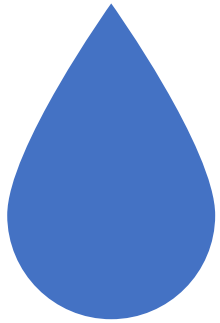
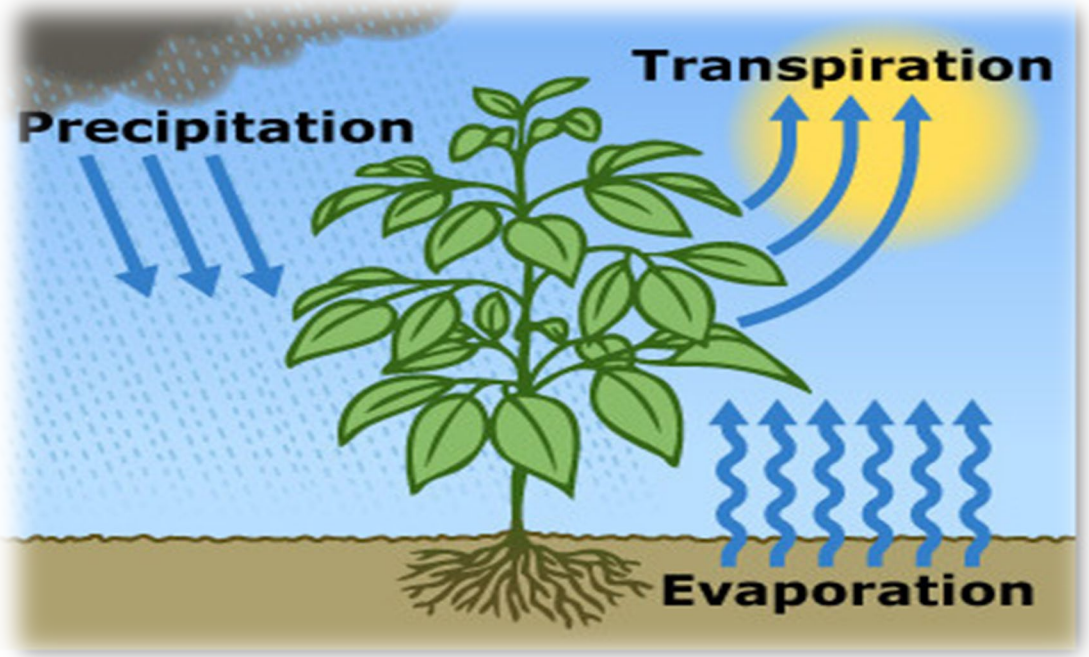
Water Management

Transpiration, Evapotranspiration, and Irrigation

Grades 9-12





Master Gardeners

The University of California Cooperative Extension (UCCE) Master Gardener Program (MGP) is an educational program designed to teach and effectively extend information to address home gardening and non-commercial horticulture needs in California.

UCCE is the outreach arm of UC's division of Agriculture and Natural Resources (ANR). Master Gardener volunteers (MG volunteers) promote the application of basic environmentally appropriate horticultural practices through UCCE-organized educational programs that transfer research-based knowledge and information.

University of California
Agriculture and Natural Resources
UCCE Master Gardener Program

Why is Water Management Important to Gardeners?

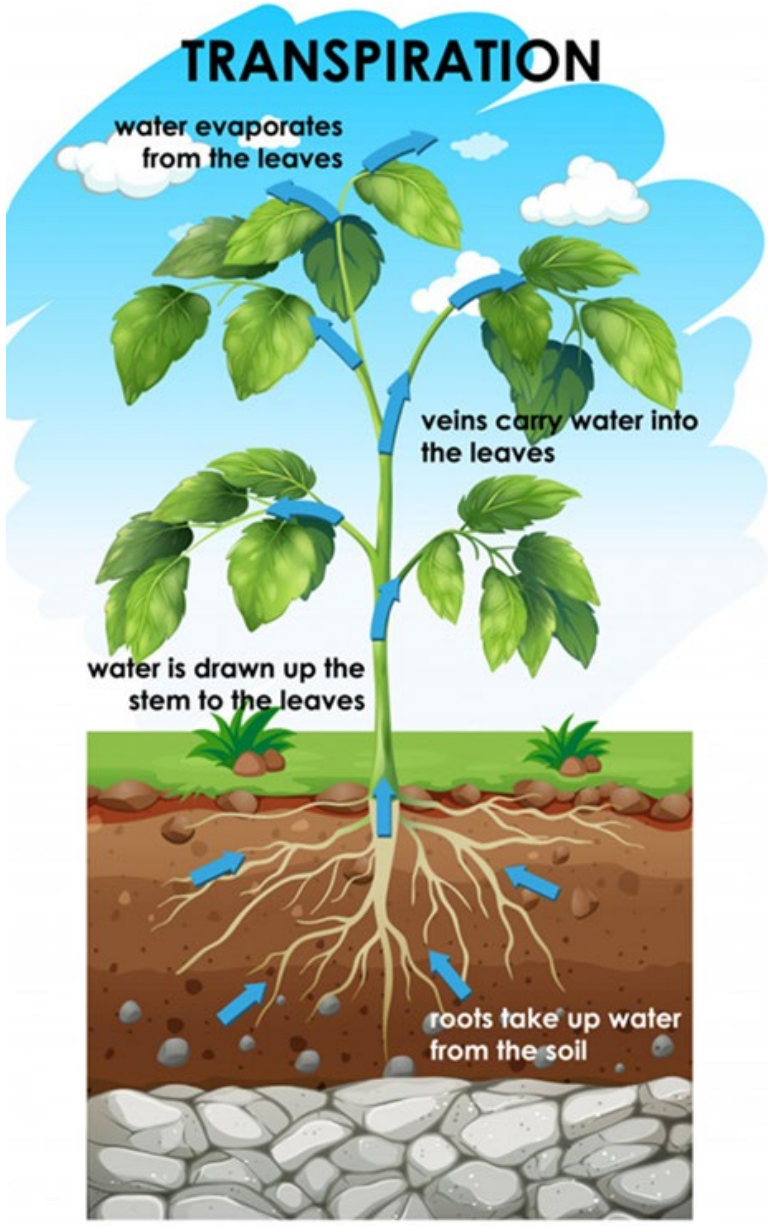
- Most plants are composed of about 90% water. Water is necessary for photosynthesis, plant cell integrity, and transporting nutrients to the plant.
- Understanding transpiration and evapotranspiration is useful for developing watering schedules, and to recognize and correct drought stress.

- It is critical that California gardeners implement sound water management practices that ensure water conservation, reduce water waste, and improve the quality of urban landscape plantings.

Learning Goal:

- Student gardeners will become familiar with transpiration and evapotranspiration and will learn how to apply this to the water management of their gardens.

Part 1: Transpiration



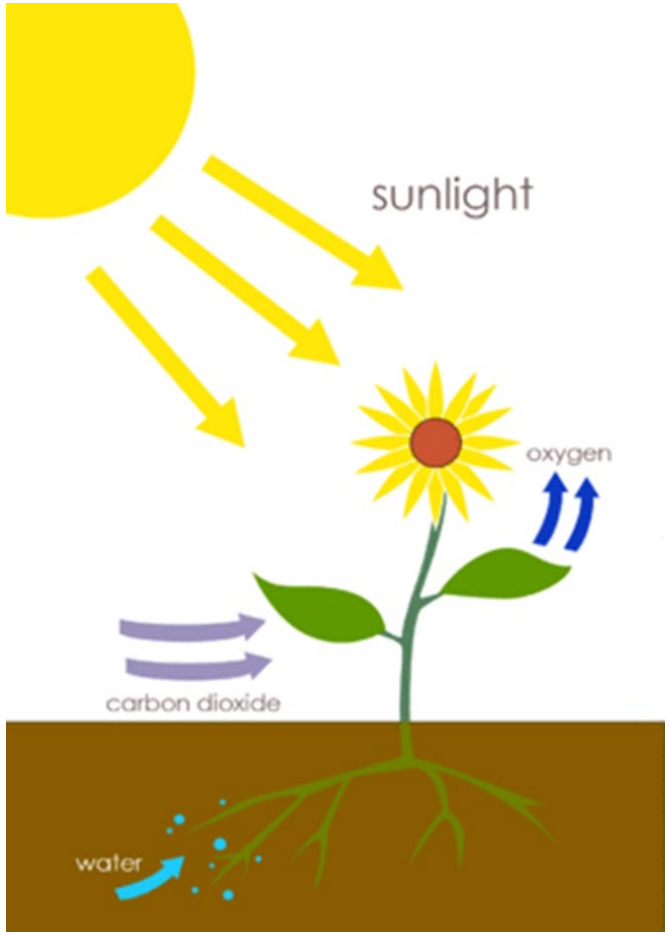
Transpiration

Transpiration is the loss of water from a plant in the form of water vapor.

- Water is absorbed by roots from the soil and transported as a liquid to the leaves via xylem.
- In the leaves, small pores allow water to escape as a vapor.
- Of all the water absorbed by plants, less than 5% remains in the plant for growth!

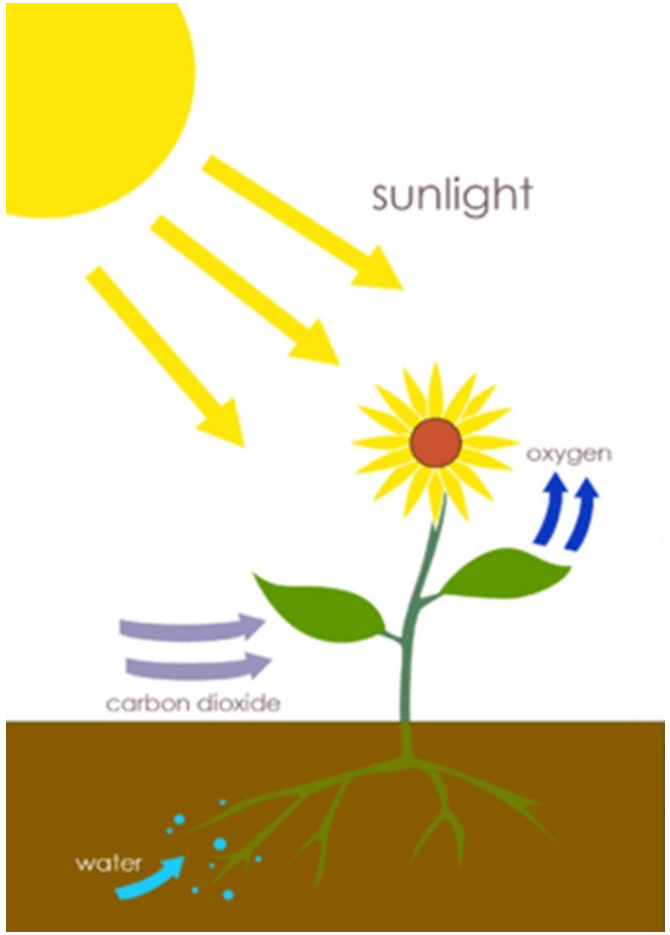
Why Do Plants Transpire?

- **Carbon dioxide entry:** Plants use the energy from sunlight to make sugars (food) from carbon dioxide taken from the atmosphere and water through the process of photosynthesis.
- **Evaporative cooling:** As water evaporates or converts from a liquid to a gas from the leaf pores, energy is released.

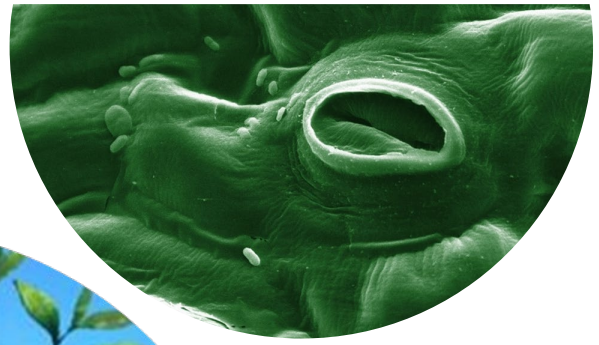


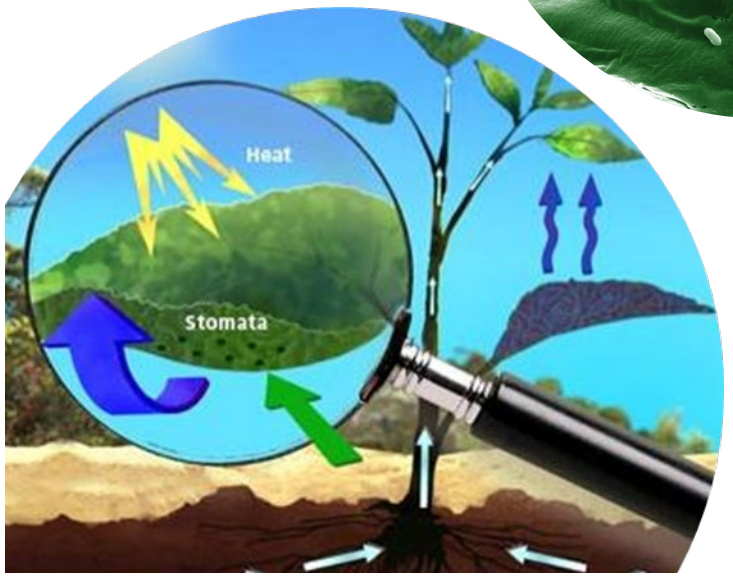
Other Reasons Plants Transpire

- **Accessing nutrients from the soil:** The water that enters the root contains dissolved nutrients vital to plant growth. Transpiration enhances nutrient uptake into plants.
- **Water uptake:** Although only less than 5% of the water taken up by roots remains in the plant, that water is vital for plant structure and function.



Why are Stomata Important to the Transpiration Process?

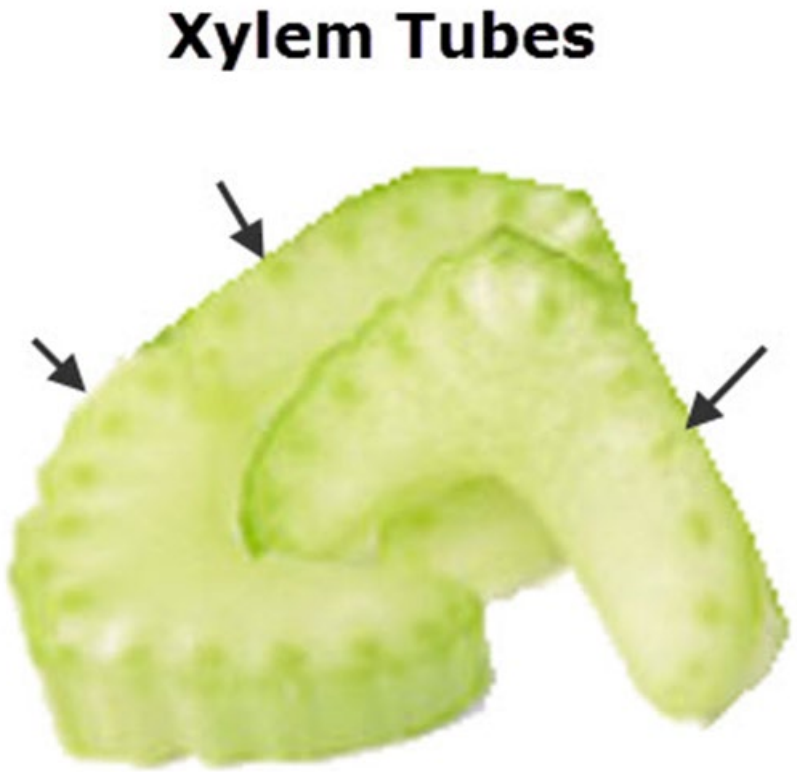




- A plant's leaves opens its stomata (pores) in order to get carbon dioxide gas from the atmosphere.
- Stomata also allow water to leave the leaf through evaporation which is caused when water heats up and becomes vapor.
- Plants that grow in full sunlight usually have most of their stomata on the shaded undersides of their leaves. This helps the plant conserve water.

What Keeps the Water Moving Through the Plant?

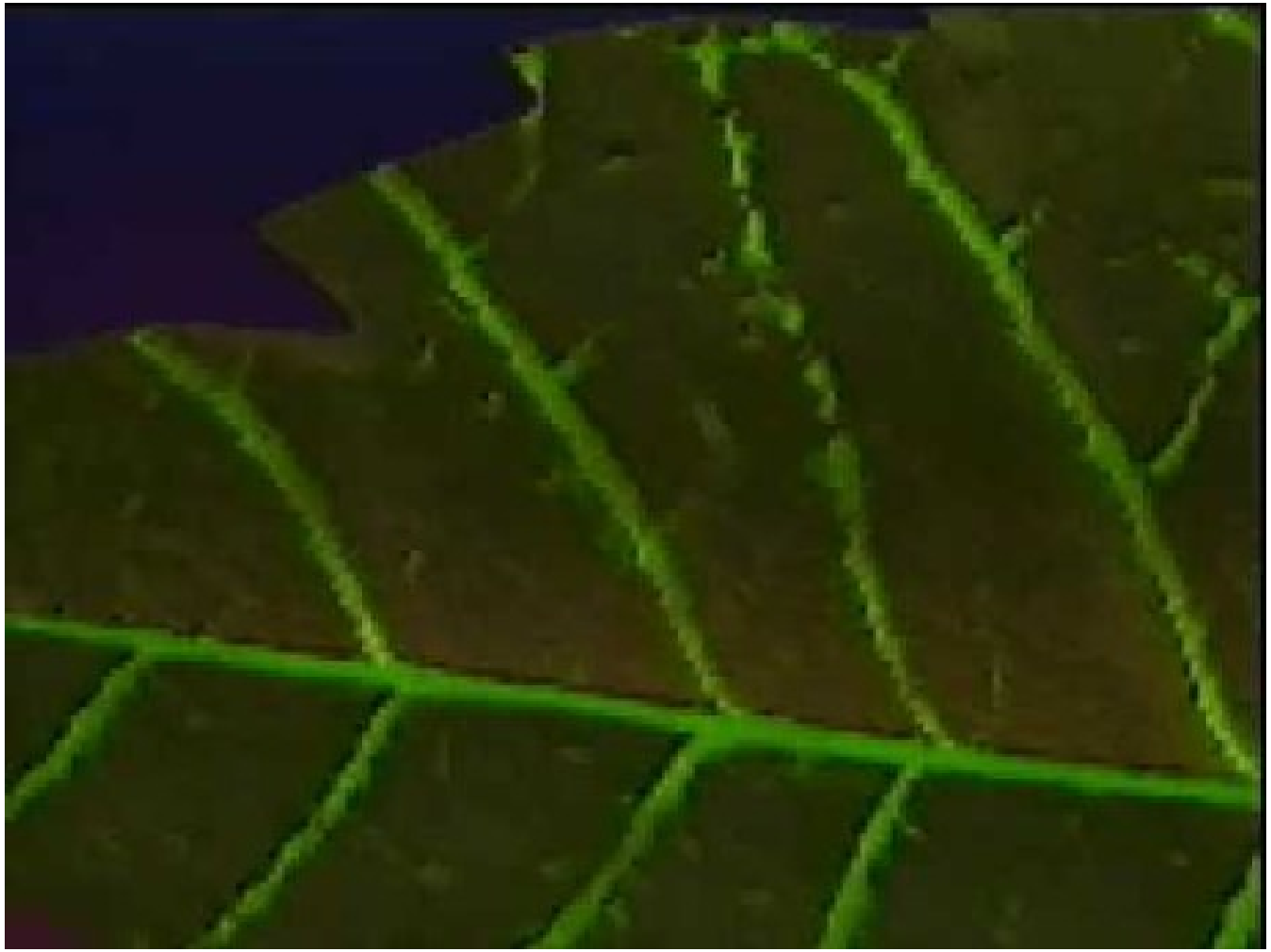
- Water gets into the plant at the roots by osmosis and it transports dissolved mineral nutrients to the upper parts of the plant through the xylem.
- Xylem are located in the plant's vascular system.
- Xylem can be thought of as "tubes" that deliver water to all parts of the plant.
- Xylem's tubes are highly effective at stacking up water molecules into long chains and pulling them upward and outward to the leaves of the plant.



Think of it Like a Milkshake

- The best way to consider this is to imagine you have a milkshake– the straw can't carry the milkshake up, but if you suck from the top of the straw, you change the pressure and force the milkshake up the straw.
- It moves in a column because the molecules are attracted to each other.
- When water evaporates from the top of the plant's leaves it changes the pressure in the xylem tubes and like the sucking action of a straw, pulls up the column of water to replace the water lost.

Video Demonstrating Transpiration



Check For Understanding: Transpiration

- What is transpiration?
- Give an example of why plants transpire?
- What is the role of stomata?
- Why is xylem important to the survival of a plant?

Apply Your Understanding: Transpiration

Observe transpiration in your garden

- Tie a plastic bag around a branch with leaves.
- After 30 minutes observe for evidence of moisture.
- Remember to remove the bag before leaving the garden!

Extend Your Understanding: Transpiration

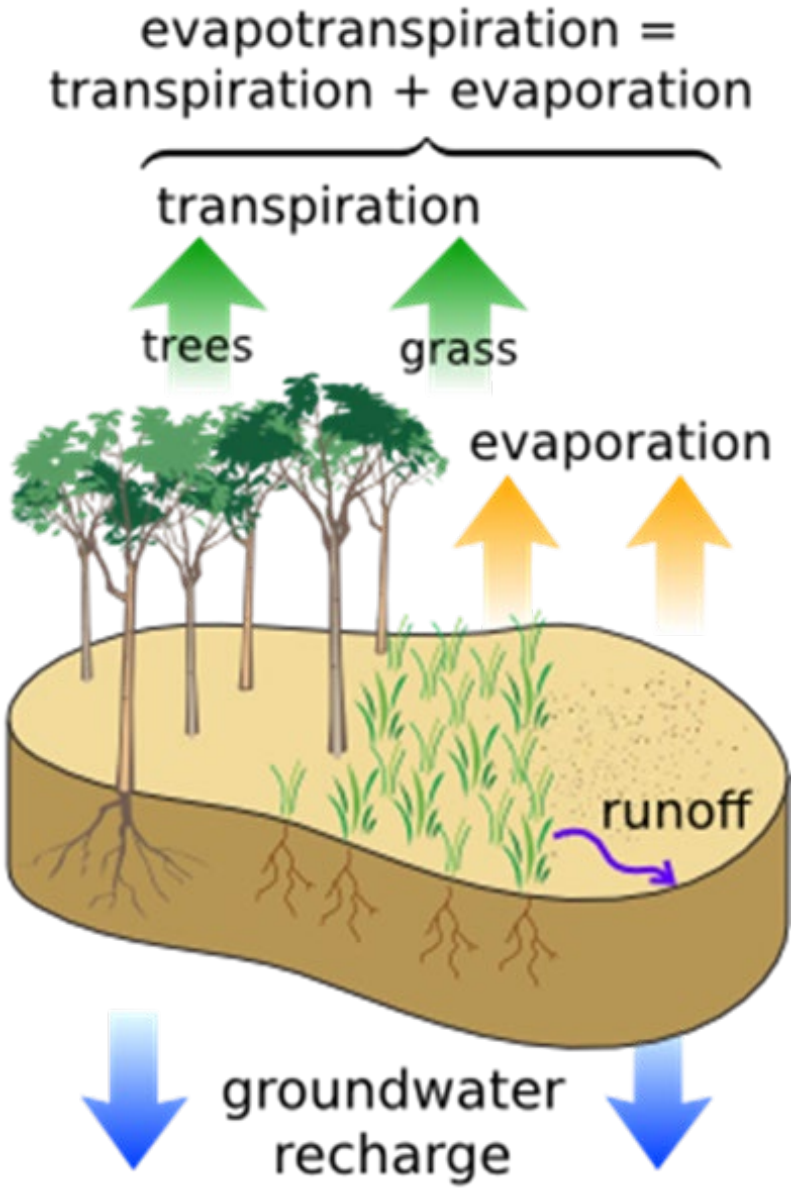
How do plants such as cacti and succulents transpire?

- Research the answer to these questions using the following suggested resources:
- Cacti and Succulents
- Dr. Universe: How Do Cacti Survive?

Part 2: Evapotranspiration

What is Evapotranspiration?

- Most of the water taken up by the plant is lost to the atmosphere through transpiration.
- In addition to transpiration, water is also evaporated from the soil.
- The combination of these two processes is called evapotranspiration (ET).



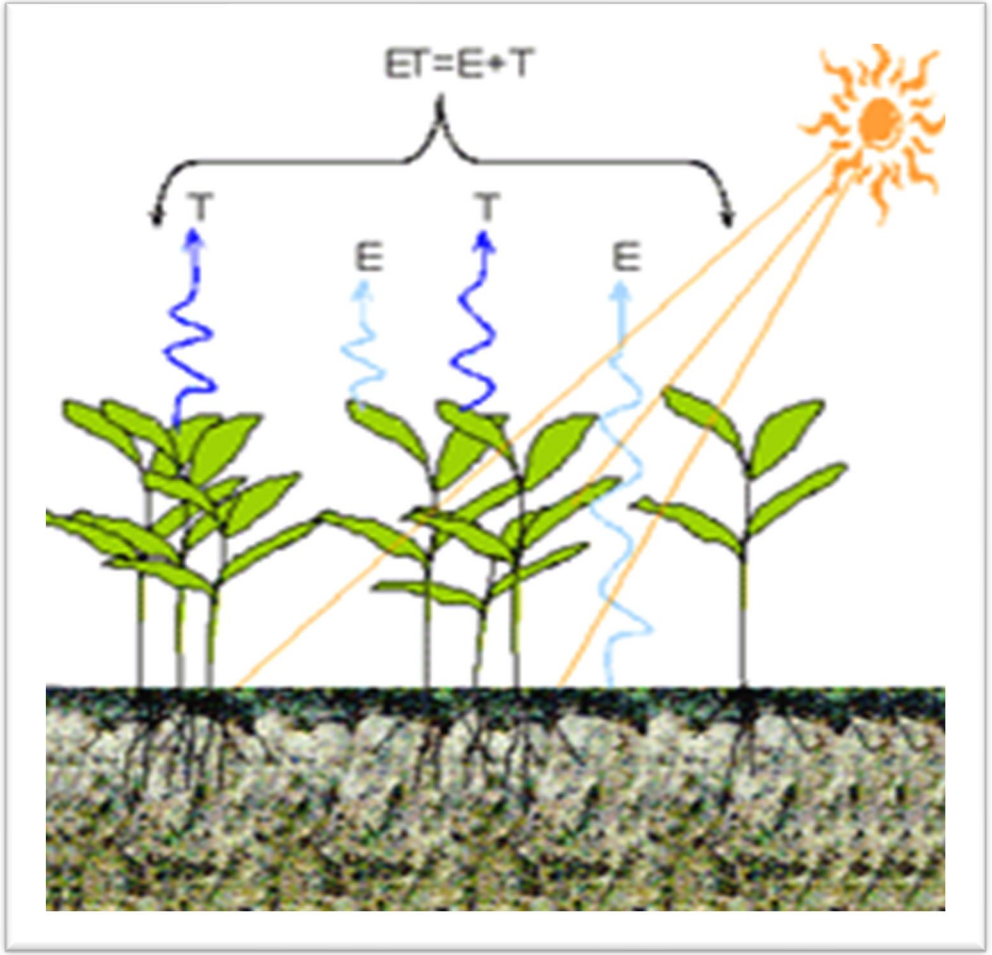
Video: Evapotranspiration

Why is Understanding Evapotranspiration Important to Gardeners?

The process of evapotranspiration (ET) is driven by environmental factors:

- Solar Radiation
- Temperature
- Relative Humidity
- Wind speed

One or more of these factors will affect plant water use.



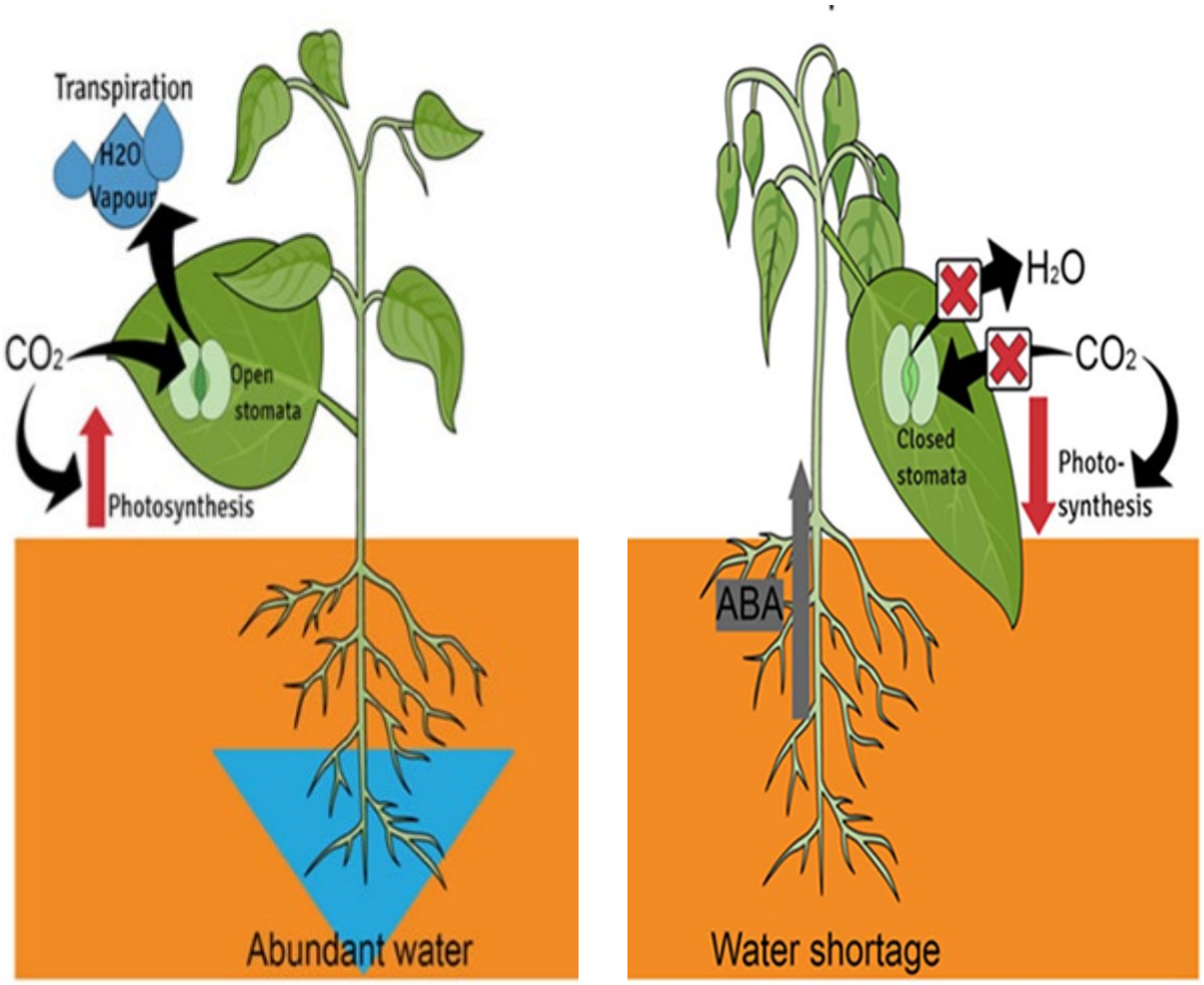
The Rate a Plant Uses Water

The term ET is often referred to as the *rate of water use* by a plant.

- The rate of water use varies depending on the type of plant.
- However, for normal growth most plant species require replacement of a large portion of water lost.

ET Affects a Plant's Turgidity

- The chains of water molecules traveling through the xylem create turgidity, meaning the plant is rigid, strong and upright; the opposite of wilting.
- When the soil of a plant runs low on available water, the water chains in the xylem become thinner and thinner due to less water.
- The plant is losing water faster than it is absorbing it.
- When this happens, the plant loses its turgidity and begins to wilt.



Understanding ET is Critical to Water Management

- ET is expressed in units of depth (inches or millimeters) or volume (gallons or liters) per day, week, month, or year.
- ET follows a bell-shaped curve through the year with the highest rate of plant water use occurring in midsummer, the lowest rate in midwinter.

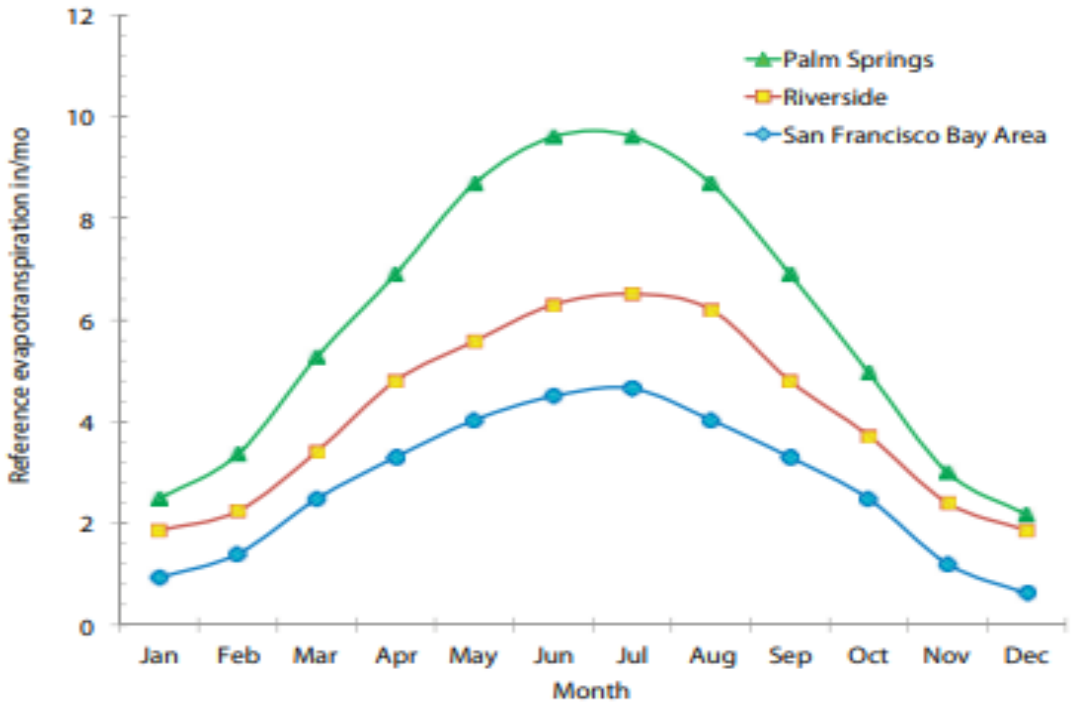


Figure 4. The same plant growing in southern California inland valley or desert areas requires more water than if grown in the San Francisco Bay Area due to higher rates of evapotranspiration. *Source:* Richard Snyder, Department of Land, Air and Water Resources, University of California, Davis.

Estimating Evapotranspiration Rates

- Several methods have been developed to estimate ET for plants. Most methods use weather data to provide an estimate of reference for potential evapotranspiration.
- These are labeled as **Eto** and **Etc**.

Eto

- **Eto** represents potential evapotranspiration of a ground cover, typically turf grass. Potential evapotranspiration (ETo) represents the loss of water when the soil is fully charged with water.

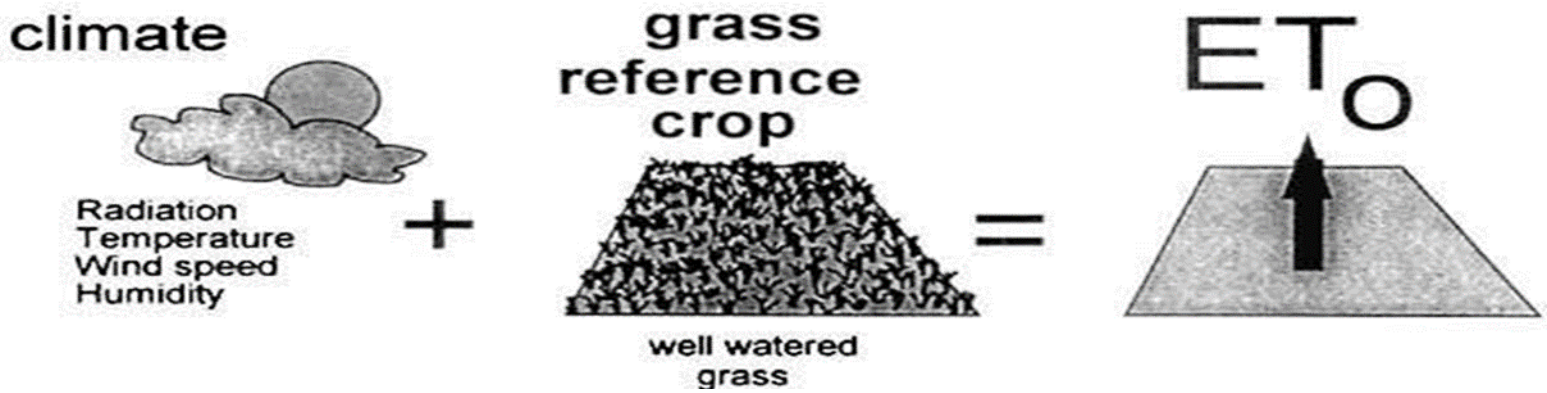


Image : United Nations Food and Agricultural Association

Etc

- **Etc** represents potential evapotranspiration of a specific plant or crop. Eto is used as a baseline and scientists factor crop coefficients called Kc values. **Kc** values are factors determining the water use of a specific species or crop and comparing it to ETo over the same time period.

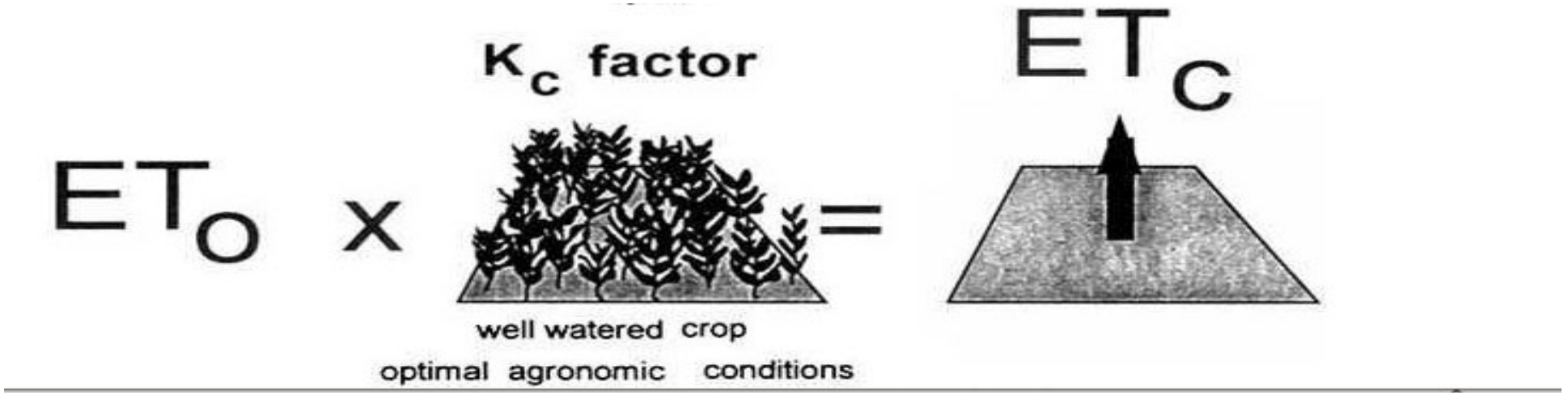


Image : United Nations Food and Agricultural Association

This Evapotranspiration Data is Available to All Gardeners

- For an overview of **Eto** rates in your general area, start at the California Irrigation Management Information System and click on the Eto Zones Map. This will provide information to identify which zone your area is in and the daily average ETo rates for each month.
- Monthly average daily **ETc** rates for specific plants, including vegetables and fruit trees, can be found using the ET data resource: California Evapotranspiration Data.

How Do Gardeners Use Eto and Etc Rates?

Since scientists can calculate the approximate amount of water that plants need daily, should gardeners simply apply that amount to irrigating their gardens daily?

- Under most conditions applying rather small amounts of water daily is an inefficient and unsound horticultural practice.
- A more practical and effective method is to wait over a period of time, usually several days, and then apply the accumulated amount of the projected ET water use.

Source: Landscape Irrigation System and Evaluation Management, UCCE

Factors That influence Irrigation Decisions

Factors Which Necessitate Frequent Irrigation:

- High plant water use rates
- Shallow rooting depth
- Sandy soils with low water holding capacity
- High runoff potential due to slope or compaction
- Poor infiltration rate due to compaction or clay soils

Factors Which Allow Less Frequent Irrigation:

- Lower ET rate (remember the bell curve)
- Presence of rainfall, dew, or fog
- Deep roots and high root density
- Plants with ability to tolerate drought
- No runoff problems
- Acceptable quality or site use under reduced irrigation

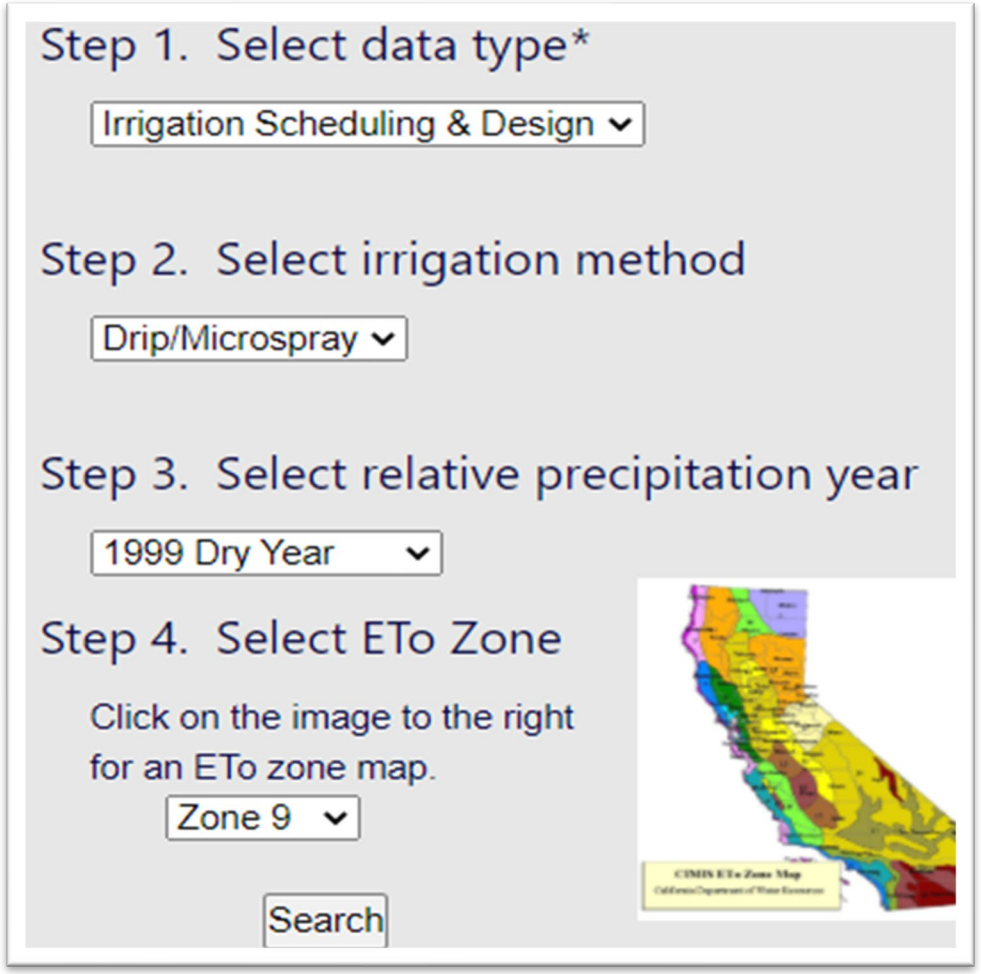
Check For Understanding: Evapotranspiration

- Evapotranspiration is a combination of water transpiration from the plant and evaporation occurring from where?
- What are the environmental factors of evapotranspiration?
- What does ET often refer to?
- What do Eto and Etc represent?
- What zone is your garden located in according to the California Irrigation Management Information System ?

Apply Your Understanding: Evapotranspiration

Identify this month's average daily ETc rate for each of the vegetables growing in your garden using the ETc data resource:

California Evapotranspiration Data.



Part 3:
Best Irrigation Management Practices

Apply the Right Amount of Water

Overwatering plants is more common than underwatering plants.

- Remember the environmental factors of evapotranspiration!
  - Water in the cooler morning hours when the sun is not directly overhead, the temperature is cooler, and it is usually less windy.
- Know how much water your garden plants lose through ET.

Apply the Right Amount of Water

Know how to estimate water delivery amount following this guidance:

1 gallon of water adds 1.6 inches of water over 1 square foot of dry ground
and wets that area to a depth of 1.5 inches,
depending on soil texture and current soil water content.

Source: California Master Gardener Handbook, Pettinger

What is Your Soil's Percolation Rate?

Know how well your soil percolates to avoid over or underwatering.

- To test your soil for percolation, dig a hole about 12" deep and 12" wide. Fill the hole with water and note how long the water takes to drain completely.

- Repeat a second time once the hole has completely drained. Lay a stick across the top of the hole and measure the distance from the top of the water to the stick each hour until it has completely drained.

- 1"-4" per hour, you have well-draining soil
- Less than 1 " per hour, your soil needs some amendments to improve drainage.
- More than 4" per hour, too sandy and you need to add organic matter.

Minimize Soil Evaporation with Mulching

Mulching

- Insulates the soil
- Mulches should be kept 4-6 inches away from plant stems to avoid “trunk” diseases
- Spread at a depth of 2-4 inches for maximum insulating benefits

- Watch this brief Master Gardener video on mulching.

Minimize Soil Evaporation with Mulching

Types of Mulches

- Organic woody material 1-3 inches in length
- Recycled material such as newspaper or old carpeting
- Do not use organic material that may be diseased or recycled material that has been exposed to environmental toxins.
  - An example of this is shredded tires.

Maintain Healthy Plant Turgidity

New Plantings

- New plantings require more frequent watering than established plants.
- Maintain moist soil around recent transplants and seedlings.
- Maintain a moist seed bed through seed germination.

Established Plants

- Most landscape plants and grasses can be maintained with less water.
- Many established plants will show some wilting mid-day during the hottest months. That may not mean they need additional water. Insert your pointer finger into the soil near the root zone at a depth of 1-2 inches. If it is moist at that depth, your established plant does not need additional water.

More Tips for Healthy Plant Turgidity

Create Hyrdozones

- Place plants with similar water requirements together in a planting bed where they will receive the correct amount of water to meet their needs.

Vegetables and Fruits

- Vegetable plants and fruit trees must receive adequate water to produce acceptable yields.
- Shallow-rooted vegetables will need more frequent watering than more deeply rooted crops. (Think hydrozone planting.)
- Fruit tree soil moisture must be maintained during growth flushes and while young fruit is setting.


Control valves


Pop-up heads (3 on left) and standard head (right)


An automatic timer

Watering Systems

No single irrigation system is perfect for every situation. However, some general principles can aid in selection.

- Design the system so that each irrigation valve or station supplies water to plants with similar water needs (hydrozones).
- Install heads and emitters of the same make on each irrigation valve or station and replace them with like products when making repairs.
- Space spray heads so that their water output fully overlaps the output of adjacent heads in the system.
- Manage water scheduling with an automatic controller. For best results choose a controller that offers three or four separate programs.

Drip Irrigation: Pros

Drip irrigation offers several advantages to home and school gardeners:

- Water is placed more accurately and efficiently in the root zone.
- Water is applied at a slow rate that reduces water loss from runoff, plant foliage remains dry which reduces the potential for disease, and dry soil between plants permits work in the garden during irrigation.
- Drip systems usually provide guidance on the amount of water the system is designed to deliver. Emitters usually deliver 1-3 gallons of water per hour.

Drip Irrigation: Cons

Disadvantages can include:

- The initial cost of the equipment.
- Possible problems with plugging of small drip openings which require routine checking.
- Overirrigation is possible because the drip system applies water to a limited area, and deep percolation below the root system can occur if the run time is too long or too frequent.

Video: How to Install a Drip System

Check For Understanding: Irrigation Management Practices

- How can you reduce evaporation of water from the soil?
- What is the formula for estimating the amount of water delivery?
- Give an example of how you can maintain healthy plant turgidity.
- What should a gardener consider when selecting an irrigation system?
- Describe both a pro and a con of using drip irrigation.

Apply Your Understanding

Find out how well your garden soil percolates following the steps described in slide 33.

- Is your soil “well-draining” or do you need to add amendments?

Extend Your Understanding: Irrigation Management Practices

1. Design a hydrozone vegetable garden bed for a fall, late winter, or spring planting based on similar ETc water use rate.

2. Evaluate your garden's existing water system using the general principles for selecting a system listed in slide 38.

Extend Your Understanding: Irrigation Management Practices

3. Learn more about irrigation practices used by the California agricultural community. A farmer and a UC Davis scientist discuss their water management work in the Growing California video.

CDFA Videos

Next Generation Science Standards

LS1.C: Organization for Matter and Energy Flow in Organisms

- The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen. (HS-LS1-5)

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. (HS-LS2-3)

ETS1.B: Developing Possible Solutions

- When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (secondary to HS-LS2-7)

Career Technical Education Standards
Agriculture and Natural Resources Pathway

G3.0 Understand plant physiology and growth principles.

- G3.1 Investigate plant systems, nutrient transportation, and energy storage
- G3.4 Research the factors that influence plant growth, including water, nutrients, light, soil, air, and climate.

Career Technical Education Standards
Agricultural Mechanics Pathway

B4.0 Select and apply plumbing system practices commonly used in agriculture.

- B4.1 Match appropriate basic plumbing fitting skills with a variety of materials, such as copper, polyvinyl chloride (PVC), steel, polyethylene, and acrylonitrile butadiene styrene (ABS).
- B4.2 Explain the environmental influences on plumbing and irrigation system choices (e.g., filter systems, water disposal, drip vs. flood).
- B4.3 Research and communicate how various plumbing and irrigation systems are used in agriculture.
- B4.4 Complete a plumbing project, including interpreting a plan, developing a bill of materials and cutting list, selecting materials, joining, and testing.

Career Technical Education Standards
AgriScience Pathway

C11.0 Analyze plant growth and development.

- C11.1 Understand the anatomy and functions of plant systems and structures. C11.2 Identify plant growth requirements.
- C11.5 Understand photosynthesis and the roles of the sun, chlorophyll, sugar, oxygen, carbon dioxide, and water in the process.
- C11.6 Summarize the respiration process in the breakdown of food and organic matter.

Career Technical Education Standards
Ornamental Horticulture Pathway

F2.0 Summarize plant physiology and growth principles.

- F2.1 Understand plant systems, nutrient transportation, structure, and energy storage.
- F2.4 Experiment with the factors that influence plant growth, including water, nutrients, light, soil, air, and climate.
- F5.0 Summarize water and soil (media) management practices.

F5.0 Summarize water and soil (media) management practices.

- F5.1 Explain how basic soil science and water principles affect plant growth.
- F5.2 Illustrate basic irrigation design and installation methods.
- F5.3 Prepare and amend soils, implement soil conservation methods, and compare results.
- F5.4 Research major issues related to water sources and water quality.

Resources

- California Master Gardener Handbook, Pettinger; Second Edition 2015
- AZMET Evapotranspiration Estimates: A Tool for improving Water Management of Turfgrass: Paul W. Brown; Extension Biometeorologist
- Crop Evaporation-Guidelines For Computing Crop Requirements- FAO Drainage and Irrigation Paper 56, 1998
- California Evapotranspiration Data; Cal Poly San Luis Obispo; ITRC
- Institute of Agriculture and Natural Resources; Cropwatch; University of Nebraska-Lincoln
- Landscape Irrigation System and Evaluation Management ; David A. Shaw and Dennis R. Pittenger; UCCE
- Transpiration – Water Movement through Plants (opens PDF); Tracy M. Sterling, Ph.D., 2004; Department of Entomology, Plant Pathology and Weed Science, New Mexico State University

Resources Continued

- The New California Landscape Drought Toolkit
- Evapotranspiration
- What Is Transpiration in Plants? - Definition, Rate and Process
- Evapotranspiration is the sum of plant transpiration and evaporation
- Images: kiddle.com; Unsplash; Creative Commons; CIMIS; Loma Vista Garden Club; UC IPM; Department of Air, Land and Water Resources; UC Davis; United Nations Food and Agricultural Association
- Videos: watchknowlearn.org; Weather Wise; Clackamas County Master Gardeners; UCANR YouTube Channel, California Department of Food and Agriculture

Gardening Questions?

- Email the UCCE Master Gardeners of Riverside County
- Email Hotline
  - mgriverside@ucdavis.edu
- Riverside Master Gardeners Website

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