Soil Management* and *Water Management*.

*Available soil water can be expressed as inches of available water per inch of soil (or millimetres of available water per metre of soil).

| SOIL TYPE | RATE OF WATER MOVEMENT INTO SOIL | |
|---|---|---|
| | ON BARE SOIL | ON CROPPED SOIL |
| SAND | fast | fast |
| SILT LOAM | medium | fast |
| LOAM | medium | fast |
| CLAY LOAM | medium | medium |
| CLAY | slow | slow |

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## CROP WATER REQUIREMENTS

The available water in the soil is used by a combination of plant transpiration and soil evaporation, i.e., **evapotranspiration (ET):**

- expressed as inches or millimetres of water used per day
- affected by temperature, light intensity, wind, humidity, crop cover and crop growth stage
- generally accepted ET values can be found in the chart on page 45, which lists ET for an average year
- more accurate maximum ET can be calculated using evaporation data from Environment Canada, a local weather station, or from on-site instrumentation

The **crop factor** is used to reflect water use by crop type and its growth stage. ET is multiplied by the crop factor and used for irrigation scheduling.

Crop factor:

- can be obtained from charts (see page 45)
- varies depending on the type of crop (crop species, annual vs. perennial) and the crop growth stage
  - for annual crops, the crop factor increases from emergence to 50–80% crop cover, remains at a maximum for 2–5 weeks, then decreases.

The moisture needed to supply the crop's ET needs is called the **crop water requirement:**

- water depleted from the soil by ET is normally replenished by rain, dew or irrigation in sufficient amounts to meet the crop's needs at any given time
- irrigation should maintain a minimum amount of available soil moisture – if water isn't applied until the crop is wilting, economic losses have already occurred, as yield and/or quality potential can be reduced
- frequency and depth of irrigation required vary, depending on soil characteristics, crop water requirements and rooting depth (see Table 2, page 41 for more details on rooting depth).

**Weather stations estimate evapotranspiration using the open pan evaporation method, which measures the daily loss of water by evaporation. Since evaporation from an open-air water surface is faster on windy days, days with low humidity, and on hot, sunny days, ET would be correspondingly higher.**

**Sampling for Field Variation**
**Soil texture and water-holding capacity can vary significantly within fields. Choose a representative area or areas to use for scheduling.**

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## IRRIGATION SCHEDULING

Irrigation scheduling is the process of planning and providing crops with the amount of water needed, when they need it. It involves monitoring, record-keeping, and calculations to determine field water capacity, losses and gains. Ultimately the producer compensates for net losses with irrigation. This system is based on known daily water losses by ET for various crops in different growth stages.

Scheduling can be done either by hand or on computer. Scheduling and a basic understanding of crop physiology can help ensure you use water only when it's needed. Scheduling should always be used, and especially so when water supplies are under stress.

### BENEFITS OF SCHEDULING

- increased yields and quality; better returns on investment of irrigation equipment
- more efficient use of water resources
- more efficient use of equipment, energy, management time and labour
- avoids delaying irrigation until moisture stress has occurred and damage to yield and quality is irreversible, i.e., optimizes application timing
- reduced possibility of excess water being applied – excess water may result in crop damage, leaching of nutrients or soil erosion

### FACTORS IN SCHEDULING

- specific infiltration rates and available water-holding capacities of the various soil types need to be known
  - some calibration work may have to be done
  - you may have to measure the performance of the soil using known quantities of soil and water
- crop rooting depth – deeper-rooted crops will need less frequent but deeper irrigations than shallow-rooted crops
- the probability of rainfall – this affects frequency and amount of irrigation needed
- plant water requirements – this depends on crop type and growth stage

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## METHODS OF DETERMINING IRRIGATION NEED

The need for irrigation can be determined by a number of methods. These include: monitoring soil moisture levels, observing crop symptoms, and measuring or estimating plant transpiration and water evaporation (evapotranspiration).

The physical properties of your soils must be known to help make irrigation scheduling work effectively. The technician in this case is taking soil samples to measure water-holding capacity.

### MONITORING SOIL MOISTURE

Soil moisture levels can be monitored to aid in scheduling irrigation events. A limit is set on the depletion of crop-available soil water in the crop rooting zone. For example, the field may be allowed to dry down to a pre-set level of 50% of crop-available water before irrigation is triggered. The allowable crop-available soil moisture will vary, depending on soil type and crop.

There may also be variations, depending on crop development or growth stage. Soil moisture may be allowed to drop lower as the growing season progresses and the critical periods of crop development pass.

Soil moisture can be measured in a number of ways, ranging from high-tech to very basic. High-tech techniques can be used in conjunction with basic techniques, and are particularly useful in refining feel-method skills. One particular method does not suit everyone. For some operations, it will be advantageous to use two or more methods. Experienced irrigators should consider using electronic methods to verify basic methods and confirm quality of moisture level assessment.

Read about different soil moisture monitoring methods in the next few pages and use the comparative chart on pages 35–37 to select the one most appropriate for your operation.

### TYPES OF MEASUREMENTS

There are three types of soil moisture measurements.

- **gravimetric** – a measure of the weight of water held within a soil (g of water/g of dry soil). It's easily measured by weighing wet soil, drying it overnight, and weighing the dry soil. The difference is the weight of the water held by the soil. However, different soil types with the same weight will occupy a different volume and hold a different amount of water.
- **volumetric** – most commonly used method. Volumetric measures allow comparisons among soils of different types. The soil bulk density is multiplied against the gravimetric measure to determine the volumetric result. It's reported as ml/cm$^3$ or ml/L of soil or % volume of water per volume of soil.
- **soil water potential** – a measure of the difficulty in extracting water from soil. As soil dries, the pore size that is water-filled decreases, the water is held more tightly, and more energy is needed to remove it. Potential or soil water suction is measured in kilopascals.

Mulch maintains soil moisture content over a long period of time.

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## FEEL METHOD

The feel method is commonly used by many to schedule irrigation. It involves a shovel or soil probe to obtain soil samples at the desired depth. The amount of moisture is estimated through the feel of the soil in the hands. While it's the quickest and simplest method, it does require experience, and due to its subjective nature, it's not especially accurate. It doesn't generate definitive numbers that can be compared.

The chart on page 31 has been used for some time as a guide in estimating soil moisture in soil samples. It relates soil appearance and feel to approximate soil moisture levels for specific soil textures. High organic matter content will influence the feel of a soil.

## TENSIOMETER

**This is a tensiometer, best suited for use in sandy soils.**

A tensiometer measures **soil water tension** rather than soil water content. Soil water tension is what the plant must pull against in order to extract water from the soil. This method is more suited to sandy soils, for repeated measurements at the same location. Users must interpret soil moisture release curves to determine the amount of water to irrigate.

### HOW IT WORKS

The tensiometer involves an airtight system consisting of a sealed tube, a vacuum gauge and a porous ceramic tip, which is initially filled with a prepared solution. The water tension in the soil pulls water out through the porous tip, until the tension (vacuum) in the tensiometer is equal to the water tension in the soil. The vacuum gauge measures this tension.

As the soil dries, more water is pulled out of the tube, and the vacuum in the tensiometer increases (measured in centibars). Irrigation is required when the soil water tension reaches a predetermined level for specific soil and crop conditions (e.g., about 50% crop-available soil water). After a rain or irrigation, which decreases soil water tension, water from the soil moves back into the tensiometer through the porous ceramic tip, causing a decrease in the vacuum gauge reading.

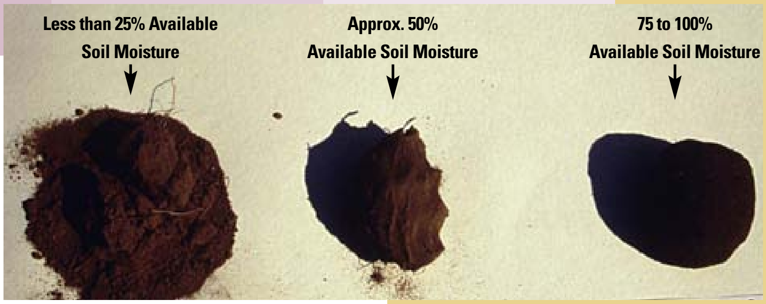
# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## "FEEL TESTING SOIL"

| AVAILABLE MOISTURE IN SOIL | FEEL OR APPEARANCE OF SOIL – SOIL TEXTURE | | | |
|---|---|---|---|---|
| | **Coarse (sands)** | **Moderately coarse (sandy loams)** | **Medium (silt loams, loams)** | **Fine and very fine (clay, clay loams)** |
| 0% | dry, loose and single-grained; flows through fingers | dry and loose; flows through fingers | hard clods that break into powder | hard, baked and cracked; has loose crumbs on surface in some places |
| 50% OR LESS | appears to be dry; does not form a ball under pressure[1] | appears to be dry; does not form a ball under pressure[1] | somewhat crumbly but holds together under pressure | somewhat pliable; balls under pressure[1] |
| 50-75% | appears to be dry; does not form a ball under pressure[1] | balls under pressure but seldom holds together | forms a ball under pressure; somewhat plastic; sticks slightly under pressure | forms a ball; ribbons out between thumb and forefinger |
| 75% TO FIELD CAPACITY | sticks together slightly; may form a very weak ball under pressure | forms weak ball that breaks easily; does not stick | forms ball; very pliable; sticks readily if relatively high in clay | ribbons out between fingers easily; has a slick feeling |
| AT FIELD CAPACITY (100%) | on squeezing, no free water appears on soil but wet outline of ball is left on hand | same as for coarse-textured soils at field capacity | same as for coarse-textured soils at field capacity | same as for coarse-textured soils at field capacity |
| ABOVE FIELD CAPACITY | free water appears when soil is bounced in hand | free water is released with kneading | free water can be be squeezed out | puddles; free water forms on surface |

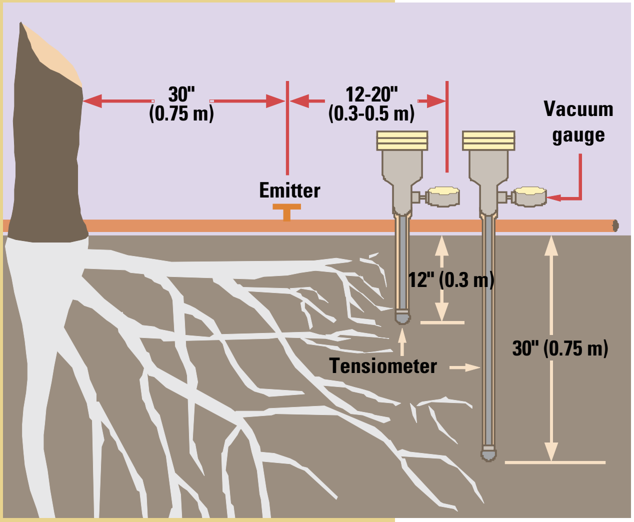
[1]Ball is formed by squeezing a handful of soil very firmly.

Adapted from R.P. Harris and R.H. Coppock, eds., *Saving Water in Landscape Irrigation,* University of California, Div. of Agriculture Science leaflet 2976, 1978




**Dry soils are loose or baked. At 100% moisture, a wet outline of water is left on the hand after squeezing.**

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE




**Tensiometers are usually installed in pairs, one in the zone of maximum root activity and one below. They only measure soil water tension near the porous ceramic tip, not the amount of water in the soil. A reading of 10-20 centibars on the vacuum gauge indicates soils at or near field capacity.**

## INSTALLATION

Tensiometers are usually installed in pairs, one in the zone of maximum root activity and one just below this zone. The ceramic tip must be in contact with the soil for the water movement to occur, so it's important to ensure a snug fit that allows the ceramic tip to have maximum soil contact. Installation procedures should be followed carefully, as air leaks may develop. Temperature may affect the readings, and the instruments need to be monitored carefully after installation to ensure that they are de-aired by pumping and fluid levels are maintained.

## LIMITATIONS

The vacuum gauge indicates soil water tension in the immediate vicinity of the porous ceramic tip, not the amount of water in the soil. Therefore, the measurements indicate when irrigation is required, but not how much water to apply.

The tensiometer can only measure tensions up to about 0.85 atmospheres or 85 centibars before the risk of air leaks develops. It's especially suited to sandier soil where much of the available soil water is held at tensions of less than 1 atmosphere. On clay soils, a reading of 70 or 80 centibars may mean that only 20% of the available soil moisture has been depleted. On sandy loam soils, a reading of half this amount may be interpreted as having lost more than 50% available soil moisture.

The system is portable, but stations, once established, are usually left for the season.

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## ELECTRICAL RESISTANCE

Similar to the tensiometer, electrical resistance blocks measure soil water tension. In wet soils, water is drawn into the blocks, while the reverse is true in dry soils. Generally, once properly installed, this is an accurate and low-cost soil water measurement device with no maintenance.

The unit consists of a block of some material with fine pores and two wires embedded in the material. For a gypsum block, the more moist the block is, the less resistance to the electrical current flowing between the two wires. The newer ones are more robust and may have a meter that reads directly in kilopascals (kPa) and makes the soil temperature adjustment. Installation will vary with the equipment used. Check manufacturer's recommendation and specification listings.

## TIME DOMAIN REFLECTROMETRY (TDR)

A TDR instrument works by sending a signal down wave guides or steel probes buried in the soil. The signal is reflected back to the TDR unit and the time taken for this is measured. The time taken is related to the dielectric of the soil. Soils typically have dielectric constants in the range of 2.0 to 4.0, while the dielectric constant of water is 78. Changes in the soil dielectric constant relates to changes in the water content of the soil. A similar method is involved in the Frequency Domain Reflectrometry or FDR.

Properly calibrated, this equipment gives very accurate results. In the past, the cost of TDR equipment restricted it to research or consultant use. Prices have come down considerably, but it's still most suited to the large-scale or intensive irrigator.

Installation will vary with the equipment used. Check manufacturer's recommendation and specification listings.

## NEUTRON MOISTURE METER

The neutron moisture meter directly measures soil water content by emitting and detecting neutrons. When neutrons bounce off the hydrogen atoms in water, they return to the probe at a slower velocity. The number of returning slow neutrons indicates the water content of the soil, which can then be expressed as percent moisture or inches (millimetres) of water for a specific depth of soil. The instrument is used mostly in research work and by crop consultants.

**C probe technology is another tool for measuring soil moisture. Its structure allows for measurements at a variety of depths, and offers a high degree of automation. However, careful siting of the probe is critical to ensure representative information of a field.**

**Until recently, use of the C probe was mostly limited to research trials due to the expense. But per unit costs have been coming down, and C probes are in use in a variety of large, intensive irrigation operations.**

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## PLACING THE MEASUREMENT UNITS

Once you've selected the soil moisture monitoring method, consider where the units need to be placed or the samples taken. Consider:

- how many areas will be monitored through the season – usually only one or two, depending on field size
- location of sample areas within the field – easy access for observation, but they need to be well within the field for an accurate measure of irrigation application, and outside of any non-representative areas, e.g., ditch spoil
- depth of equipment placement – it's often recommended that there be two depths (one at 30 cm or 1 ft.; the other at the bottom of the root zone for that crop type), so that the top one will capture the moisture status of the active root zone while the other will indicate if there is under-irrigation
- placement of units relative to the crop or drip emitters – usually in the plant row in the active root zone and about 30 cm (1 ft.) away from an emitter (maintaining a consistent distance from the emitter is important).

Neutron moisture meter

Time domain reflectometry

Electrical resistance

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## SOIL MOISTURE MEASUREMENT TOOLS

| SOIL MOISTURE MEASUREMENT TOOL | SIMPLICITY OF USE | RELIABILITY | RANGE OF SOIL TYPES | EASE OF AUTOMATION | PORTABILITY | OBSERVATIONS | COST |
|---|---|---|---|---|---|---|---|
| FEEL METHOD measures soil water depletion | ✓✓✓ | ✓ | • All | • NA | • High | • Requires experience<br>• Open to misinterpretation | • Operator time |
| SOIL SAMPLE (gravimetric) measures water content by mass | ✓✓✓ | ✓✓ | • All | • NA | • High | • Time-consuming and slow – lots of weighing, waiting and calculating<br>• Highly variable, depending on sampling technique, temperature of drying etc. | • Operator time<br>• Inexpensive |
| TENSIOMETER measures soil water tension | ✓✓ | ✓✓ | • Most, except clays | • Easy<br>• Requires specialized unit and connections | • Low in season | • Indicates when irrigation is needed, but not how much<br>• Successful operation depends on proper installation<br>• Placement is important to avoid damage from field operations<br>• High maintenance and regular checking of units needed<br>• Soil type-dependent, i.e., most suited for sandy soils as tension can be too high in clay soils<br>• If the sand is coarse, may require a special unit<br>• An excellent tool to be used for calibrating the hand-feel method<br>• A combination of tensiometers and the hand-feel method will give more reliable results with the ability to cover large areas | • $100 + per unit<br>• Usually two units are installed at two different depths and the units stay in one site in the field for the season |

**Legend**

✓✓✓ **Best**
✓✓ **Good**
✓ **Least**

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## SOIL MOISTURE MEASUREMENT TOOLS

| SOIL MOISTURE MEASUREMENT TOOL | SIMPLICITY OF USE | RELIABILITY | RANGE OF SOIL TYPES | EASE OF AUTOMATION | PORTABILITY | OBSERVATIONS | COST |
|---|---|---|---|---|---|---|---|
| ELECTRICAL RESISTANCE BLOCKS<br>e.g., watermarks, gypsum blocks measure soil water tension | ✓✓✓ | ✓✓ | • Most, except clays | • Easy<br>• Requires datalogger/ connections | • Buried for crop season, but moveable from season to season | • Installation generally easy but depends on soil type<br>• Requires some calibration with soil type<br>• Sensitive to salt levels<br>• Low maintenance<br>• Low impact on field operations with appropriate placement<br>• Less sensitive at high soil moisture<br>• Lifespan ~3 years +<br>• Readings are affected by soil temperature (1% per 0.6 °C)<br>• An excellent tool to be used for calibrating the hand-feel method<br>• A combination of electrical resistance blocks and the hand-feel method will give more reliable results with the ability to cover large areas | • Individual ER blocks – $40–50<br>• One meter ($300) can be used to measure many ER blocks<br>• Similar to tensiometers – often two units at different depths |
| • TDR – TIME DOMAIN REFLECTRO-METRY<br><br>• FDR – FREQUENCY DOMAIN REFLECTRO-METRY measure volumetric soil water | ✓✓✓<br>• Depends upon unit used | ✓✓✓ | • All, but clay may pose some problems | • Easy | • High<br>• May require an access tube previously placed in the soil | • Cost in the past has restricted use to researchers and large-scale irrigators<br>• Depending on unit, may need calibration<br>• Insertion under dry conditions may be difficult<br>• FDR – sample volume 10 inches (25 cm) diameter around probe | • Cost has come down in recent years – $1000+ |

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## SOIL MOISTURE MEASUREMENT TOOLS

| SOIL MOISTURE MEASUREMENT TOOL | SIMPLICITY OF USE | RELIABILITY | RANGE OF SOIL TYPES | EASE OF AUTOMATION | PORTABILITY | OBSERVATIONS | COST |
|---|---|---|---|---|---|---|---|
| NEUTRON MOISTURE METER measures moisture content | ✔ | ✔✔✔ | • All | • Unit usually too expensive | • High<br>• Requires an access tube previously placed in the soil | • Suited to research<br>• Uses a radioactive source of neutrons<br>• Requires calibration | • High cost – in $1000s |

**Legend**

✔✔✔ **Best**
✔✔ **Good**
✔ **Least**

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## USING THE PLANT TO INDICATE WATER STRESS

Using the plant as an indicator is difficult because once symptoms appear, the plant has usually already experienced a reduction in growth or damage to plant tissues, and economic damage has been done to the crop. However, a few methods have been developed to indicate the onset of plant water stress.

Although these methods may show that the plant needs water, they give no indication of how much. Also, they probably don't indicate the onset of water stress early enough for irrigation scheduling purposes.

### VISUAL SYMPTOMS

Plant colour, plant wilting, leaf growth, fruit growth, and stem or trunk growth have been measured to determine when to irrigate.

### LEAF TEMPERATURE

Leaf temperature tends to be higher for a stressed plant than for an unstressed plant. Temperature can be quickly measured using an infrared thermometer.

### LEAF REFLECTANCE

Water-stressed leaves reflect less infrared light than the leaves of well-watered plants. Aerial infrared photography has been used to detect water stress in this way.

### INSTRUMENTS

Instruments measure stomatal (leaf breathing pore) conductance and transpiration, which tend to decrease as water stress becomes more severe.

**Using signs of water stress to schedule irrigation has obvious limitations. This peach orchard has suffered reduced tree size and possible damage to plant tissues due to a lack of water.**

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## EVAPOTRANSPIRATION

Irrigation can also be scheduled based on estimates of evapotranspiration – the total amount of water lost by **transpiration** from the crop canopy and **evaporation** from the soil. The water needed for **evapotranspiration** is the **crop water requirement.**

### METHODS OF ESTIMATING EVAPOTRANSPIRATION

**Pan Evaporation**

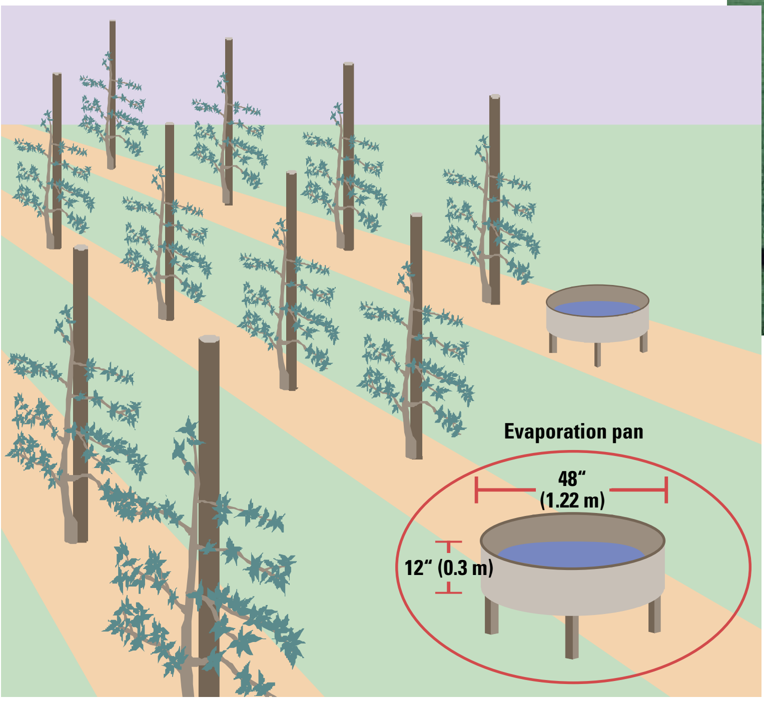
- local weather stations may collect evaporation data

**Modified Penman**

- uses data on temperature, percent sunshine, relative humidity and wind velocity
- interprets air temperature and radiation data

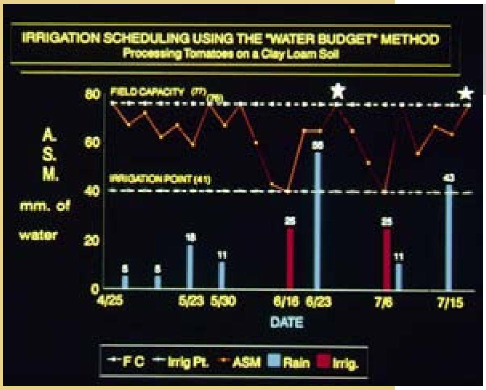
The method used depends on the availability of climate data. Not all data required are available everywhere. In all cases, the evapotranspiration value is multiplied by a crop factor that reflects percent ground cover as well as type of crop and crop growth stage.

Weather stations estimate evapotranspiration using the open pan evaporation method, which measures the daily loss of water by evaporation. Since evaporation from a free water surface is faster on windy days, days with low humidity, and on hot, sunny days, ET would be correspondingly higher.




The pan evaporation method provides a reasonable estimate of cropland evapotranspiration. To be most useful, pans should be placed close to the crop grown.

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE




**This graph illustrates rainfall dates and amounts, irrigation periods and available soil moisture contents over the growing season. Shown here are available soil moisture contents for processing tomatoes on clay loam soil over the growing season.**

## IRRIGATION SCHEDULING USING EVAPOTRANSPIRATION DATA: THE WATER BALANCE METHOD

With the help of evapotranspiration data, the water balance method can be used to schedule irrigation. The method is inexpensive, simple and relatively accurate. It assumes:

- ▸ soil water is a reservoir of available water
- ▸ field capacity is reached when reservoir is full (this is the amount of water held in the soil after the excess has drained following a saturating rainfall)
- ▸ crop water use (evapotranspiration) takes water out of the reservoir
- ▸ rainfall and irrigation add water to the reservoir.

The following example, using a tomato grower in Southwestern Ontario, might help you better understand the water balance method. Each step is described, illustrated, and corresponds to the irrigation scheduling worksheet on page 42.

Here is some essential information about the grower's operation:

| | |
|---|---|
| **Nearest weather station** | **Windsor** |
| **Soil texture** | **sandy loam** |
| **Crop** | **tomato** |
| **Soil-saturating rainfall** | **June 19** |
| **Irrigation system** | **sprinkler.** |

**Table 1. RANGES IN AVAILABLE WATER CAPACITY FOR SOIL TEXTURES**

| SOIL TEXTURE | AVAILABLE WATER CAPACITY (inch of water/inch of soil = mm of water/mm of soil) | |
|---|---|---|
| | **Range** | **Average** |
| SANDS | 0.05–0.08 | 0.065 |
| LOAMY SAND | 0.07–0.10 | 0.085 |
| SANDY LOAM | 0.09–0.12 | 0.11 |
| LOAM | 0.13–0.17 | 0.15 |
| SILT LOAM | 0.14–0.17 | 0.16 |
| SILTY CLAY LOAM | 0.15–0.20 | 0.18 |
| CLAY LOAM | 0.15–0.18 | 0.17 |
| CLAY | 0.15–0.17 | 0.16 |

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

**Before you start:**

**Estimate the maximum amount of crop-available soil water in the root zone (field capacity).**

Total crop-available soil water in the root zone at field capacity:

= available water capacity of the soil texture (Table 1 on page 40) x crop rooting depth (Table 2 below)

= 0.11 mm/mm x 300 mm = 0.11 in/in x 12 inch

= 33 mm = 1.32 inch

**Enter CROP-AVAILABLE SOIL WATER at Field Capacity on the worksheet on page 42.**

**Establish allowable soil water depletion in the root zone (irrigation point).**

Allowable soil water depletion (irrigation point):
= 50% crop-available soil water

= 33 mm x 50% = 1.32 inch x 50%

= 16.5 mm = 0.66 inch

**Enter IRRIGATION POINT (50% CROP-AVAILABLE SOIL WATER) on the worksheet.**

(For this example we will use metric, as millimetres are used to record rainfall and predict ET.)

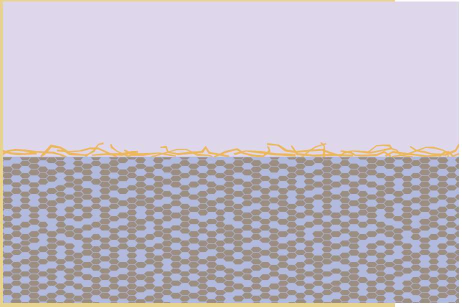
**Table 2. CROP ROOTING DEPTH – HORTICULTURAL CROPS**

| CROP | DEPTH TO IRRIGATE mm (inches) |
|---|---|
| BEANS, CABBAGE, CELERY, CUCUMBERS, LETTUCE, MELONS, ONIONS, PEAS, RADISHES, TOMATOES, POTATOES | 300 (12) |
| APPLES | 900 (36) |
| CHERRIES | 750 (30) |
| GRAPES | 900 (36) |
| PEACHES | 750 (30) |
| PEARS | 750 (30) |
| RASPBERRIES | 600 (24) |
| STRAWBERRIES | 300 (12) |

**Table 2a. CROP ROOTING DEPTH – COMMON FIELD CROPS**

| CROP | DEPTH TO IRRIGATE mm (inches) |
|---|---|
| CORN | 600 (24) |
| SOYBEANS, WHITEBEANS, TOBACCO, FIELD PEAS | 300 (12) |

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE



**STEP 1** From the example on the previous page, fill in the CROP-AVAILABLE SOIL WATER and IRRIGATION POINT on the Irrigation Scheduling Worksheet. Select a starting date. In this example, a soil-saturating rainfall occurred on June 19. June 20 will be used as the starting date. Enter this date on the first line of the crop in column 1 of the worksheet. Enter the starting value of available soil water (in this case 33.0, crop-available soil water at field capacity) in the SOIL WATER BALANCE (start) column (7).

## IRRIGATION SCHEDULING WORKSHEET

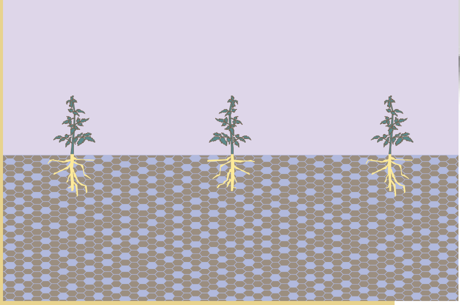
Field: ____________ Crop: Tomatoes

CROP-AVAILABLE SOIL WATER at Field Capacity: 33 mm

IRRIGATION POINT at 50% Crop-Available Soil Water: 16.9 mm

| Column (1) DATE | (2) CROP FACTOR | X | (3) ET mm | = | (4) ADJUSTED ET mm | (5) RAINFALL mm | (6) IRRIGATION mm | (7) SOIL WATER BALANCE (START) mm | (8) SOIL WATER BALANCE (END) mm |
|---|---|---|---|---|---|---|---|---|---|
| June 20 | 0.7 | X | 4.2 | = | 2.9 | | | 33.0 | 30.1 |
| June 21 | 0.7 | X | 4.2 | = | 2.9 | 20 | | 30.1 | 33.0 |
| June 22 | 0.7 | X | 4.2 | = | 2.9 | | | 33.0 | 30.1 |
| June 23 | 0.7 | X | 4.2 | = | 2.9 | | | 30.1 | 27.2 |
| June 24 | 0.7 | X | 4.2 | = | 2.9 | | | 27.2 | 24.3 |
| June 25 | 0.7 | X | 4.9 | = | 3.4 | | | 24.3 | 20.9 |
| June 26 | 0.7 | X | 4.9 | = | 3.4 | | | 20.9 | 17.5 |
| June 27 | 0.7 | X | 4.9 | = | 3.4 | | 18.9 | 17.5 | 33.0 |
| June 28 | 0.7 | X | 4.9 | = | 3.4 | | | 33.0 | 29.6 |
| June 29 | 0.7 | X | 4.9 | = | 3.4 | | | 29.6 | 26.2 |
| June 30 | 0.7 | X | 4.9 | = | 3.4 | 5 | | 26.2 | 27.8 |
| July 1 | 0.7 | X | 4.9 | = | 3.4 | | | 27.8 | 24.4 |

**A blank copy of this worksheet has been provided on the inside back cover for you to photocopy and use.**



**STEP 2** Choose the CROP FACTOR for each day from Table 3 or 4. The crop factor is an estimate of the percent of the soil covered by plant foliage and is used with the Evapotranspiration (ET) value (see Table 5) to estimate daily water use by the crop. In the example above, the tomatoes have had a 1st flower. From Table 3, we know the crop factor is 0.7 after 1st flower. See column 2 above. As the plants grow, the crop factors change.

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## Table 3. CROP FACTORS FOR VEGETABLES

| | | |
|---|---|---|
| BARE SOIL | 0.2 | |
| CABBAGE, CAULIFLOWER | 0.4 | from seeding or transplanting to start of heading |
| | 0.7 | from start of heading to full row fill |
| | 1.0 | remainder of crop |
| SWEET CORN | 0.4 | from seeding to 1st showing of tassel in whorl |
| | 0.7 | 1st tassel to silking |
| | 1.0 | remainder of crop |
| TOMATOES, POTATOES, PEPPERS | 0.4 | from seeding or transplanting to 1st flower |
| | 0.7 | from 1st flower to maximum row fill (TOMATOES) |
| | 0.7 | from 1st flower to tuber sizing (POTATOES) |
| | 0.7 | from 1st flower to fruit sizing (PEPPERS) |
| | 1.0 | remainder of crop |

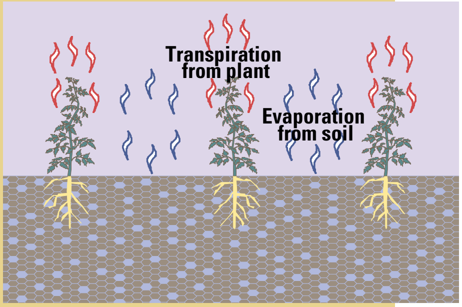
## Table 4. CROP FACTORS FOR FRUIT TREES

*will vary with crop type and planting density*

| MONTH | PERMANENT SOD WITH HERBICIDE STRIP | | CLEAN CULTIVATION PLUS COVER CROP | |
|---|---|---|---|---|
| | **Non-bearing** | **Mature** | **Non-bearing** | **Mature** |
| APRIL | 0.2 | 0.2 | 0.2 | 0.2 |
| MAY | 0.3 | 0.3 | 0.3 | 0.3 |
| JUNE (1–15) | 0.3 | 0.4 | 0.3 | 0.4 |
| JUNE (16–30) | 0.5 | 0.6 | 0.4 | 0.5 |
| JULY | 0.6 | 1.0 | 0.5 | 0.65 |
| AUGUST | 0.6 | 1.0 | 0.5 | 0.65 |
| SEPTEMBER | 0.5 | 0.95 | 0.3 | 0.5 |

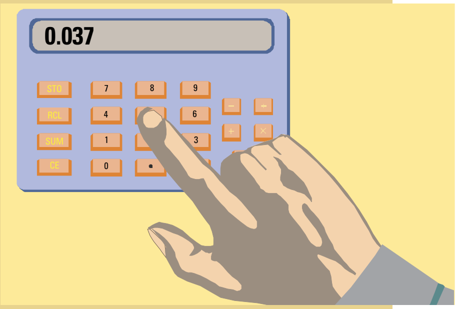
**Non-bearing trees (ages 1-4 years); mature trees (age > 4 years)**

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE




## STEP 3

Enter the EVAPOTRANSPIRATION (ET) value for each day from Table 5, or from another reliable source of ET data. Examples are entered in column 3 of the worksheet.

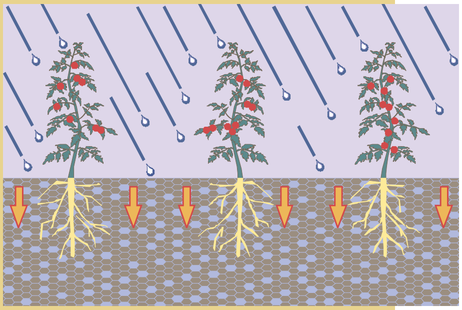



## STEP 4

Calculate the adjusted ET for each day = ET x crop factor
For June 20:

| | |
|---|---|
| = 4.2 mm x 0.7 | = 0.17 inch x 0.7 |
| = 2.9 mm | = 0.12 inch |

Enter this value in the ADJUSTED ET column for June 20. See column 4 of the worksheet.



## STEP 5

Record the daily RAINFALL or IRRIGATION amounts for each day. Have rain gauges in the field to measure rainfall. With overhead irrigation they may also be used to confirm the amount of irrigation water applied. If surface runoff occurs, use only 75% of the total rainfall if heavy rainfall occurs within a short time period.

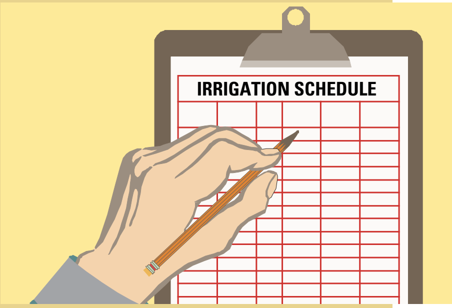
In this example, rain fell on June 21 and June 30. See column 5 of the worksheet.

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

**Table 5. AVERAGE MAXIMUM DAILY ET VALUES (mm)**

| Month | Date | Windsor | Ridgetown | London | Simcoe | Vineland | Toronto | Mt. Forest | Trenton | Ottawa | North Bay | Thunder Bay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAY | 7 | 2.1 | 2.2 | 2.4 | 2.8 | 2.0 | 2.3 | 3.0 | 2.1 | 3.0 | 2.7 | 2.4 |
| | 14 | 3.5 | 3.7 | 3.7 | 3.7 | 3.6 | 3.6 | 3.6 | 3.5 | 3.7 | 3.1 | 3.1 |
| | 21 | 3.6 | 3.8 | 3.9 | 4.6 | 3.2 | 3.9 | 4.0 | 3.6 | 4.2 | 3.3 | 3.3 |
| | 28 | 4.1 | 4.0 | 3.7 | 4.9 | 3.3 | 3.8 | 3.3 | 3.3 | 3.5 | 2.9 | 3.7 |
| JUNE | 4 | 4.2 | 4.3 | 4.1 | 4.8 | 3.9 | 4.3 | 4.5 | 4.3 | 4.6 | 3.9 | 4.0 |
| | 11 | 4.3 | 4.2 | 4.2 | 5.2 | 4.4 | 4.2 | 3.8 | 4.1 | 4.6 | 4.1 | 4.1 |
| | 18 | 4.2 | 4.3 | 4.1 | 5.4 | 4.3 | 4.4 | 4.5 | 4.0 | 4.6 | 3.9 | 4.1 |
| | 25 | 4.9 | 4.7 | 4.5 | 5.5 | 5.3 | 4.6 | 5.2 | 4.8 | 4.5 | 4.0 | 4.9 |
| JULY | 2 | 4.6 | 4.7 | 4.9 | 5.3 | 4.7 | 4.5 | 5.3 | 4.5 | 4.7 | 4.1 | 4.3 |
| | 9 | 5.4 | 5.2 | 4.5 | 5.5 | 5.2 | 4.9 | 5.1 | 5.1 | 5.0 | 4.2 | 4.7 |
| | 16 | 4.9 | 4.9 | 4.4 | 5.0 | 4.8 | 4.7 | 4.8 | 4.4 | 4.3 | 4.0 | 4.8 |
| | 23 | 4.7 | 4.6 | 4.4 | 5.6 | 4.4 | 4.8 | 4.5 | 4.5 | 4.9 | 4.0 | 5.1 |
| | 30 | 4.8 | 4.2 | 4.3 | 5.1 | 3.3 | 3.9 | 4.7 | 4.2 | 4.5 | 3.7 | 4.5 |
| AUG | 6 | 4.8 | 4.7 | 4.2 | 4.6 | 4.3 | 4.5 | 4.8 | 4.1 | 4.3 | 3.6 | 4.0 |
| | 13 | 3.6 | 3.8 | 3.5 | 4.5 | 3.3 | 3.6 | 3.2 | 3.3 | 3.2 | 2.6 | 4.2 |
| | 20 | 3.4 | 3.0 | 3.6 | 3.5 | 3.2 | 3.2 | 3.7 | 3.4 | 3.4 | 2.6 | 2.8 |
| | 27 | 3.5 | 3.3 | 3.5 | 4.3 | 3.3 | 3.4 | 3.5 | 3.0 | 3.1 | 2.4 | 2.7 |
| SEPT | 3 | 3.5 | 3.2 | 3.4 | 4.5 | 3.2 | 3.3 | 3.3 | 3.2 | 3.5 | 2.7 | 2.8 |
| | 10 | 3.3 | 3.4 | 2.8 | 3.9 | 2.7 | 3.0 | 3.4 | 2.6 | 2.4 | 2.5 | 2.3 |
| | 17 | 2.4 | 2.4 | 2.3 | 3.0 | 2.5 | 2.7 | 2.2 | 1.7 | 1.3 | 1.0 | 1.6 |
| | 24 | 2.3 | 2.4 | 2.3 | 2.9 | 2.2 | 1.6 | 1.7 | 1.7 | 1.9 | 0.7 | 1.1 |

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE




## STEP 6

Calculate the daily SOIL WATER BALANCE.
= Soil Water Balance (start) – adjusted ET + rainfall + irrigation
For June 20:

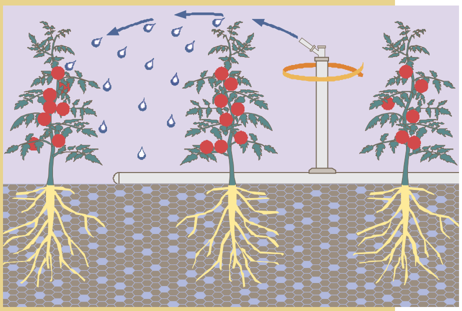
= 33 mm – 2.9 mm + 0 mm + 0 mm = 1.32 inch – 0.11 inch + 0 inch + 0 inch

= 30.1 mm = 1.21 inch

Enter this value in the SOIL WATER BALANCE (end) column for June 20.
Carry this over to the SOIL WATER BALANCE (start) column for June 21.

On June 21, the soil water balance adds up to 47.2 mm (1.86 in). The soil water balance cannot be greater than the crop-available soil water. When this occurs, enter the value for crop-available soil water (33 mm or 1.32 in). See column 8 of the worksheet.

Continue this calculation for each day of the growing season.



## STEP 7

Irrigate when the soil water balance drops to the irrigation point (50% crop-available soil water). In this example, the soil water balance drops to 17.5 mm (0.69 in) to trigger an irrigation. On June 27, the grower irrigates to 100% of crop-available soil water (33 mm or 1.32 in). Since this grower uses sprinkler irrigation, a 75% irrigation efficiency is assumed, and the amount of water required is adjusted upwards by dividing by 0.75.

Water required:

= 100% crop-available soil water + adjusted ET – Soil Water Balance (start)

= 33 mm + 3.4 mm – 17.5 mm = 1.32 inch + 0.13 – 0.69 inch

= 18.9 mm = 0.76 inch

Assume 75% irrigation efficiency for sprinkler irrigation:

= Water required ÷ 0.75

= 18.9 mm ÷ 0.75 = 0.76 inch ÷ 0.75

= 25.2 mm = 1.01 inch

Record the water required in the IRRIGATION column. On the irrigation date, the SOIL WATER BALANCE (end) should be entered as 100% of crop-available soil water.

With monitoring and simple calculations, irrigation scheduling can make irrigations more timely, precise and less wasteful.

# SCHEDULING: KNOWING WHEN AND HOW MUCH TO IRRIGATE

## SCHEDULING BY COMPUTER

In some areas and in some crops, computer programs are being used to schedule irrigation. Data such as crop information, rainfall, previous irrigation and water monitoring equipment (e.g., tensiometer readings) are used to calculate the water balance for a particular crop and determine the need for irrigation. The computer may be used to turn irrigation on and off for automated systems (applicable to drip, centre pivots and permanent sprinkler systems). The Ontario Ministry of Agriculture and Food continues to evaluate the available irrigation scheduling programs and equipment and their suitability.

## CONSIDERATIONS FOR APPLYING IRRIGATION WATER

Avoid wasting water during application. Be aware of the water intake rate of the soil. This is the rate at which water infiltrates the soil and it determines how much water to apply per hour. Applying water at a higher rate than the soil can absorb will lead to runoff. Table 6 below lists the maximum rate of water to apply per hour for various soil textures. Coarse-textured soils have a higher water intake rate than fine-textured soils. Rain or irrigation gauges should be placed in the field to help you determine how much irrigation water (overhead only) you've applied. These gauges will also help you track rainfall amounts, which will aid in irrigation scheduling.

**Most crops have certain growth stages, during which drought stress can severely reduce yield and/or quality. While adequate moisture is desirable at all growth stages, irrigation is especially important during the critical growth periods.**

**Using simple monitoring methods and calculations, scheduling can make irrigation more timely and precise and less wasteful.**

### TABLE 6. RANGES OF INTAKE RATE FOR SOIL TEXTURES

| SOIL TYPE | INTAKE RATE | | | |
|---|---|---|---|---|
| | (in/hr) | | (mm/hr) | |
| | Range | Average | Range | Average |
| SANDS | 0.5–1.0 | 0.70 | 12–25 | 18 |
| LOAMY SAND | 0.3–0.8 | 0.55 | 7–20 | 14 |
| SANDY LOAM | 0.3–0.8 | 0.55 | 7–20 | 14 |
| LOAM | 0.3–0.8 | 0.55 | 7–20 | 14 |
| SILT LOAM | 0.2–0.3 | 0.25 | 4–8 | 6 |
| SILTY CLAY LOAM | 0.2–0.3 | 0.25 | 4–8 | 6 |
| CLAY LOAM | 0.2–0.3 | 0.25 | 4–8 | 6 |
| CLAY | 0.1–0.25 | 0.20 | 2–6 | 4 |