Watering Resource for the School Garden

An Overview

Water is essential for all plant growth and development. It is the main constituent of the sap in plant cells. Without a consistent and ample supply of water the plant is unable to photosynthesize, producing food for itself and in the process for all other life on earth.

Water is also essential for transpiration, which pulls water from the soil through the roots to the leaves. There it cools the plant and keeps it from wilting and dying. In the process nutrients are also transported through the plant. Respiration, seed germination and subsequent development of roots, shoots, leaves flowers, and fruit are also dependent upon an adequate water supply. To understand how plants take in and utilize water, it is important to understand the role of leaves, stems and roots.

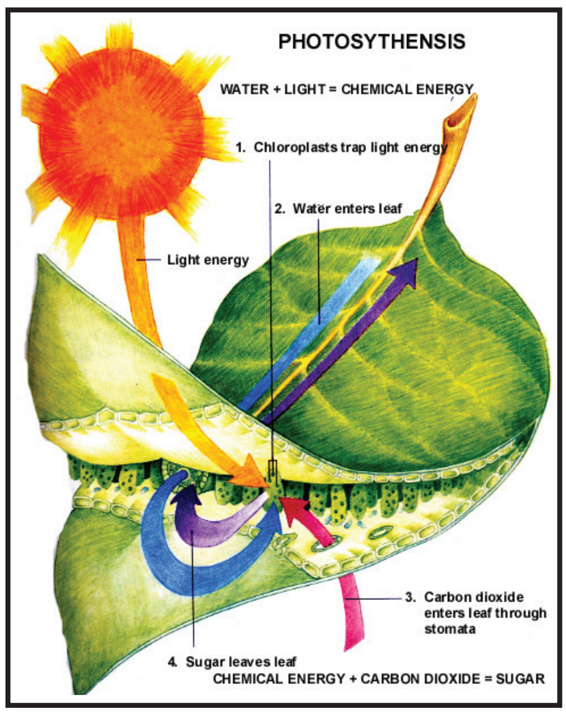
Leaves

The leaves of green plants are essential for supporting all life on earth. They **capture and convert the sun's energy** to make food for themselves, while also supplying the energy source that every other living organisms utilizes for growth and sustained metabolic processes. At the same time, they maintain an atmospheric balance between carbon dioxide and oxygen, absorb pollutants from the air and cool and shade the terrestrial environment. The three processes that carry out this important work in plant leaves are photosynthesis, transpiration and respiration.

Photosynthesis in Leaves

Photosynthesis is the connecting link between solar energy and the energy required for all life on earth. It is a chemical reaction that takes place inside the leaves of plants in the green pigment tissue known as **chlorophyll.** In order for photosynthesis to take place, chlorophyll must be present.

The leaf is well adapted to harvest the energy of the sun. Its broad, flattened surface enables it to expose the most green tissue to sunlight. The leaf also has openings, known as **stomata,** that allow for movement of water and air into and out of the leaf. Other green parts of plants, such as stems, can make food, but are not as well adapted to capture and process sunlight.



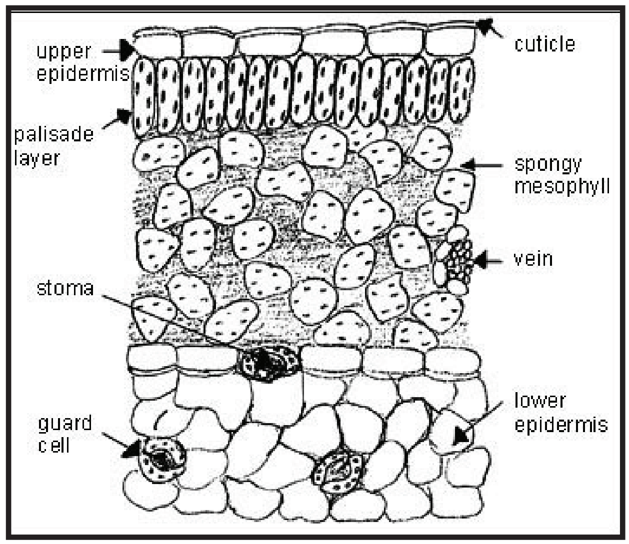
Photosynthesis is a complex chemical reaction in which carbon dioxide from the air and water from the soil, in the presence of sunlight, produce sugar. The water and carbon dioxide enter chlorophyll containing cells called **chloroplasts.** There light energy in the form of red, blue and violet rays are absorbed by antenna-like structures inside the chlorophyll molecule. This starts a chain reaction whereby water molecules are split, new molecules are formed, and oxygen is produced as a waste product and liberated as a gas into the atmosphere. Some of the new molecules are energy rich six-carbon **glucose** molecules. Excess glucose can be converted into starch, another carbohydrate, which can be stored. Plants and all other organisms metabolize these carbohydrates, turning them back into energy when needed through respiration.

Simplified, the **chemical equation** for photosynthesis is **$6CO_2 + 6H_20$ ---> chlorophyll/sunlight ----> $C_6H_{12}O_6 + 6O_2$.** However, photosynthesis is actually a much more complicated two stage chemical process. In the **Light Dependent Process,** light strikes chlorophyll in such a way as to excite electrons to a higher energy state. In a series of reactions the energy is converted along an electron transport process into ATP and NADPH. Water is split in the process, releasing oxygen as a by-product. The ATP and NADPH are used to make C-C bonds in the next phase.

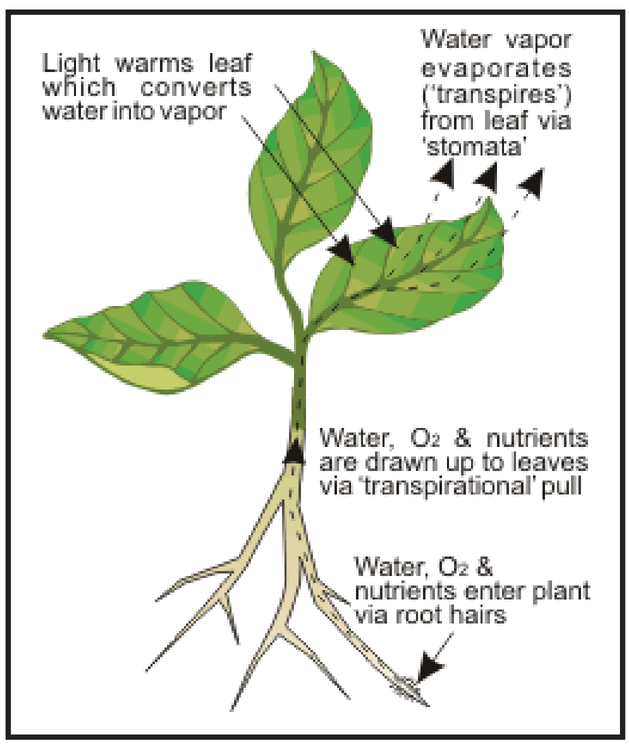
In the **Light Independent Process**, carbon dioxide from the atmosphere is captured and modified by the addition of hydrogen to form carbohydrates. This incorporation of carbon dioxide into organic compounds is known as carbon fixation. Energy comes from the first phase of the photosynthetic process. Living systems cannot directly utilize light energy, but can, through a complicated series of reactions, convert it into C-C bond energy that can be released by glycolysis and other metabolic processes.

Transpiration in Leaves

Leaves regulate the amount of water in a plant through **transpiration.** When soil moisture is adequate, the plant gives off excess water, because the roots absorb more than is needed. Transpiration uses about ninety percent of absorbed water, the other ten percent is used in chemical reactions and tissue expansion.



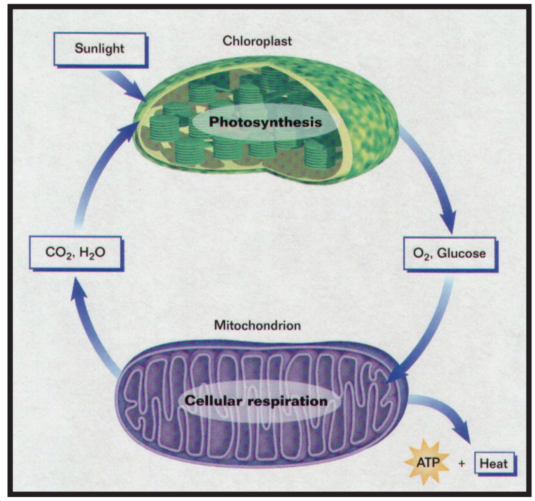
During transpiration moisture is pulled through the plant bringing dissolved minerals from the soil and transporting sugars and plant chemicals to other parts of the plant. Kidney-shaped **guard cells,** bound and control the **stomata,** regulating the amount of water transpired, thus cooling the plant and maintaining turgidity. Potassium ions are pumped into the guard cells; water follows by osmosis, causing an increase in internal **turgor pressure.** As pressure increases, water pushes against and stretches the guard-cell walls, bowing the cells outward, which opens the stoma (singular of stomata).



Stress due to insufficient soil moisture or excessive transpiration triggers the release of the hormone abscisic acid, which causes potassium ions to move from the guard cells. Water passively follows. When the guard cells lose their water they become limp and close. This seals the stomatal opening, and reduces the amount of transpiration. When dark guard cells also close to retain water.

Transpiration of water at the leaf surface may be affected by several factors. As temperature or the air movement increases, transpiration also increases. As humidity decreases, transpiration increases. Water loss also occurs more slowly in cool conditions. If adequate moisture is unavailable in soil, or if rate of evaporation from leaves exceeds the rate at which water can move upward, the plant becomes stressed and wilts.

Respiration in Leaves



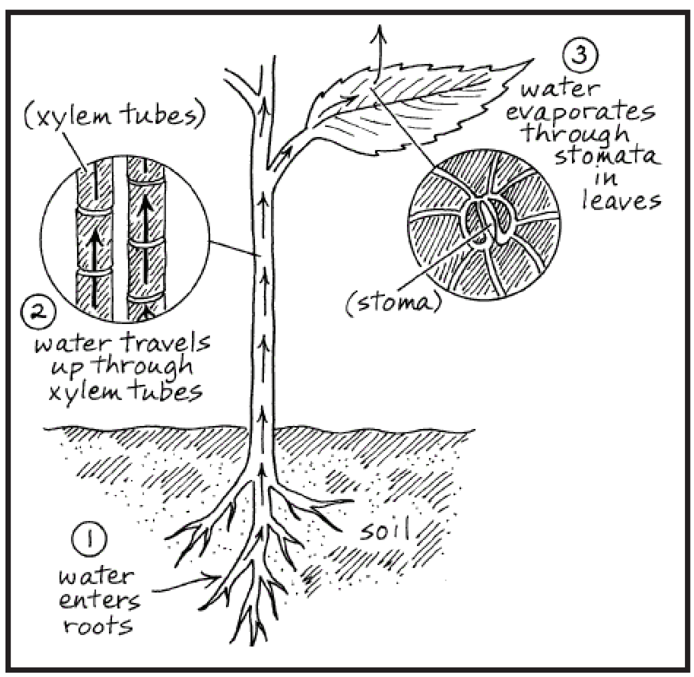
Respiration is the third process that takes place in leaves as well as throughout the rest of the plant. Through respiration the energy in food is released. It fuels plant processes and the growth of new tissues. Sugars and starches made during photosynthesis are converted to energy through a chemical process that utilizes oxygen and releases water and carbon dioxide. It is essentially the reverse of photosynthesis, and the two use the byproducts of each forming a cycle.

Release of accumulated carbon dioxide and uptake of oxygen occur at the cellular level. In plants, these gases pass by simple diffusion into the open spaces within the leaf and then through the stomata. For growth to occur, carbohydrate gains from photosynthesis must be greater than losses through respiration.

Respiration occurs in every cell of all living things all of the time, as they obtain the energy needed to live and grow. Only when living things die do they stop respiring. The amount of energy from food released during respiration is measured in calories.

Since energy does not cycle, plants must continually photosynthesize to harvest sunlight and produce the food that is the source of energy for all living things. The path of energy through a living community is called a **food chain.** Food chains connect to form **food webs.** Because all living things use some food energy to live and grow, there is less energy available at the next step in the chain. Approximately one tenth of the food energy reaches each next step along the food chain.

Stems



The stem connects the leaves and roots. Stems transport the water and dissolved minerals absorbed by the root hairs up to the leaves. The water and minerals are carried in tube like structures called **xylem** cells. Capillary action aids in carrying fluids up the xylem tubes. Stems also transport the food made by the leaf down to the roots. This occurs in the **phloem** cells. If a plant didn't have a transport system, all of its parts would have to be close to the ground **t**o have access to water and minerals.

Water and dissolved minerals actually move upwards through a plant against the force of gravity, through stems. This results from a combination of factors. Water moving into the roots pushes water upward into the stem. Water molecules cohere to one another, forcing the water column further upward, and they adhere to sides of the conducting stems. In addition, transpiration, evaporation of water through leaf openings, actually pulls the water column upward. water can be pulled up stems as 30 inches per minute.

Roots

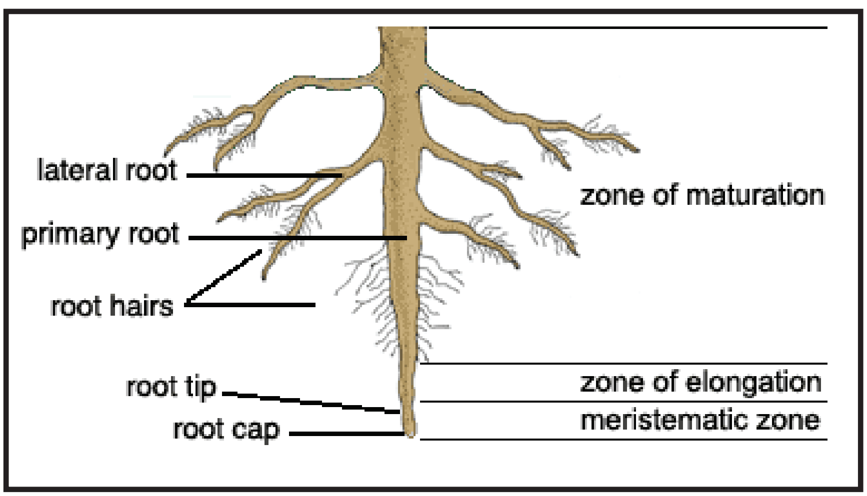
Roots play an essential role in the growth and vigor of a plant. They provide the anchor that keeps it from blowing or washing away. The roots support the stem and the vascular tissues that are continuous throughout the root to the stem and then to the rest of the plant. Roots absorb water and dissolved nutrients from the soil, transporting it through the vascular system to the rest of the plant for photosynthesis and transpiration. Roots also store sugars and carbohydrates that are used by the plant to survive winter and carry out other functions. Some roots can produce new plants.

When a seed germinates, the first structure to appear is a young root, **the radicle.** The radicle develops into the primary root. It grows downward in response to gravity, anchors the seedling and begins to absorb water and minerals. Depending on the type of plant, root development will proceed into a tap or fibrous root system.

The **taproot,** is an extension of the primary root of the young seedling. It grows into a single dominant root reaching deep into the soil to bring up water and nutrients. Smaller secondary roots support it. In a **fibrous root system** the primary root is quickly displaced by numerous fine roots that develop from the base of the stem, with no single root dominating. Fibrous roots spread out to form a network of branching rootlets located close to the surface. Fibrous roots are more common than taproots and particularly good at holding soil. Once the plant is established, additional roots, called **adventitious roots,** may emerge from the stem. They help plants cling to surfaces and also search out nutrients.

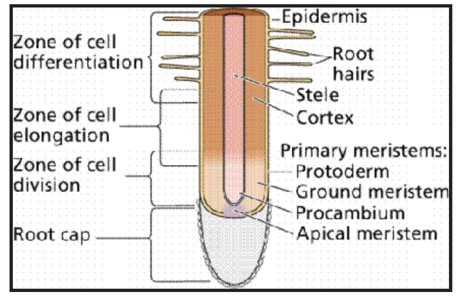
Root Structure: Internally, there are three root zones. At the tip is the **meristem**, an area of rapid mitotic cell division that manufactures new cells for root growth. Behind the meristem is the **zone of elongation.** Cells absorb food and water to increase in size and elongate. As they grow, the root lengthens and is pushed downward. The **zone of differentiation** contains mature, specialized cells, such as epidermis, cortex or vascular tissue.

The **epidermis** is the outermost layer of cells surrounding the root, responsible for the absorption of water and minerals dissolved in water. **Cortex** cells are involved in the movement of water from the epidermis and in food storage. Vascular tissues conduct food and water through the **xylem** and **phloem.**



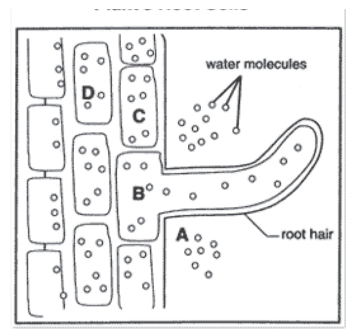
Externally, there are two areas of importance: the root cap and the root hairs. The **root cap** is a mass of actively dividing cells at the root's outermost tip. It protects the root tip or meristem (growing point) during its passage through the soil. Its flattened and hardened cells are constantly sloughed off and replaced by fresh cells as they force their way through the soil. Cells formed just behind the tip lengthen rapidly and push the tip further into the soil with considerable force. The root cap is able to guide the root growth direction by sensing gravity. Dead root cap cells are shed ahead of the root tip, making a pathway that allows the delicate root to work its way through the soil. Old cap cells may also lubricate the tip as it grows downward.

Root hairs are tiny, delicate, elongated epidermal cells that occur in a small zone just behind the root's growing tip. Auxin, a plant growth hormone, concentrates in the root hairs and causes these cells to divide and grow larger. They penetrate the soil, increasing the root's surface area and absorbing water and nutrients. Each root hair is a single cell and has only a brief existence. As the root pushes downward, hairs in the growing region are sheared off and quickly replaced with new hairs.



Water in Soil

In typical soil, water is available to plants mostly as a thin film surrounding each microscopic soil particle. Root hairs absorb this water through **osmosis** when they grow into the vicinity of the soil particle. The liquid inside the root hairs is a rather strong solution of sugars and mineral salts. In the soil, the water is a weak solution of mineral salts. The outer skin of the root hairs is a semipermeable membrane, that allows weak solutions to pass through into strong ones. So long as the solution inside the root hairs is stronger than outside, they will take in water.



Molecule by molecule, water diffuses through the root hair's cell membrane. The absorbed liquid passes from cell to cell to the center of the root. It is then carried up to the above-ground parts of the plant through slender tubes called xylem. The movement of fluids from the root hairs to the xylem can occur through one of two conductive pathways. Water may travel **along cell walls through intercellular spaces** from the root surface to the core in a method known as apoplast. The symplast route moves fluids through the cells, via channels that connect their content.

An excess of water in the soil can be as damaging to plants as a lack of water. Roots require a flow of **oxygen** into the soil and a flow of their respiration product (mostly carbon dioxide) out of the soil. Compacted soils resist air flow, making it difficult for many plants to thrive. In water-logged soils, the spaces that would normally hold air are filled with water.

In a well structured soil, water is held in fine capillary pores which actually are less than 1/ 160 inch in diameter, with air in the larger pores. It is therefore possible for soil to be described as both moist and well drained. Water is most readily available to plants from pores of the largest diameter. As the pores become smaller, it becomes increasingly difficult for the plants to extract moisture, which means that some soil moisture always remains unavailable.

Clay soils hold the greatest amount of water but they have a high percentage of fine capillary pores, so plants are not always able to extract enough water for their needs.

Sandy soils contain coarse pores, and so the water held within them is more readily available than in clay. However, these soils have a high drainage rate, and there is relatively little capillary movement of water sideways and upward.

Silt Soils have pores that are larger than those in clay and smaller than those in the sandy soils. They allow for some water to move through the soil, while also making water available for plant growth.

Most garden soils are a combination of soil types. **Loam soils** usually contain a balanced mixture of coarse and relatively fine pores. The coarse pores allow rapid drainage while the finer ones retain water, much of which may be extracted by plants for growth.

Improving Soil Moisture: The best way to improve the water holding capacity and the availability of soil moisture for the roots in any soil type is through the addition of organic material to the soil. Add composted garden and kitchen wastes, composted manures, chopped leaves, grass clippings from lawns that have not been treated with chemicals and materials from worm bins. The organic material will absorb and hold the moisture in the soil, making it available for absorption by root hairs.

You can also improve drainage in water logged soils by cultivating the soil to reduce compaction. Never walk on the garden or work the soil when the soils is soggy and wet. The addition of compost and other organic material will improve drainage. In severely water-logged soils, you will have to provide a drainage system .

Be aware of the water table in your garden area. Moisture raises to the soil surface by capillary action from the water table below. Heavy clay soils may be saturated to six feet above the water table, with some moisture available to plant roots as much as 11 foot above it. Silt and most clay soils are saturated to five feet, with moisture available to eight feet above the water table. In fine sand the water may be available to five feet, in coarse sand to 3 feet, and on gravel there is no water rise at all.

Determining the Watering Needs of Plants:

For optimum growth, plants need a steady supply of water. When there is not enough water, photosynthesis and transpiration are slowed. Eventually leaves will wilt and die. However, rainfall is variable in both frequency and quantity throughout the world. It also varies seasonally and is often unavailable for the plant to use. Learn as much as you can about a plant's native habitat in order to determine it water needs. You can also look at the leaves of plants to learn much about their needs.

Plants from a lush tropical environment with lots of available soils moisture will have very large leaves with lots of exposed surface area. The leaves are usually thin and may be pointed. This allows them to expose a lot of surface area to the sun for photosynthesis, while also allowing water to wick to the edge of the leaf and run to the ground. These plants typically get enough water to meet their needs and have little protection from drought, they will readily wilt when soils are dry.

Plants that live in **arid environments**, must be adept at conserving and storing water. They can tolerate conditions of low water, bright sunlight, extreme heat, dry winds and rapid temperature changes through a diverse variety of mechanisms, both physical and behavioral. Most successful plants utilize a combination of these characteristics. These plants may even languish and die if over-watered. Look for these signs that will tell you a plant has adapted to drought.

1) Small or narrow, needle-like leaves with reduced surface area for transpiration.
2) A waxy coating on the leaves and stems that serves as a waterproof barrier that seals in moisture.
3) A powdery bloom that protects from glaring sunlight, temperature extremes, wind and salt spray.
4) Downy hairs of silver, gray-green or white on leaves that reflects the sunlight and trap water moisture near the leaf surface.
5) Pale leaf undersides, often covered with downy hairs to reflect sunlight from snow or water.
6) Thickened leaves that store water.
7) Vertical leaf orientation decreases the exposure and absorption of sunlight.
8) A reservoir in the plant that holds water, such as in bromeliads
9 Spines and thorns to provide shade, break wind currents andcollect moisture.
10) A whorled, compact shape that's low to the ground reduces exposure to winds and extreme temperatures.
11) a long tap root or a shallow but expansive root system that is able to collect large amounts of surface water when it rains.

How and When to Water

With the exception of newly sown seeds, young seedlings, new transplants or plants grown in containers it is best to **water well and deeply, but with less frequency.** This will allow the plants to develop a healthy root system with roots that have expanded beyond the surface deep into the soil. If there is sufficient rain during the week (usually two or more inches of rain), you may not have to water the garden at all, especially if you use mulch to conserve soil moisture.

Purchase a **rain gauge** or set an empty tuna or cat food can in the garden and measure the water level in the can after the rain. You should also dig a small hole in the garden to make sure that the water has penetrated into the soil. Sometimes after it has been very dry, the soil will resist moisture penetration and will require several waterings before it can hold water.

The **benefits of** a**dding organic moisture to the soil and mulching** can not be overemphasized. The organic matter will quickly absorb the moisture after watering or rainfall and will hold the moisture in the soil. Mulch will protect the soil from drying out. It will also quickly absorb water from rain and waterings so that it does not runoff the soils surface. More importantly it will protect the soil from being washed away.

Whenever possible, **water in the very early morning or late in the afternoon.** This will reduce loss of water from evaporation during the hottest hours of the day. It will also allow the plants to dry off before nightfall which will reduce fungus disease. Try to keep the water off the foliage as much as possible. Occasionally plants watered during the brightest part of the day may scorch as the water on the leaf magnifies the sunlight produces circles of burnt and dead tissue. Always water a wilted plan when you see it needs water, no matter the time of day.

New Seeds: Plant seeds in moist soil. Seeds may be presoaked to improve germination. Once seeded, water the soils with a fine spray. Water regularly until you see the seedlings emerge. Keep the soil moist but not wet. Seeds need oxygen as well as water to germinate.

Seedlings: Young seedlings also need lots of soil moisture to help them grow, but will die in waterlogged soil. They do not yet have extensive root systems, so they will need frequent waterings with a gently spray.

New transplants: Water the plants well about an hour before transplanting to reduce stress from transpiration. Water the soils into which they will be transplanted, so it will be cool and moist. During the transplanting process, the root hairs are easily torn off or may dry out in the sun. When the root hairs are broken the plant will have difficulty meeting its water needs. Replant into soil as quickly as possible.

Water well with a gently spray to keep the soil cool and allow root hairs to adhere to soil particles. Keep the plants out of bright sunlight for several days, by providing shading with newspaper or garden fabric. Watch plants for several weeks to make sure they do not wilt.

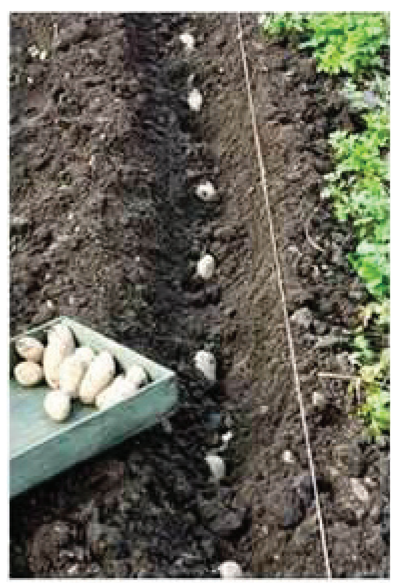
Plants in Containers: Some of the same elements that make container gardening ideal for the gardener can add environmental stress for the plant. Pots hold only a limited amount of soil in which roots can spread. The soil temperature in containers is higher than that in the ground. During the heat of summer, roots may be restricted by heat from growing near the container sides. Darker pot will heat up more quickly than lighter ones, and are better suited for the shade. Pruning will help keep plants in proportion to roots.

Use **a soil mixture that drains rapidly yet also retains enough moisture** for the roots. “Soilless” potting mixtures are best, because they drain well, hold moisture, are light weight and free of disease and weed seeds and are available at all garden stores. You can also use garden compost or make your own mix from equal parts of sand, loamy garden soil and peat moss. Consider adding water-retaining polymers that hold several hundred times their weight in water to the soil. Mycorrhizal fungi packets are also available and will improve the ability of a plant to take up water and nutrients.

Wet soil thoroughly prior to planting. Leave a 2” space at the top of the container. You will be able to add ½ inch or so of mulch later or gravel. Clay pots are very porous and lose water from the sides. Plants grouped in containers must have similar water needs. Those that require a lot of moisture can be placed in the shade. Self-watering pots can make for worry free vacations and weekends. A two- to three-inch layer of mulch covering the soil surface will cool the soil and help it retain moisture. It increases soil fertility as it decomposes and prevents crusting of the soil surface, allowing water to penetrate to the root zone.

Proper watering is essential; most containers will require water at least once a day. Water well, so that water drains from the bottom. Plants that are pot bound, or in a very sunny or windy location, may need more than one watering. Avoid wet foliage which encourages diseases. Poor drainage will water logged the soil; repot and add proper drainage. **Group pots together** to help raise humidity and reduce water loss from transpiration. Utilize drought resistant plants such as mediterranean herbs and South African geraniums in containers. They will require less moisture.

Tips for Improving Watering Success in the Garden: There are several planting strategies that can be used to improve the ability for water to collect and then soak into the soil in the area where it is most needed by plant roots.



Set each plant slightly deeper in the soil than the surrounding ground level, creating **a basin around each plant.** This will ensure that when it rains or when watering that the water collects in the basin, slowly soaking into the soil. This also works when seeding. Make the seed bed slightly lower than the surrounding soil level, so that water collects and seeps into the soil around the seeds and young seedlings.

To get water deep into the soils to soil roots, try **burying a large pot** with a drainage hole close to the plant. Slowly fill the plant with water. The water will slowly seep into the soil below.

Trickle feed and drip irrigation are also successful techniques for supplying water in a manner where it will be able to slowly seep into the soil and reach the roots.

Watering Supplies and Equipment

Irrigation makes it possible to grow plants that require more water than in provided by rainfall, and to grow plants both indoors and in the greenhouse. Equipment such as watering cans, hoses and sprinklers helps make routine watering easier and faster. There are also watering systems that can be used to manage watering of larger gardens. Here are some of the supplies that will help you with your watering needs:

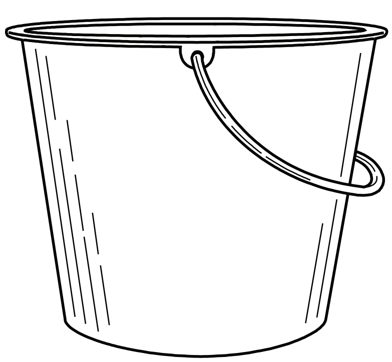
Watering Can

The traditional watering can is efficient for watering indoor plants, seedlings, containers and small garden areas. It is also useful when transplanting. You can easily monitor the flow, watering each plant according to its requirements. Using a watering can in the garden can be time consuming, however, since watering is a favorite activity for children, this task can be used to help occupy a large group in the garden.

Watering cans come in plastic and metal; both are sturdy and durable. Choose one that is light-weight so it will not be too heavy to carry when full. For general watering needs a capacity of two gallons will reduce the need to constantly refill. You may want to have some smaller plastic watering cans available for younger children. Make sure that the opening is wide enough to make filing easy. The watering can should also feel comfortable and well balanced. Some cans have a strainer at the base of the spout to help to prevent the spout from becoming clogged. This is useful if you will be watering from a source that may have debris in the water.

Some watering cans have an extra long spout. This is ideal for indoor plants and container gardens where the length of the spout will allow you to easily reach each pot. These watering cans may also have a bar across the handle, to help with the accuracy of watering plants that are far away or difficult to reach.

Many watering plants also come with a nozzle or rose. A fine nozzle will produce a gently spray that is needed for seeds and seedlings. It does not damage fragile plants or wash away the soil. These nozzles are usually made of metal. A nozzle with large holes will produce a coarser and faster spray which is suitable for established plants.



Bucket

It is a great idea to have one or more buckets in the classroom or garden to serve as a reservoir for filling small watering cans or cups, to immerse dry plants and for mixing fertilizer solutions. A five gallon bucket with a handle is ideal. The bucket can serve as a storage container for tools and other supplies when not being used to hold water. Plastic cups and jugs are also useful for watering and fertilizing.

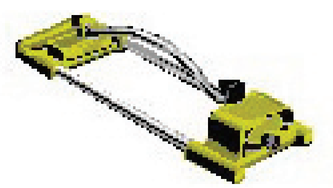
Garden Hose

A garden hose is very useful for irrigating the garden, especially during the hot summer months. Most hoses are made of PVC. They come in a variety of lengths and most have couplings that allow for multiple hoses to be linked together. Make sure you have enough hose to reach all parts of the garden.

Garden hoses also vary in the way that they are finished and reinforced. It is worth the investment to purchase flexible double-walled and reinforced hoses that are resistant to kinking. Kinks take time to unravel and will eventually weaken the hose wall.

Hose reel: A reel with a handle or wheels is useful in the school garden. It is easy to move around the garden and provides a good storage place for the hose. Look for a reel that allows the water to flow through the hose even when partially wound. You may also choose to store hoses close to the tap in a half whiskey bottle or large pot. Either way be sure to put roll up hoses and put them away, as they provide a tripping hazard in the garden.

Hose attachments: There are a variety of spray attachments available for hoses. Purchase a trigger-action nozzle that can be adjusted to provide a fine mist for seedlings and new transplants while also offering a jet stream for watering a larger area or more than one plant simultaneously. A soaker hose attachment is also available for providing water to newly planted trees and shrubs, allowing the water to soak into the soil over a long period of time. Fertilizing attachments may also be used to provide injections of fertilizer while watering.



Garden Sprinkler: A garden sprinkler automatically delivers a fine spray of water over a specific area. They come in many shapes and sizes, including standing sprinklers, rotating sprinklers, pulse-jet sprinklers and oscillating sprinklers. The standing sprinkler is used primarily for lawns. Rotating sprinklers can be used for lawns and garden beds. They cover a large circular area and should be set on tall stems for gardens. Pulse-jet sprinklers also cover very large areas of lawn and borders. These should also be set on long stems for garden areas. The oscillating sprinklers are best for vegetable garden areas and small borders. They can be attached to a hose and will fan a stream of water back and forth across the garden area, applying an even amount of water to the garden. The water is distributed fairly evenly and the area of distribution can easily be adjusted, so that water is not wasted. Some have automatic shut offs and dial settings.

Soaker Hoses: These are hoses with small holes along their length that allow water to slowly seep into the ground around the roots of plants. These are useful for rows of plants. Make sure that the holes face towards the ground. These hoses deliver water best on level ground. Use a length of 100 feet or less and snake the soil through the bed, around the base of each plant about 1-2 inches from the plant. Lay hoses twelve to eighteen inches apart for maximum coverage. Turn the water on just enough that the water is seeping from the hose – not spraying. Start by running the soaker hose about 30 minutes. Check to see how far the soil has penetrated the ground. Adjust timing. Cover the garden and the soaker hose with an inch or two of mulch to hold moisture in and prevent evaporation.

Drip Feed or Trickle Feed Irrigation: Drip irrigation dribbles out tiny quantities of water to provide a steady stream of water over a large area in the garden or to containers. It is efficient and easy to design and install this semi-permanent irrigation system. It works by applying water slowly, directly to the soil and plants. Kits for drip irrigation are inexpensive and assembly is straightforward. You can install one in as little as one day's time, and few tools are required. Always mulch over drip irrigation to retain soil moisture and reduces evaporation. Use a timer to assure that you do not waste water.

Hose Timers: Hose timers may be used with ordinary garden sprinklers or more elaborate water systems. They fit between the faucet and the hose or irrigation pipe. Most hose timers turn off water after a determined set of time. Some can also turn off the water and others can even be linked to a soil moisture detector.

Rain barrels: A rain barrel collects and stores rainwater from the roof. Connect the barrel directly to the rain spout. Make sure that you purchase a rain barrel with a tap, and also a lid to keep out insects and debris. Raise the rain barrel on blocks, so that you can fit a bucket or watering can beneath the tap. Use the rain water on acid-loving plants.

Tips for Conserving Water

1. Group plants with similar water needs together, allowing them to be watered as needed with little waste of water.

2. Use drip irrigation systems to apply water directly to plants, reducing water consumption as much as sixty percent from the use of sprinkler.

3. Choose plants that either avoid or tolerate dry conditions, including native plants. While these plants are tolerant to drought once established, they need watering for the first year or two after planting.

4. Plant annuals at least twelve inches apart and perennials eighteen to twenty four inches apart to reduce competition for water.

5. Amend soil, whether clay or sand, with organic material, such as compost, aged manure and shredded leaves to promote water percolation and retention.

6. Grade beds to allow water to soak into the soil and avoid runoff. Raised beds are discouraged in dry conditions as they dry out more quickly.

7. Mulch garden beds to reduce water demand by as much as forty percent, keep the soil cooler, eliminate weed competition, and reduces evaporation from the soil surface. However, keep mulch away from the crowns of native plants and from against the trunks of trees. You can add a thin layer of sand or fine gravel around plants from arid climates to keep the crowns dry and avoid winter heaving in heavy soils.

8. The lawn is the most demanding user of water in the home landscape. Where ever possible, reduce lawn size by adding walkways, ground covers, and shrub borders. Consider the use of turf grasses other than Kentucky Bluegrass. Water lawns only when there has been less than one inch of rainfall in a week. Consider allowing the lawn to go dormant when there is no rainfall.

Plants for the Dry Garden

Annuals: California poppy; cleome; dahlberg daisy; gazania; globe amaranth; dusty miller; helichrysum; lantana; lavatera; nasturtium; nicotiana; perilla, portulaca, sanvitalia, senecio, sweet alyssum, verbena and viola.

Perennials: achillea; amsonia; antennaria; anthemis; arabis; armeria; aster; baptisia; centaurea; cimicifuga; coreopsis; crambe; dictamnus; echinacea; echinops; epimedium; eryngium; euphorbia; geranium; helleborus; hemerocallis; heuchera; hosta; Iris sibirica; lamium; liatris; limonium; lychnis; oenothera; *Patrinia scabiosifolia*; papaver; penstemon; *Perovskia atriplicifolia*; *Potentilla tridentata*; rudbeckia; salvia; sedum; sempervivum; solidago (Goldenrod); verbascum; veronica; *Viola labradorica*; waldsteinia and yucca.

Herbs: artemesia, basil; catmint; chamomile; chives, coriander; dill; fennel; germander; lady's mantle; lamb's ear, lavender, mint; oregano, rosemary; rue; sage; santolina; sweet woodruff, tansy & thyme.

Grasses: Calamagrostis; *Carex glauca, Carex pensylvanica*; *Miscanthus sinensis* 'Morning Light', *Miscanthus sinensis* 'Strictus'; *Molinia caerulea* 'Variegata'; *Panicum virgatum*, Pennisetum, and *Schizachrium scoparium*.

Woody Trees & Shrubs: *Acanthopanax sieboldianus*; *Acer negundo*; *Amorpha canescens*; *Aronia arbutifolia*; Caryopteris; *Ceanthus americanus*; *Comptonia peregrina*; *Cornus sericea* 'Silver & Gold'; *Cotinus coggygria*; Cytissus; *Fothergilla* 'Blue Shadow'; *Hydrangea arborescens* 'Annabelle'; Indigofera; *Heptacodium miconoides*; Juniperus; Lespedeza; *Myrica pensylvanica*; *Physocarpus opulifolius*; *Pinus banksiana*; *Pinus virginiana*; *Rhus typhina*; *Rosa glauca*; *Rosa rugosa*; *Salix elaeagnos*; *Sorbaria sorbifolia*; *Spiraea japonica*; *Spiraea thunbergii*; *Thuja occidentalis* 'Rheingold'; and Weigela.

Watering Resources

Mass Nursery & Landscape Association
P.O. Box 387   Conway, MA 01341
www.mnla.com

Massachusetts Flower Growers' Association
8 Gould Road
Bedford, MA 01730-1241
www.massflowergrowers.com

Massachusetts Water Resources Authority
Gardening and Landscaping Tips
www.mwra.state.ma.us/04water/html/gardening.htm

NE Vegetable & Berry Growers Association
125 Main Street   P.O. Box 387
Deerfield, MA 01342-0387

Massachusetts Agriculture in the Classroom Newsletter on Plants That Defy Drought
http://www.aginclassroom.org/Newsletter/spring2008.html

Watering Resources

UMass Extension
Water Conservation Checklist
www.umassgreeninfo.org/fact_sheets/plant_
culture/water_conservation_checklist.html

U.S. Environmental Protection Agency
www.epa.gov/reg3esd1/garden/natres.htm
www.epa.gov/greenacres/wildones/handbk/wo8.html

Ecological Landscaping Association
841 Worcester Road # 236
natick,MA 01760
www.ecolandscaping.org

Books

The American Horticultural Society Encyclopedia of Gardening: The Definitive Guide to Gardening Techniques, Planning and Maintenance, Edited by Christopher Brickell and Elvin McDonald, Dorling Kindersley, 1994

10,000 Garden Questions Answered by 20 Experts, edited by Marjorie J. Dietz, Doubleday and Co. 1974.

The American Horticultural Society Illustrated Encyclopedia of Vegetables, The American Horticultural Society, Ortho Books, 1980.

Information for this Watering Guide was taken from the resources listed above.

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