Fresh water is essential to all plant growth.

Introduction

Water provides a medium to transport nutrients necessary for plant life and make them available for absorption by the roots. Water quality is essential for this process to work at maximum potential. The laws of physics govern plant water uptake. Applying these laws, a gardener can provide precise, properly balanced components to grow outstanding plants indoors.

Microscopic root hairs absorb water and nutrients in the oxygen present in the growing medium and carry them up the stem to the leaves. This flow of the water from the soil through the plant is called the transpiration stream. A fraction of the water is processed and used in photosynthesis. Excess water evaporates into the air, carrying waste products along with it via the stomata in the leaves. This process is called transpiration. Some of the water also returns manufactured sugars and starches to the roots.

Look at a rooting clone. Check out the fine, fuzzy roots closely. You can see the minute hairlike feeder roots.

The roots support the plants, absorb nutrients, and provide the initial pathway into the vascular system. A close-up look at a root reveals the xylem and phloem core, vascular tissue that is enveloped by a cortex tissue or the layer between the internal vascular and the external epidermal tissue. The microscopic root hairs are located on the epidermal tissue cells. These tiny root hair follicles are extremely delicate and must remain moist. Root hairs must be protected from abrasions, drying out, extreme temperature fluctuations, and harsh chemical concentrations. Plant health and well-being is contingent upon strong, healthy roots.

The nutrient absorption begins at the root hairs, and the flow continues throughout the plant via the vascular system. Absorption is sustained by diffusion. In the process of diffusion, water and nutrient ions are uniformly distributed throughout the plant. The intercellular spaces—apoplasts and connecting protoplasm, symplast—are the pathways that allow water and nutrient ions and molecules to pass through the epidermis and the cortex to the xylem and phloem's vascular bundles. Xylem channels the solution through the plant while phloem tissues distribute the food manufactured by the plant. Once the nutrients are transferred to the plant cells, each cell accumulates the nutrients it requires to perform its specific function.

The solution that is transported through the vascular bundles or veins of a plant has many functions. This solution delivers nutrients and carries away the waste products. It provides pressure to help keep the plant structurally sound. The solution also cools the plant by evaporating the water via the leaves' stomata.

Water Quality
Hard Water

The concentration of calcium (Ca) and magnesium (Mg) indicate how "hard" the water is. Water containing 100 to 150 milligrams of calcium ($CaCO_3$) per liter is acceptable to grow plants. "Soft" water contains less than 50 milligrams of calcium per liter and should be supplemented with calcium and magnesium.

Check the pH of the irrigation water and adjust when necessary.

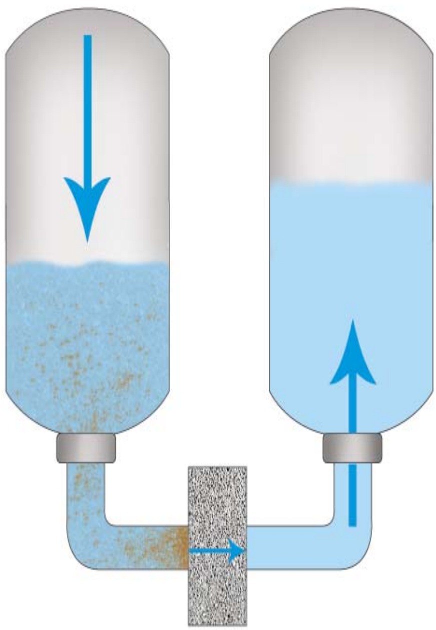
Sodium Chloride

Water with high levels of chloride frequently contains high levels of sodium, but the opposite is not true. Water with high levels of sodium does not necessarily contain excessive levels of chloride (chlorine).

At low levels sodium appears to bolster yields, possibly acting as a partial substitute to compensate for potassium deficiencies. But when excessive, sodium is toxic and induces deficiencies of other nutrients, primarily potassium, calcium, and magnesium.

Chloride (chlorine) is essential to the use of oxygen during photosynthesis, and it is necessary for root and leaf cell division. Chloride is vital to increase the cellular osmotic pressure, modify the stomata regulation, and augment the plant's tissue and moisture content. A solution concentration of less than 140 parts per million (ppm) is usually safe for plants, but some varieties may show sensitivity when foliage turns pale green and wilts. Excessive chlorine causes the leaf tips and margins to burn and causes the leaves to turn a bronze color.

Simple water filters do not clean dissolved solids from the water. Such filters remove only debris emulsified (suspended) in water; releasing dissolved solids from their chemical bond is more complex. A reverse-osmosis machine uses small polymer, semipermeable membranes that allow pure water to pass through and filter out the dissolved solids from the water. Reverse-osmosis machines are the easiest and most efficient means to clean raw water.



The drawing shows that pure water with no salts or dissolved solids migrates to the solution with more dissolved solids.

Osmosis

Roots draw the nutrient solution up the plant by the process of osmosis. Osmosis is the tendency of the fluids to pass through a semipermeable membrane and mix with each other until the fluids are equally concentrated on both sides of the membrane. Semipermeable membranes located in the root hairs allow specific nutrients that are dissolved in the water to enter the plant while other nutrients and impurities are excluded. Since salts and sugars are concentrated in the roots, the electrical conductivity (EC) inside the roots is (almost) always higher than that outside the roots. Transporting the nutrients by osmosis works because it depends on relative concentrations of each individual nutrient on each side of the membrane; it does not depend on the total dissolved solids (TDS) or EC of the solution. For nutrients to be drawn in by the roots via osmosis, the strength of the individual elements must be greater than that of the roots.

This reverse osmosis machine transforms water with a high ppm or EC into water with less than 10 ppm.

Typical bottled water analysis	mg per liter
Calcium	25.6
Magnesium	6.4
Potassium	<1.0
Sodium	6.4
Bicarbonate	98.3
Sulphate	10.1
Nitrate	<2.5
Fluoride	<0.1
Chloride	6.8
Silicate	7.6
Dry residue at 180°C	109.1
pH	4.6

The dissolved solids in bottled water are measured in milligrams per liter (m/L). Before the year 2000, bottlers in the USA were required by law to print a detailed analysis of the dissolved solids on their product's label. Relaxed rules now simply allow them to direct consumers to where that knowlege can be obtained, usually an internet website.

But, the transport of water (instead of nutrients) across the semipermeable membrane depends on EC. For example, if the EC is greater outside the roots than inside, the plant dehydrates as the water is drawn out of the roots. In other words, salty water with a high EC can dehydrate plants.

Reverse-osmosis

Reverse-osmosis machines are used to separate the dissolved solids from the water. These machines move the solvent (water) through the semipermeable membrane, but the process is reversed. It moves from lower concentrations to higher. The process is accomplished by applying pressure to the "tainted" water to force only "pure" water through the membrane. The water is not totally "pure" with an EC of zero, but most of the dissolved solids are removed. The efficiency of reverse osmosis depends on the type of membrane, the pressure differential on both sides of the membrane, and the chemical composition of the dissolved solids in the tainted water.

Unfortunately, common tap water often contains high levels of sodium (Na), calcium (Ca), alkaline salts, sulfur (S), and chlorine (Cl). The pH could also be out of the acceptable 6.5 to 7 range. Water containing sulfur is easily smelled and tasted. Saline water is a little more difficult to detect. Water in coastal areas is generally full of salt that washes inland from the ocean. Dry regions that have less than 20-inches-annual rainfall also suffer from alkaline soil and water that is often packed with alkaline salts.

Table salt, sodium chloride (NaCl), is added to many household water systems. A small amount of chlorine, below 140 ppm, does not affect most plants' growth, but higher levels cause foliage chlorosis and stunt growth. Do not use salt-softened water. Salty, brackish, salt-softened water is generally detrimental to most plants. Chlorine also tends to acidify soil after repeated applications. The best way to get chlorine out of the water is to let it sit one or two days in an open container. The chlorine will evaporate (volatilize) as a gas when it comes in contact with the air. If chlorine noticeably alters soil pH, adjust it with a commercial "pH UP" product or hydrated lime.

The metric system facilitates the measurement of "dry residue per liter." Measure the dry residue per liter by pouring a liter of water on a tray and allowing it to evaporate. The residue of dissolved solids that remains after all of the water evaporates is the "dry residue per liter." The residue is measured in grams. Try this at home to find out the extent of impurities. Fertilizers have a difficult time penetrating root tissue when they must compete with resident dissolved solids.

Water that is loaded with high levels of dissolved solids (salts in solution) is possible to manage but requires different tactics. Highly saline water that contains sodium will block the uptake of potassium, calcium, and magnesium. Salt-laden water will always cause problems. If water contains 300 ppm or less dissolved solids, allow at least 25 percent of the irrigation water to drain out of the bottom of containers with each watering. If raw water contains more than 300 ppm of dissolved solids, use a reverse-osmosis device to purify the water. Add nutrients to pure water as a way to avoid many nutrient problems.

Dissolved salts, caused by saline water and fertilizer, quickly build up to toxic levels in container gardens. Excessive salts inhibit seed germination, burn the root hairs and tips or edges of leaves, and stunt the plant. Flush excess salt buildup from growing mediums by applying two gallons of

Flush your plants regularly to avoid salt and excess nutrient buildup.