Plant Growth Factors: Photosynthesis, Respiration, and Transpiration

Outline

- Photosynthesis
- Respiration
- Transpiration

Thought Questions

Explain the science behind the following gardening questions:

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 and water.

- **Respiration –** the process of metabolizing (burning) sugars to yield energy for growth, reproduction**,** and other life processes.
- **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 ***photosynthates*** (sugars, starches, carbohydrates, and proteins) and release oxygen as a byproduct. [Figure 1]

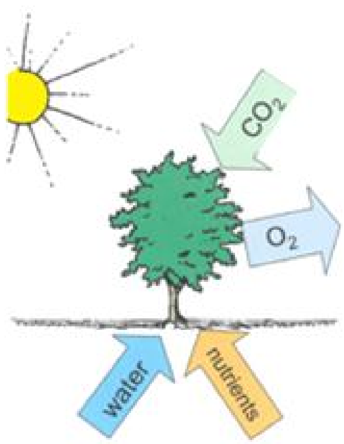

Figure 1. In photosynthesis, the plant used water and nutrients from the soil, carbon dioxide from the air with the sun's energy to create photosynthates. Oxygen is releases as a byproduct.

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 in Figure 2.

Photosynthesis

carbon dioxide + water + light energy = glucose + oxygen

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

Figure 2. Simple chemical equation for photosynthesis.

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 CO2 levels can become limiting, thus limiting plant growth. In the winter, many large commercial greenhouses provide supplemental CO2 to stimulate plant growth.

The rate of photosynthesis is somewhat temperature dependent. For example, with tomatoes, when temperatures rise above 96o F the rate of food used by respiration rises above the rate of which food is manufactured by photosynthesis. Plant growth comes to a stop and produce loses its sweetness. Most other plants are similar. [Figure 3]

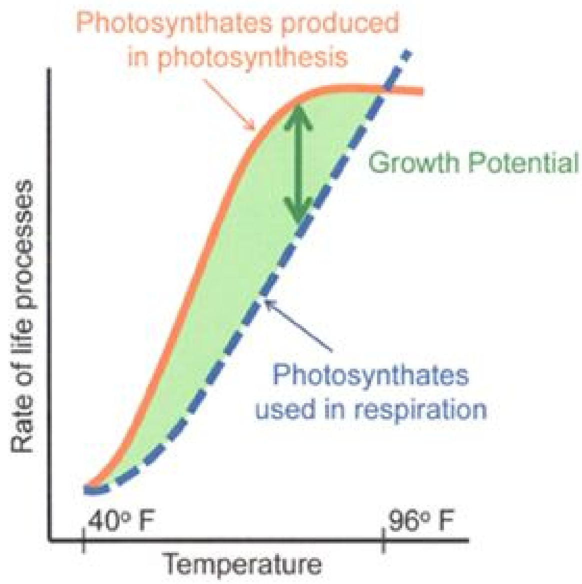

Figure 3. For the tomato plant, rates of photosynthesis and respiration both increase with increasing temperatures. As the temperature approaches 96o, the rate of photosynthesis levels off, while the rate of respiration continues to rise.

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. Notice that the equation for respiration is the opposite of that for photosynthesis. [Figure 4.]

Respiration

glucose + oxygen = energy + carbon dioxide + water

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

Figure 4. Simple equation for respiration.

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 is 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 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.

Table 1. **Comparison of photosynthesis and respiration**	
Photosynthesis	**Respiration**
Produces sugars from light energy	Burns sugars for energy

Stores energy	Releases energy
Occurs only in cells with chloroplasts	Occurs in most cells
Releases oxygen	Uses oxygen
Uses water	Produces water
Uses carbon dioxide	Produces carbon dioxide
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% of the water that enters the plant. The other ten percent 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 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 poor 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. 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 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.