MASTER GARDENER
COLORADO STATE UNIVERSITY
EXTENSION

CMG GardenNotes #141

Plant Physiology:
Photosynthesis, Respiration, and Transpiration

Thought question

Explain the science behind the following question

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

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 carbon dioxide (CO_2) and water (H_2O).
- **Transpiration –** The loss of water vapor through the stomates of leaves
- **Respiration –** The process of metabolizing (burning) sugars to yield energy for growth, reproduction**,** and other life processes

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 ***photosynthates*** (sugars, starches, carbohydrates, and proteins) and release oxygen as a byproduct. [Figure 1]

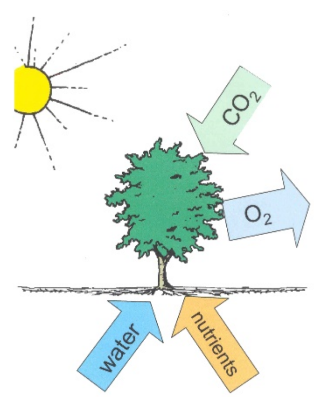

Figure 1. In photosynthesis, the plant uses water and nutrients from the soil and carbon dioxide from the air, with the sun's energy to create photosynthates. Oxygen is released as a byproduct.

Photosynthesis literally means *to put together with light.* It occurs only in the ***chloroplasts***, tiny sub-cellular structures contained in the cells of leaves and green stems. A simple chemical equation for photosynthesis is given as follows:

carbon dioxide + water + light energy = glucose + oxygen

$$6CO_2 + 6H_2O + \text{light energy} = C_6H_{12}O_6 + 6O_2$$

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This process is directly dependent on the supply of water, light**,** and carbon dioxide. Limiting any **one** of 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. An implication of drought or severe restrictions on landscape irrigation is a reduction in photosynthesis and thus a decrease in plant vigor and growth.

In a tightly closed greenhouse there can be very little fresh air infiltration and carbon dioxide levels can become limiting, thus limiting plant growth. In the winter, many large commercial greenhouses provide supplemental carbon dioxide to stimulate plant growth.

The rate of photosynthesis is somewhat temperature dependent. For example, when temperatures rise above 96°F in tomatoes, the rate of food used by respiration rises above the rate of food manufacture through photosynthesis. Plant growth comes to a stop and produce loses its sweetness. Most other plants are similar. [Figure 2]

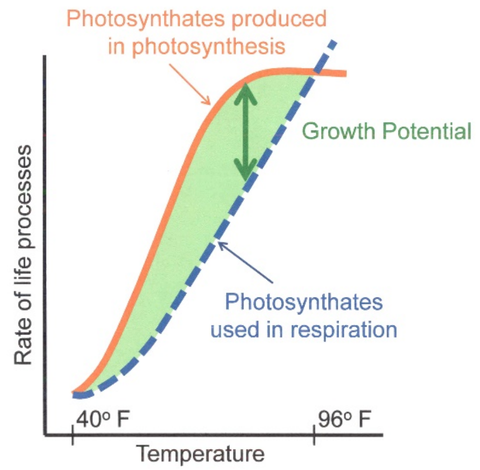

Figure 2. In the tomato plant, rates of photosynthesis and respiration both increase with increasing temperatures. As the temperature approaches 96°F, the rate of photosynthesis levels off, while the rate of respiration continues to rise.

Transpiration

Water in the roots is pulled through the plant by **transpiration** (loss of water vapor through the stomates of the leaves). Transpiration uses about 90% of the water that enters the plant. The other 10% is an ingredient in 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% 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 have a competitive advantage when it comes to light. Turgidity is also important for the functioning of the guard cells, which surround the stomates 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 dehydrates 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. The salt level in the soil's water becomes 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 apply too much 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.

Respiration

In ***respiration***, plants (and animals) convert the sugars (photosynthates) back into energy for growth and other life processes (metabolic processes). The chemical equation for respiration shows that the photosynthates are combined with oxygen releasing energy, carbon dioxide, and water. A simple chemical equation for respiration is given below. Notice that the equation for respiration is the opposite of that for photosynthesis.

$$\text{glucose} + \text{oxygen} = \text{energy} + \text{carbon dioxide} + \text{water}$$
$$C_6H_{12}O_6 + 6O_2 = \text{energy} + 6CO_2 + 6H_2O$$

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, athletes "burn" energy (sugars) as they exercise. The harder they exercise, the more sugars they burn so the more oxygen they need. That is why at full speed, they are breathing very fast. Athletes take in oxygen through their lungs. Plants take up oxygen through the stomates in their leaves and through their roots.

Again, respiration is the burning of photosynthates for energy to grow and to 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 root growth and function, as well as the decomposition processes carried out by microorganisms in the soil.

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

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 is produced
Requires light		Occurs in dark and light

Additional Information – *CMG GardenNotes* on Botany:

#121	Horticulture Classification Terms	#136	Plant Structures: Fruit
#122	Taxonomic Classification	#137	Plant Structures: Seeds
#131	Plant Structures: Cells, Tissues, and Structures	#141	Plant Growth Factors: Photosynthesis, Respiration and Transpiration
#132	Plant Structures: Roots	#142	Plant Growth Factors: Light
#133	Plant Structures: Stems	#143	Plant Growth Factors: Temperature
#134	Plant Structures: Leaves	#144	Plant Growth Factors: Water
#135	Plant Structures: Flowers	#145	Plant Growth Factors: Hormones

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Revised June 2016