Carbon, Oxygen, and Hydrogen Fertility and Corn Grain Yield

CROP BULLETIN

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KEY POINTS

- Carbon, oxygen, and hydrogen comprise approximately 94% of the dry weight of the corn plant.
- Plants acquire these three elements from water and the atmosphere.
- The key to managing these essential nutrients is to manage soil water.

ELEMENTAL COMPOSITION OF CORN PLANTS

Carbon, oxygen, and hydrogen are considered "freebie" nutrients because they do not need to be applied as fertilizer in crop production. These three nutrients comprise approximately 94% of the dry weight of the corn plant (carbon – 44%, oxygen – 45%, and hydrogen – 6%) (Figure 1) (Latshaw and Miller, 1924). Yet they are hardly ever considered in a corn fertility program. Carbon, oxygen, and hydrogen are principal components of starch, protein, oil, and fiber, which comprise about 85% of the final grain yield. (The remaining 15% is water.) What can corn producers do to increase carbon, oxygen, and hydrogen uptake? This Field Facts article discusses the sources of carbon, oxygen, and hydrogen and considers management options to increase uptake of these essential nutrients.

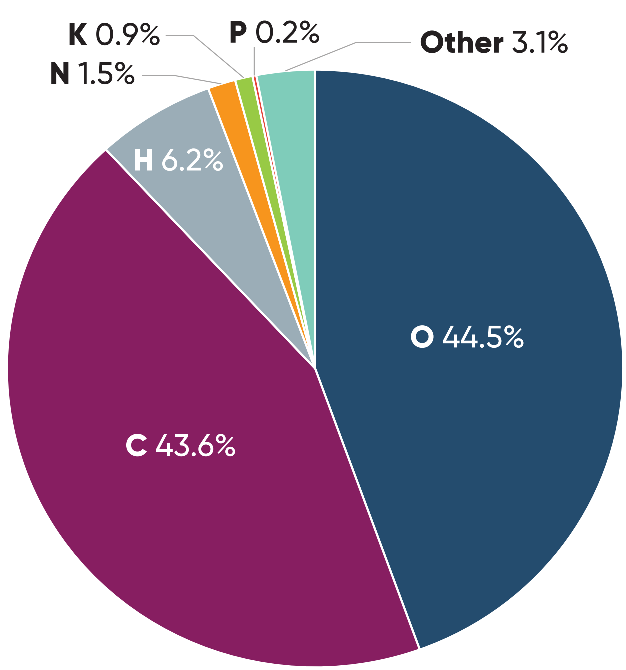

Figure 1. Elemental composition of corn plant dry weight.

SOURCES OF CARBON, OXYGEN, AND HYDROGEN

Carbon

Carbon is extracted from carbon dioxide (CO_2) in the atmosphere. Photosynthesis converts low-energy carbon-oxygen (C-O) bonds primarily to higher energy carbon-hydrogen (C-H) and carbon-carbon (C-C) bonds in sugars, starch, oil, amino acids, and other organic compounds. From a fertility perspective, CO_2 is an unlimited resource in the atmosphere, so we do not need to fertilize corn with carbon. Carbon is and will continue to be a "freebie" nutrient.

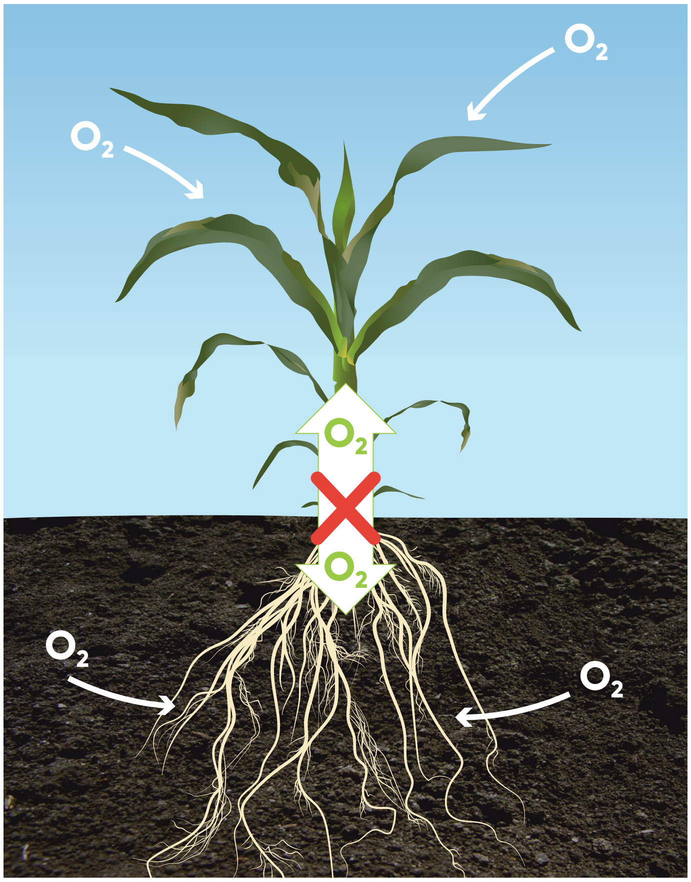

Figure 2. Sources of oxygen for the corn plant. Shoots extract oxygen from the air, while roots extract oxygen from the soil atmosphere. Very little oxygen translocates between corn shoots and roots.

Oxygen

There are three sources of oxygen (O_2). The first source is molecular oxygen extracted from the air or from the soil atmosphere. Mitochondria in corn plant cells require oxygen to function properly to produce energy. Mitochondria in corn shoot cells consume oxygen extracted from the air while mitochondria in corn root cells consume oxygen extracted from the soil atmosphere. Transport of oxygen from corn shoots to corn roots is very limited and insufficient to meet root demand because water can dissolve only very low amounts of oxygen (Figure 2).

The second source is oxygen extracted from water as water molecules are split during photosynthesis (Figure 3). The vast majority of this oxygen is released into the atmosphere as molecular oxygen. However, a low percentage of oxygen molecules could be consumed by plant mitochondria to generate energy during mitochondrial respiration.

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{Photosynthesis}} \text{Sugar } (C_6H_{12}O_6) + 6\ O_2$$

Figure 3. Photosynthesis converts carbon dioxide and water into sugar and oxygen.

The third source is oxygen contained in carbon dioxide (CO_2) (Salisbury and Ross, 1978). During photosynthesis, this oxygen is incorporated into sugar, which is the starting material for all plant organic compounds. This is the oxygen that contributes to yield.

Hydrogen

The source for essentially all hydrogen in the corn plant is hydrogen extracted from water (Figure 3). During photosynthesis, as plant cells assimilate oxygen, extracted from CO_2, into sugar, these cells also assimilate hydrogen, extracted from water, into sugar. Approximately 91% of corn grain dry matter is derived from air and water.

CARBON, OXYGEN, AND HYDROGEN UPTAKE

The key to managing these essential nutrients is to manage soil water. If the soil contains too much water, mitochondria in the corn root cells suffocate from lack of oxygen and die, leading to overall root death. The soil atmosphere contains up to about 21% oxygen, whereas the solubility of oxygen in water is about 6 to 12 parts per million. Oxygen in the soil atmosphere in a well-aerated soil is about 30 times more available to the corn root than oxygen in a water-saturated soil.

If the soil contains too little water, evapotranspiration is limited, plant stomates close, and very little carbon dioxide and oxygen are captured in stomatal chambers (Figure 4). Reduced carbon dioxide levels limit the amount of carbon that is converted into sugar, and reduced oxygen levels inhibit mitochondrial respiration for energy production. Limitations of both functions reduce grain yield. When the corn plant is transpiring properly, stomates are open to allow for release of water vapor into the atmosphere. These open stomates also allow CO_2 and O_2 to move from the atmosphere into stomatal chambers. As stomates close to conserve water during dry conditions, these closed stomates also restrict the capture of CO_2 and O_2.

Managing water in the soil is like managing the oil in your tractor engine. As long as you maintain the oil level between the "full" and the "add" marks on the dipstick, oil pressure is suitable for proper engine function. For water, as long as the water content in the soil is greater than the wilting point and is at or less than field capacity, corn grows properly. Management practices to better ensure maximum corn growth and yield include:

- Install tile drainage to more rapidly remove excess water during rainy periods.
- Manage soil tillage to create a soil structure that allows maximum water percolation and capture during and after rains or irrigation events.
- Improve the soil structure to allow better retention of water between rainfalls or irrigations.
- Conserve soil moisture by maintaining surface residue to reduce evaporation of water directly from the bare soil surface.
- Fertilize properly to allow the corn plant to efficiently capture all of the carbon it can.
- Select hybrids that perform well in drier environments.

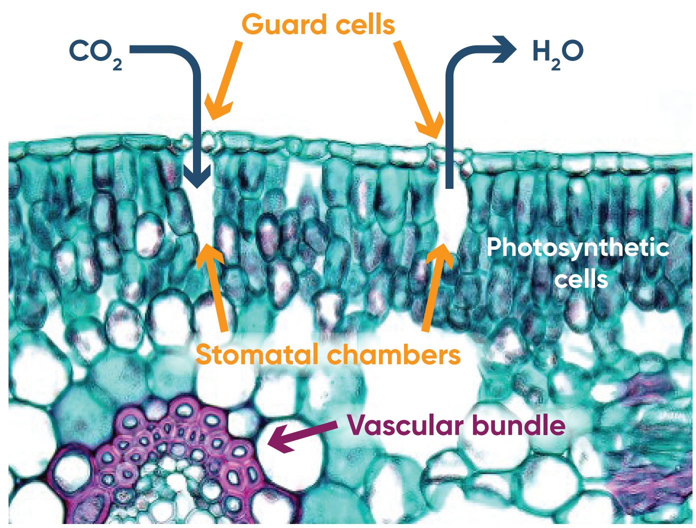

Figure 4. Stomatal guard cells regulate the exchange of materials between the atmosphere and the corn plant. Proper soil moisture better ensures guard cells are open to allow for maximum uptake of CO_2 and other gases.

REFERENCES

Latshaw, W. L., and E. C. Miller. 1924. Elemental composition of the corn plant. Journal of Agricultural Research 27:845-860.

Salisbury, F. B. and C. W. Ross. 1978. Plant Physiology. 2nd Ed. Wadsworth Publishing Co., Belmont, CA. pp. 123-159.