Tree of Knowledge

BASIC WOODY PLANT BIOLOGY – *Part 3*

by Chris Starbuck
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Leaves

The most important function of leaves is photosynthesis. Photosynthesis is the process in which carbon dioxide (CO_2) gas from the air is combined with water from the soil to form the sugars used as an energy source by plants (Figure 3). The energy driving this process is derived from solar radiation that is absorbed by the pigment chlorophyll in the chloroplasts. The plant arranges its leaves in a pattern that is most effective in intercepting sunlight. Sugar (photosynthate) produced during photosynthesis is translocated to other parts of the plant where it is used directly as an energy source or stored in the form of starch in leaves, stems or roots for future use. Sugars and starch are often referred to as carbohydrates and are processed through respiration in the cells' mitochondria to release energy. Some of the sugar is also used to produce cellulose, fats, proteins, and other materials required as structural materials or chemical reactants by growing cells.

Damage to leaves from insect feeding, foliar diseases or air pollution can drastically reduce the rate of photosynthesis as can excessive shading or stress. Carbon dioxide is taken into the leaf through pores called stomata. If a plant is under drought stress, the stomata close, restricting the uptake of CO_2 and limiting photosynthesis. The net result of reduced photosynthesis is a reduction in sugars available for direct use or storage reserves. This reduction weakens the plant, making it more susceptible to stress and attack by pests.

Another important function of leaves is transpiration – the evaporation of water from the stomata. Transpiration, often referred to as evapotranspiration, has a cooling effect on the leaf. It also aids in the uptake of water and minerals from the soil.

Roots

The main functions of roots are to absorb water and nutrients, to anchor the plant, and to move water and minerals taken from the soil to the aerial parts of the plant. Roots also serve as storage organs for sugar, starch and other materials translocated from the aboveground parts. Most of the absorption of materials by roots occurs very near the actively growing tips where delicate structures called root hairs are found. Root hairs may last only a few days but are quickly replaced by new ones as the root tip elongates. Considerable water is also absorbed by older, suberized roots (covered with a waxy material called suberin).

Most of the water taken up by plants moves into the roots by a process called passive absorption in which transpiration of water from the leaves acts like a wick, pulling water into the roots. As long as there is sufficient water available in the soil to meet this transpirational demand, the plant can continue to grow normally. However, once moisture becomes limiting, the stomata close to reduce water loss from the leaves. Further soil drying results in wilting of leaves and stems because cells lose their turgidity (they shrink due to water loss). Loss of cell turgor also interferes with cell enlargement, so growth is limited. Wilting also greatly reduces photosynthesis, leading to a reduction in stored carbohydrates.

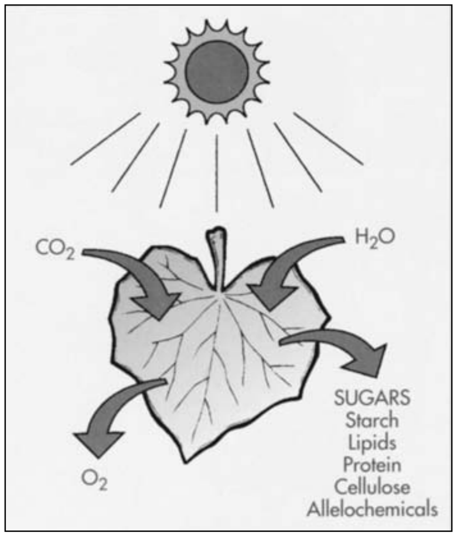

Figure 3. Biochemical building blocks from which plants are constructed are manufactured from the simple sugars produced during photosynthesis.

Uptake of minerals from the soil by roots is a complex process. Some materials move into the root by diffusion, but a considerable amount simply moves by being dissolved in water and taken up by passive absorption. Once these materials are inside the root, certain cells have the ability to regulate which ions can actually enter the cells and which are left behind. Many woody plants have a beneficial association called mycorrhizae between their roots and fungal organisms; mycorrhizae greatly increase the effective surface area for root absorption of water and nutrients from the soil (Figure 4).

Just like stems and leaves, roots need oxygen to grow. Therefore, anything limiting the penetration of air into the soil will limit root growth. Soil compaction, paving and poor soil drainage promote shallow root growth, making a plant more susceptible to drought stress and windthrow. These stresses also make roots susceptible to attack by fungal pathogens that cause root rot. Compaction can be reduced during construction by placing barriers around trees or putting a deep layer of mulch over the root system. Installing subsurface drain tiles or planting on a berm may be necessary when planting a species not adapted to poor soil drainage in a tight soil.

Contrary to popular belief, the root system of a tree is not a mirror image of the top. Most of the absorbing roots are found in the top 18 inches of the soil, but they may spread to a diameter 5 or 6 times that of the tree's drip line. Water and fertilizer should therefore be applied so that they move into this rooting zone. Light, frequent applications may be taken up by turf roots before they reach the roots of trees and shrubs. Mulching to reduce competition between tree roots and turf is important during the first few years after planting.

Identification Characteristics

In most cases, the first step in diagnosing a plant problem is to identify the plant. Doing so may be easy during the growing season, but it can be a challenge when a tree or shrub has lost its leaves. A close look at the winter twigs reveals many characteristics that can be used for identification. For example, the green ash twig has rounded, opposite buds with fuzzy, overlapping bud scales. The twig is easily distinguished from that of a red oak, which has alternate rather than opposite buds. The twig also has distinct, whitish pores called lenticels. The leaf scar, where the petiole was attached during the growing season, is straight on the top rather than shaped like that on a white ash. The

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Figure 4. One of many types of mycorrhizae found on or in roots. Mycorrhizae facilitate absorption of elements.

terminal bud scar indicates when growth started during the previous growing season and is useful in determining whether the tree put on a reasonable amount of growth during the growing season.

Other characteristics useful in identifying plants include leaf shape, bark pattern, flower structure and arrangement of water-conducting vessels in the xylem. For example, a persimmon tree is easily identified by its diamond-shaped plates of bark, a tulip poplar by its odd, tuliplike flowers, and an oak by the presence of very large xylem vessels in stem cross section (this arrangement is referred to as ring porous as opposed to the more scattered, diffuse porous vessel arrangement of tulip poplar). Conifers have no vessel elements; instead, they have resin ducts in their xylem. These ducts are important in helping them resist insect attack.

The PHC diagnostician should continually hone his or her plant identification skills. While reference books, such as those listed at the end of this article, are helpful in learning what characteristics to look for, there is no substitute for close observation in the field.

Dormancy and Winter Hardiness

Most woody plants in temperate climates go through alternating periods of growth and rest. Toward the end of the growing season, shortening days and low temperatures induce plants to stop growing, to set buds, and in the case of deciduous plants, to drop their leaves. By late fall, many plants will not resume growth even if they are moved to an environment favoring growth. They are dormant.

Associated with dormancy is the ability to withstand low temperatures. A Norway maple tree that withstands a temperature of -30˚F when dormant may be severely damaged by a temperature just below freezing during the growing season. Bark damage commonly occurs during the winter when the sun shining on the southwest side of dark-colored trunks warms the bark. Then, when the sun goes down, the bark temperature may drop 50 degrees in a few hours, leading to freezing injury to the deacclimated bark cells. This damage, commonly called trunk scald, can be counteracted by wrapping the trunk with a light-colored material. Cultural practices, such as late summer fertilization and pruning that encourages a plant to grow late in the season, may interfere with the development of cold tolerance.

Roots never really go dormant and cannot tolerate temperatures nearly as low as aboveground plant parts can. While the top of a boxwood shrub may be able to tolerate -10˚F, the roots will probably be killed at 20˚F. For this reason, container-grown nursery stock must be stored over the winter under conditions that will keep the temperature of roots from getting much below freezing. Roots of trees and shrubs permanently planted in large, aboveground containers are also susceptible to freezing injury. Containers should be insulated and designed so that they conduct ground heat into the root zone.

Usually, when a plant has gone dormant, it must be exposed to a period of cold (below 40˚F) in order for buds to begin growth when conditions favorable for growth return. This means that dormant plants cannot simply be stored over the winter in a warm building.

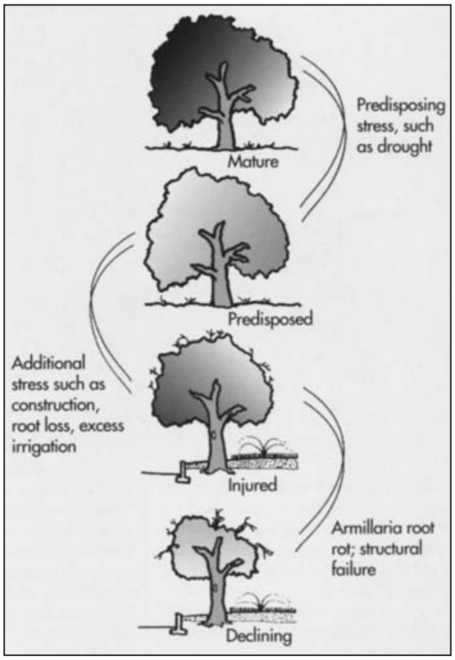

Figure 5. The mortality spiral illustrates how stress factors compound predisposing a tree to additional problems and leading to decline.

How Do Woody Plants Die?

It is usually difficult to attribute the death of a plant to a single cause. Rather, mortality is most often the result of a combination or series of factors such as drought stress, defoliation, mechanical damage, or nutrient deficiency. The term "mortality spiral" has been used to describe a series of interrelated events leading to the gradual death of a tree (Figure 5). Mortality can occur over a period of several months, as with Dutch elm disease or pine wilt disease. In most cases, however, the ultimate failure of a tree or shrub was initiated by an event that occurred several years before actual mortality. During the mortality spiral, one stress predisposes the plant to another until finally the plant loses the ability to protect itself from even minor stress factors. At this point, opportunistic insects and decay organisms can quickly destroy the structural integrity of the stems, branches, and roots, and cause mechanical failure.

When plant death is viewed as a mortality spiral, the importance of preventing stress becomes clear. Over-irrigation and poor soil drainage, for example, have been shown to predispose some trees to attack by Phytophthora root rot. Infection with this disease often seriously impairs the ability of a plant to take up water and nutrients from the soil, leading to a rapid decline. Defoliation by insects or diseases drastically reduces the amount of carbohydrates a plant is able to manufacture and store. With limited carbohydrate reserves, the plant has less energy available to defend itself from attack by other pests. In both cases, the beginning of a mortality spiral could be prevented by good cultural practices such as judicious watering and insect control.

Suggested Further Reading

Dirr, M.A. 1998 *Manual of Woody Landscape Plants.* Stipes Publishing, Champaign, IL.
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Zimmerman, M.H., C.L. Brown and M.T. Tyree. 1971. *Trees: Structure and Function.* Springer-Verlag, New York, NY.

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Corresponding test questions for this article are available in the ISA compendium entitled "Tree Biology." The compendium is a collection of Arborist News CEU articles with corresponding test questions worth a total of 9 CEU credits. ISA compendiums are available to purchase from the ISA online at www.isa-arbor.com or by phone at 888-472-8733.