

Using a Chlorophyll Meter to Improve Foliar Fertilizer Efficiency & Customer Returns

Introduction

The chlorophyll meter will give a relative measurement of the chlorophyll content of plants. "Relative" means that the meter does not measure actual units of chlorophyll, but rates it on a number scale, the higher the number the higher the chlorophyll.

Question: How can this meter help you?

Answer: Chlorophyll is a group of compounds found in all green plants that actually takes the energy from the sun (light energy) and through a complicated process converts it into chemical energy that "fuels" plant growth. Raising the number of "units" and effectiveness of this system of converting light energy into chemical energy is directly related to how well the plant grows and produces.

More Chlorophyll = More "fuel" (energy) = Higher yields (profit)

Question: Why should you use this meter?

Answer: A leaf or petiole test will give you an indication of the nutrient level of your plants. However, it does not give you an indication of how "available" (biologically active) these nutrients are in the plant's system. An example of this can be illustrated in the case of iron. In high pH, calcareous soils, often visual iron deficiencies can be seen. Yet, a tissue analysis reveals that there is adequate iron in the leaf. In this case the iron is there but it is not biologically active in the plant's system. When you apply foliar nutrients you can use this meter to monitor the effectiveness of your nutrient foliar applications in how available they are to the "fuel" system of the plant.

Question: How can you use this meter to improve foliar product performance?

Answer: Bio-Gro, Inc. has an excellent line of quality products designed for maximum efficiency and return to the customer. However, you can have the best products in the world, but if you do not apply them and use them properly, you will not get the best response and yield improvement possible. This chlorophyll meter will help you get the most out of the investment your customer puts into the product line. However, before you can effectively use this meter, you must understand the basic function of how plants use chlorophyll in the PHOTOSYNTHESIS process.

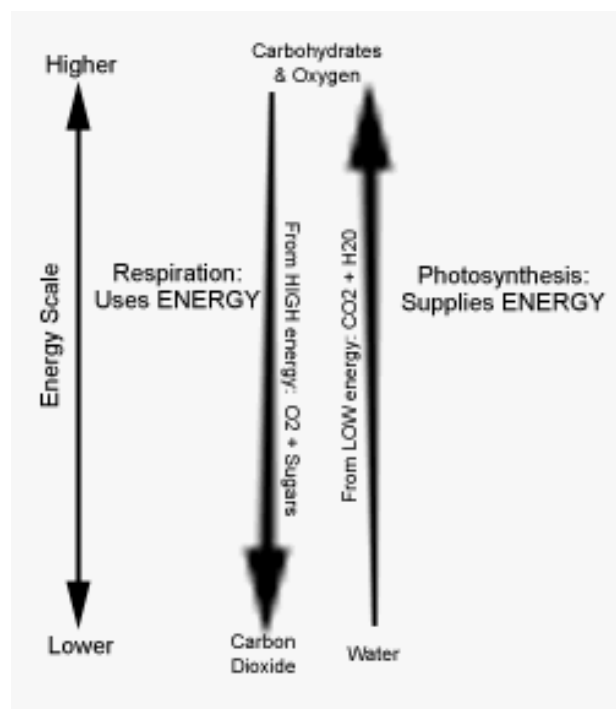
The Photosynthesis Process

The Basics

Photosynthesis is the most important mechanism by which energy is put back into the living world of plants, animals and even for humans. Animals and humans cannot get energy directly from the sun, we must consume food to get this energy to live and function.

"PHOTO" refers to light. "SYNTHESIS" refers to making or manufacturing. Therefore, the word "photosynthesis" means light manufacturing or light driven synthesis of chemicals.

The process of photosynthesis converts LOW ENERGY compounds of water (H₂O) and carbon dioxide (CO₂) into HIGH ENERGY compounds of Carbohydrates (sugar) and Oxygen (O₂).



Photosynthesis: Yield - The Source-Sink Relationship

More than 90% of a plant's dry matter consists of organic compounds mainly cellulose, starch, lipids and proteins. Therefore the total dry matter production of plants is directly related to the SOURCE of all these compounds: PHOTOSYNTHESIS. Although we do not get directly paid for the photosynthesis compounds, the rate of the production of source (mature green leaves) is directly related to the potential production of the SINK (roots, shoots, seeds and fruits).

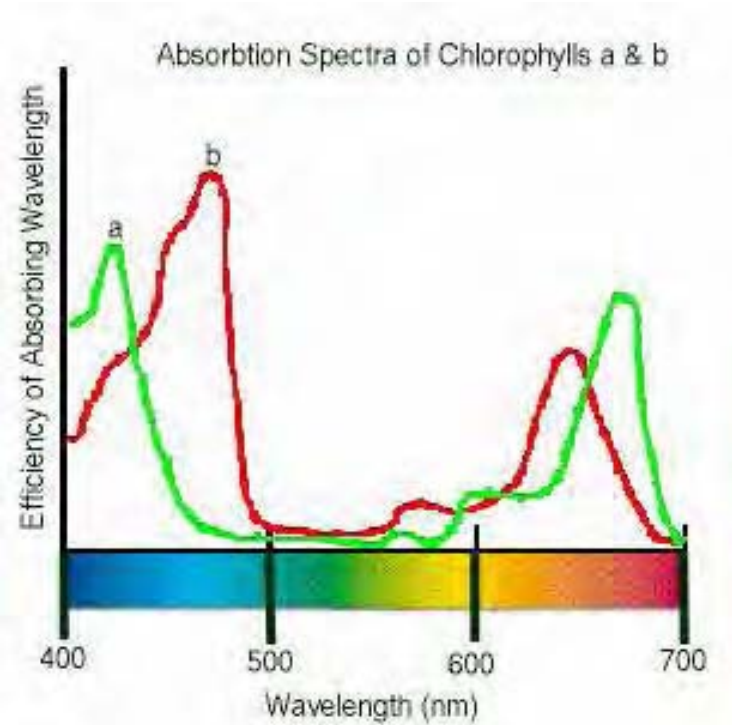
In order to fully understand how to improve the rate of photosynthesis, we will explain the basics of the process which converts the sun energy into chemical energy for plants to grow. We will focus on the nutrients used in this process.

The Light

Why are plants green?

The colors that you see are bands of light which are reflected back to your eyes. The visible band of light is from about 380 nm (violet color) to 750 nm (red color). Does “nm” stand for New Mexico? No, here it means “nanometer”. A nanometer is equal to 1 billionth of a meter and is often also expressed as 10^{-9} . If it were possible to “see” a wave of light, the distance from peak to peak of the violet light wave would be 380 nanometers.

The graph below illustrates the wavelengths of light that are best absorbed by two major types of chlorophyll found in plants. Study the graph and figure out why plants are green.



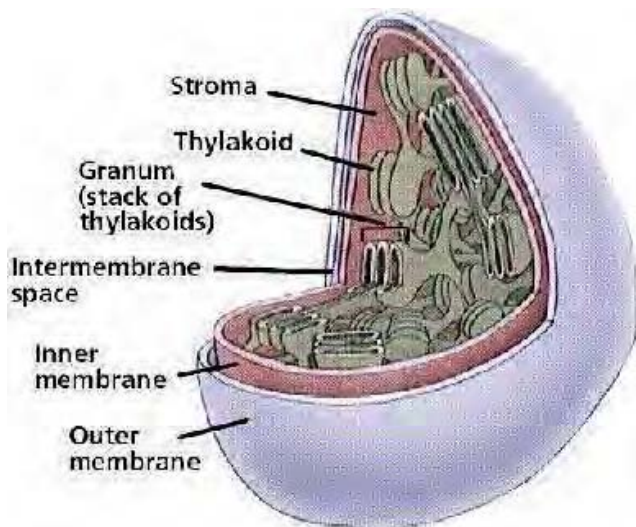
The Photosynthesis Factory - The Leaf



In order to catch sunlight, the plant must have leaves which contain the chloroplasts that convert the sun's energy into chemical energy and compounds which the plant uses to grow and produce. Therefore, leaves are the “solar” collectors of plants. The bigger, the healthier and the more chloroplasts and chlorophyll they contain the more energy they can manufacture for growing plants.

The light from the sun strikes the surface of the leaf. Certain wavelengths are absorbed by the chlorophyll located in the chloroplasts.

Photosynthesis: The Chloroplast

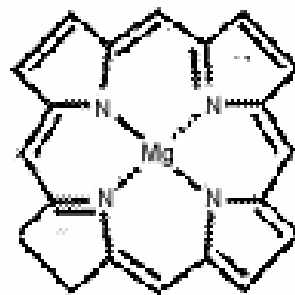


The rays of sunlight strike the surface of the leaves of plants and are absorbed by pigments located in the chloroplast.

On average, a square inch of leaf area can contain up to 300,000,000 chloroplasts!

Chlorophyll

The rays of sunlight are absorbed by special pigments located in the thylakoid of the chloroplast. Pigments are molecules that are very effective at absorbing wavelengths from the visible spectrum of light (violet to red). These pigments are the chlorophyll. Each chlorophyll molecule has a magnesium center. This picture is just the center of the molecule.



Magnesium in the Center of the Chlorophyll Molecule

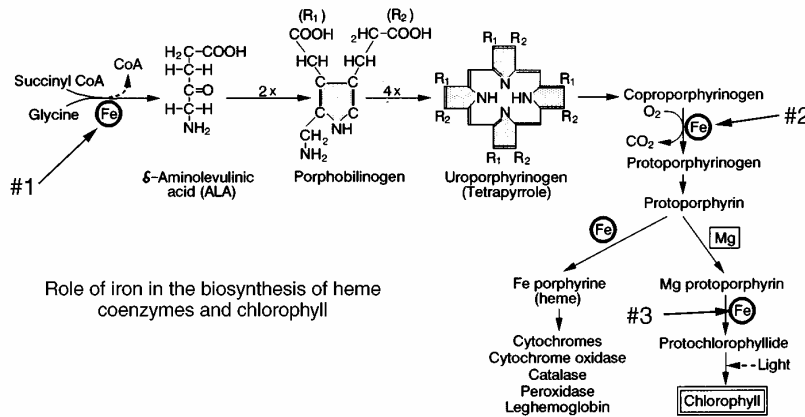
Interesting Point

In the photosynthesis process, there are still parts of it that are not yet fully understood, however, what is known in regards to the minerals involved in the process is that in order to get one electron out of a water molecule a total of 29 metal ions and 7 aromatic groups are involved in the transfer process. The metals are:

19 - Iron (Fe), 5 - Magnesium (Mg), 4 - Manganese (Mn) and 1- Copper (Cu).

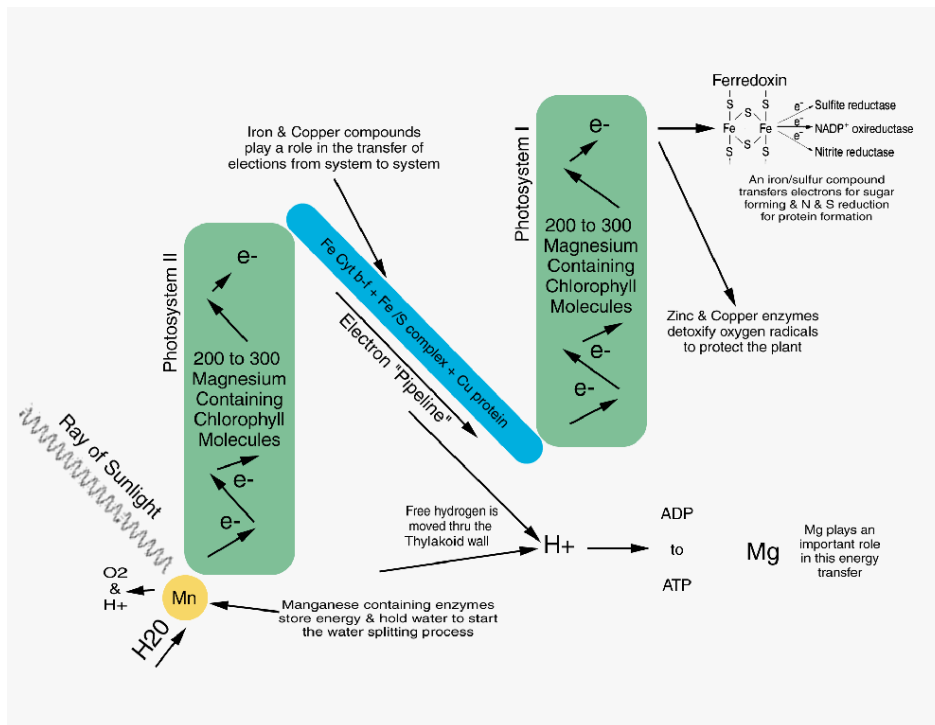
Chlorophyll: How it is Made

Iron plays an important role in the photosynthesis process, even in the formation of the chlorophyll molecules. As you can see in the diagram below, iron is used three times. Many of the heme (iron based) enzymes produced from this process also play very critical roles in the photosynthesis process.



From: "Mineral Nutrition of Higher Plants", Horst Marschner, Academic Press, Pg 315

To fully understand the role of minerals in the photosynthesis process, it is important to get a basic idea of the sequence of “events” in the conversion of light into chemical energy. Study the simplified flow chart and refer back to it in the following pages.



Important Minerals in the Photosynthesis Process

Magnesium (Mg)

Uptake of Mg into plants can be strongly depressed by other cations such as; K, Ca, NH₄ and Mn. Magnesium is mobile in plants; therefore a deficiency will first occur in the mature leaves.

Magnesium is the most familiar nutrient because it is the center of the chlorophyll molecules, which “catch” the sun’s rays. However, in Mg sufficient leaves only 6% to 10% of the total Mg is in the chlorophyll. As a matter of fact, when the Mg in the chlorophyll reaches 20% to 25%, most plants slow growth and visual deficiencies are noticed.

Balancing the level of Mg in plants is very important to photosynthesis. For example, a small amount of free Mg is required in the external solution of the chloroplast to maintain the manufacture of proteins required for photosynthesis and other plant protein based compounds. However, an excess of Mg applied can strongly inhibit the photosynthesis process by effecting potassium influx and causing of over acidification of the stroma.

When leaves become deficient in Mg, the first indication is not lower chlorophyll levels, but enhanced degradation of protein (including the thylakoid protein) and impaired exports of the photosynthates from the chloroplasts. This deficiency will first lead to less manufacture of chlorophyll containing units (thylakoids) and also the export and use of the compounds that have been made in the working chloroplasts. Therefore, when a noticeable Mg deficiency occurs such as a visual reduction of chlorophyll, the plant has been suffering a production loss for some time.

As shown in the photosynthesis flow chart on the preceding page, Mg is an absolute requirement as a bridging component between ADP and an enzyme for the transfer of electrons (energy) is one of the two energy transfer systems plants use. Without an ample supply of Mg, the plant losses a great part of its production.

Iron (Fe)

As stated earlier, Fe is used in the formation of the very chlorophyll molecules themselves. This flow chart also shows the importance of Fe in the formation of the needed iron containing compounds that make up the photosynthesis mechanisms. Iron is also required in levels of 3 to 4 times the level of Mg in the photosynthesis process. Under controlled conditions, up to 80% of the Fe in newly forming leaves is in the chloroplasts. Iron is very immobile in plants and therefore its deficiency first appears in new growth.

Iron is essential for the transfer of electrons (energy) from photosystem II to photosystem I. It is also most important for the distribution of electrons to one of two major systems of converting carbon dioxide to sugar. This same ferridoxin compound also reduces nitrogen and sulfur compounds for incorporation into proteins.

When deficient, iron has a limited visual effect on leaf growth, cell number & area, or even the number of chloroplasts in cells. The first negative effect is on the physical size of the chloroplasts and the protein content thereof.

As iron deficiency increases, production of electrons from photosystem I slows rapidly at first. Most plants can immediately “restart” this system with iron supplied by foliars. However, if this deficiency persists, the effectiveness of photosystem II is also decreased and more irreversible damage occurs.

Iron & Calcareous Soils

Acid soils rarely show visual deficiencies of iron because Fe is more soluble at lower pH levels. (In some areas & crops this is debatable.) However, in high pH (alkaline) and high calcium (calcareous) soils there is a double negative. First the solubility of iron is limited at increasing pH levels. Secondly, the high levels of bicarbonates associated with many irrigated calcareous soils cause the iron taken up by certain types of plants to be very inactive. Often there are visual Fe deficiencies, yet tissue tests can show higher levels of Fe. In this condition the use of a chlorophyll meter with iron foliars is essential.

Although the exact reason for higher levels of iron in these Fe chlorosis conditions is not fully understood, it is believed that some plants cannot convert Ferrous (Fe^{2+}) to Ferric (Fe^{3+}) effectively in the electron transfer process. (A detailed paper on this subject is available by calling Bio-Gro, Inc. at 1-800-738-7457.)

Manganese (Mn)

Manganese plays a most important role in photosystem II, where a Mn containing complex stores energy and possibly even acts as a binding site for the water that is split for the energy gain needed.

Light deficiencies of Mn do not cause an immediate drop off in chlorophyll itself. However, the production of oxygen drops off immediately. Under some conditions, cellular oxygen deficiency is an overlooked cause of limited crop production. This light Mn deficiency can cause changes in the thylakoid membrane structure. This deficiency can be easily corrected when Mn is supplied.

In heavier deficiencies of Mn, the structure of thylakoid membranes are severely altered and chlorophyll content will become visually lower. At this point damage caused by Mn deficiency can be irreversible.

This is an important point to note in the use of a chlorophyll meter with the element Mn. Balancing the levels of Mn is important in providing overall better sugar production from the photosynthesis process, but if the chlorophyll drops due to Mn deficiency, the damage caused is permanent.

Zinc/Copper (Zn & Cu)

A copper-protein plays an important role in the actual transfer of electrons from photosystem II to I. Zinc and copper enzymes play a very important role in maintaining a detoxifying process of the photosynthesis mechanisms. The importance of this system will be illustrated further in the following section discussing the balancing process.

Photosynthesis: Nutrient Availability & Balance

The purpose of illustrating the photosynthesis process and introducing the concept of utilizing a chlorophyll meter with foliar applications of nutrients is to stimulate a change in the way agricultural professionals view fertilizer applications. The concept of supplying the most limited nutrient has been recognized and utilized by fertility experts for many years. Foliar feeding has been an important development in this process.

“Nutrient Supply is Important”

Yet, years of experience in tissue testing and fertility recommendations show that it is possible to diagnose and treat certain nutrient deficiencies. However, can we be sure that the nutrient that is applied is utilized by the plant? Can we be sure that the nutrients we supply increase plant production every time?

Nutrient Availability

The above illustrated photosynthesis process brings out an important point. Under certain conditions, a plant can show a visual iron deficiency, but when leaves are analyzed, the iron levels are the same (sometimes even higher) in the deficient leaves versus the visually sufficient leaves. This concept is especially important in the foliar application of minerals where the soil nutrient uptake system (biological) is surpassed. When plants take up iron from the soil, it is most likely taken up in a complex organic compound. How do you try to apply iron on the leaves?

Nutrient Balance

Photosynthesis is a factory. A delicate process that is the beginning of 90% of a plant's dry matter content. The purpose of this write-up is to bring attention to the importance of considering a balanced application of nutrients, especially foliar. Take for instance the balance of magnesium and iron. If iron is deficient (or unavailable) will the addition of large amounts of magnesium lead to more chlorophyll production? Manganese is also very important, it is also as important as the magnesium. Without it, the “factory” cannot hold and split water effectively.

However, let us look at manganese from another view. Let us say that the soil is acidic and manganese is taken up in large quantities. In this case, especially under high light conditions, excess manganese could cause an oversupply of water splitting, free oxygen and excess electrons. Under these conditions, it is possible to produce excess oxygen radicals that could cause physical damage to the factory mechanism. In this case it becomes important to assure a good “pipeline” for electron translocation and a good supply of zinc and copper enzymes to detoxify the free radicals.

Vitamin B plays an important role in one of the most important electron transfer systems. Have you ever considered the application of this compound?

Organic phosphates (NADP and ADP) are the only mechanisms by which your photosynthesis factory can deliver the electrons (energy) it produces to the formation of sugars and organic compounds the plant needs to function. Is the phosphate you apply soluble and available, or is it tied up by a trace element in the foliar mix?

Applying the Concept

A professional field agronomist is the photosynthesis plant manager. The larger you can make the surface area of your leaves, the more manufacturing space you have. The more chlorophyll you can produce, the more manufacturing machines you have. The more you can balance the production lines, the more efficiently your factory can produce and ship electrons down the line. This is only the beginning, but without the production of energy from the photosynthesis process, all the fertilizer you can put on does not give the optimum return to your growers.

Getting the most out of the chlorophyll meter:

- 1) Figure out which of the elements involved in the photosynthesis process is most limiting (or excessive) by tissue and soil analysis.
- 2) Figure out which forms of the elements you need are the most effective by spraying small plots with a backpack sprayer and monitoring the chlorophyll levels for the first 1 to 4 days after application.
- 3) Continue to experiment with different foliar products and levels of foliar additives such as NUE Chelate, Carbo-Cal, NUE Stimulant, NUE DeStress and other formulations.
- 4) Try various combinations on balances of N-P-K and minerals such as Mg, Fe, Mn, Zn or Cu.