Colorado MASTER GARDENER

Plant Physiology: Photosynthesis, Respiration and Transpiration

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Outline. . .

Thought question:

- What's the impact on air temperatures when restrictions in landscape irrigation create droughty urban landscapes?

Plants are self-sufficient. They make their own food in the process of photosynthesis using light energy to make sugars from carbon dioxide ($C0_2$) and water (H_20).

The three major functions that are basic to plant growth and development are:

- **Photosynthesis** – the process of capturing light energy and converting it to sugar energy, in the presence of chlorophyll using CO_2 and H_2O,
- **Respiration** – the process of metabolizing (burning) sugars to yield energy for growth, reproduction and other life processes, and
- **Transpiration** – the loss of water vapor through the stomata of leaves.

Photosynthesis

A primary difference between plants and animals is the plant's ability to manufacture its own food. In **photosynthesis** carbon dioxide from the air and water from the soil react with the sun's energy to form carbohydrates (sugars and starches). Photosynthesis literally means *to put together with light*.

The photosynthetic process occurs only in the **chloroplasts**, tiny subcellular structures contained in the cells of leaves and green stems. In photosynthesis, the sun's energy combines hydrogen from water (H_20) with carbon dioxide (CO_2) turning them into carbohydrates. Oxygen (O_2) is given off as a by-product of photosynthesis. The chemical equation for the process of photosynthesis is:

$$6CO_2 + 6H_20 + \text{light} \longleftrightarrow C_6H_{12}O_6 + 6O_2$$

This process is directly dependent on the supply of water, light and carbon dioxide. Any **one** of

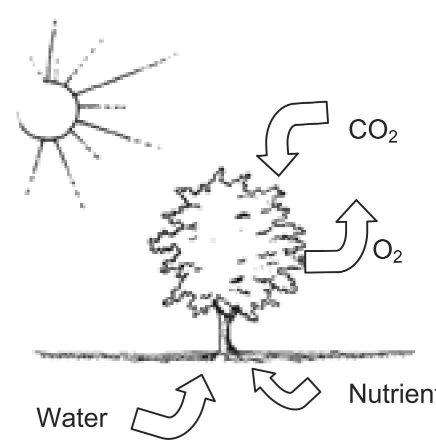

Figure 1. The photosynthetic process.

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Putting Knowledge to Work

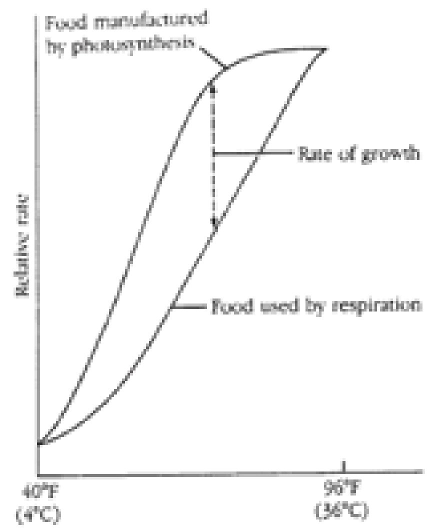

Figure 2. The rate of photosynthesis is somewhat dependent on temperature.

the factors on the left side of the equation (carbon dioxide, water, or light) can limit photosynthesis regardless of the availability of the other factors. If any one of these factors is limiting, then the whole process slows down or stops. An implication of drought or severe restrictions on landscape irrigation is a reduction in photosynthesis and thus a decrease in plant vigor.

In a tightly closed greenhouse there can be very little fresh air infiltration and CO_2 levels can become limiting. This in turn limits plant growth because the production of sugars needed to do the work involved with growing is limited. Many greenhouses provide supplemental CO_2 to stimulate plant growth.

The rate of photosynthesis is somewhat temperature dependent. For example, with tomatoes, when temperatures rise above 96 degrees Fahrenheit the rate of food used by respiration rises above the rate that food is manufactured by photosynthesis. Plant growth comes to a stop and produce loses its sweetness.

Respiration

In **respiration**, plants (and animals) convert the sugars back into energy for growth and to energize life processes (metabolic processes). The chemical equation for respiration shows that the sugars from photosynthesis are combined with oxygen. Notice that the equation for respiration is the opposite of photosynthesis.

$$C_6H_{12}O_6 + 6O_2 \longleftrightarrow 6CO_2 + 6H_20 + \text{energy}$$

Chemically speaking, the process is similar to the **oxidation** that occurs as wood is burned, producing heat. When compounds combine with oxygen, the process is often referred to as *burning*. For example, athlete's *burn* energy (sugars) as they exercise. The harder they exercise, the more sugars they burn so the more oxygen they need. That's why at full speed, they are breathing very fast. Athletes take up oxygen through their lungs. Plants take up oxygen through the stomata in their leaves and through their roots.

Again, respiration is the burning of sugars for energy to grow and do the internal work of living. It is very important to understand that both plants and animals (including microorganisms) need oxygen for respiration. This is why overly wet or saturated soils are detrimental to both root growth and function, and the decomposition processes carried out by microorganisms in the soil.

The same principles regarding limiting factors are valid for both photosynthesis and respiration.

Table 1. Comparison of photosynthesis and respiration

Photosynthesis	←→	**Respiration**
Produces sugars from energy		Burns sugars for energy
Energy is stored		Energy is released
Occurs only in cells with chloroplasts		Occurs in most cells
Oxygen is produced		Oxygen is used
Water is used		Water is produced
Carbon dioxide is used		Carbon dioxide produced
Requires light		Occurs in dark and light

Transpiration

Water in the roots is pulled through the plant by **transpiration** (loss of water vapor through the stomata of the leaves). Transpiration uses about 90 percent of the water that enters the plant. The other 10 percent is an ingredient of photosynthesis and cell growth.

Transpiration serves three essential roles:

- Movement of minerals up from the root (in the xylem) and sugars (products of photosynthesis) throughout the plant (in the phloem). Water serves as both the solvent and the avenue of transport.
- Cooling – 80 percent of the cooling effect of a shade tree is from the evaporative cooling effects of transpiration. This benefits both plants and humans.
- Turgor pressure – Water maintains the turgor pressure in cells much like air inflates a balloon, giving the non-woody plant parts form. Turgidity is important so the plant can remain stiff and upright and gain a competitive advantage when it comes to light. Turgidity is also important for the functioning of the guard cells, which surround the stomata and regulate water loss and carbon dioxide uptake. Turgidity also is the force that pushes roots through the soil.

Water movement in plants is also a factor of osmotic pressure and capillary action. **Osmotic pressure** is defined as water flowing through a permeable membrane in the direction of higher salt concentrations. Water will continue to flow in the direction of the highest salt concentration until the salts have been diluted to the point that the concentrations on both sides of the membrane are equal.

A classic example is pouring salt on a slug. Because the salt concentration outside the slug is highest, the water from inside the slug's body crosses the membrane that is his skin. The slug becomes dehydrated and dies. Envision this same scenario the next time you gargle with salt water to kill the bacteria that are causing your sore throat.

Fertilizer burn and dog urine spots in a lawn are examples of salt problems related to gardening. The salt level in the soil's water is higher than in the roots, and water flows from the roots into the soil's water in an effort to dilute the concentration. So what should you do if you accidentally over apply fertilizer to your lawn?

Capillary action refers to the chemical forces that move water as a continuous film rather than as individual molecules. Water molecules in the soil and in the plant cling to one another and are reluctant to let go. You have observed this as water forms a meniscus on a coin or the lip of a glass. Thus when one molecule is drawn up the plant stem, it pulls another one along with it. These forces that link water molecules together can be overcome by gravity.

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