Commercial Greenhouse and Nursery Production

Water-soluble and Controlled-release Fertilization

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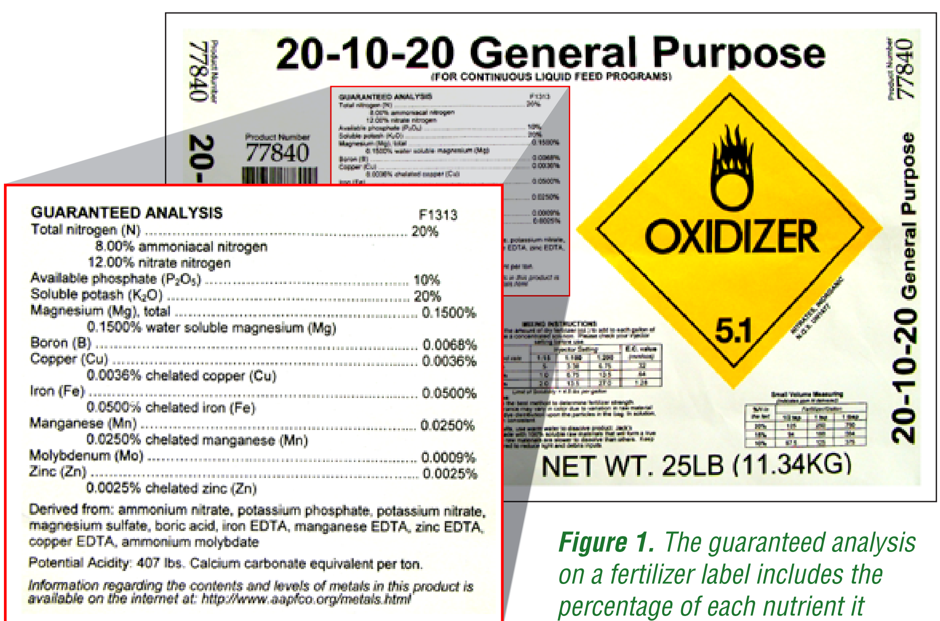
Soil vs. Soilless Substrates

In nature, plants can absorb essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K) from the soil. These nutrients (considered primary macronutrients) are provided through the decay of organic matter in nature, as well as inorganic materials (minerals). In the case of N, this nutrient can be converted from atmospheric nitrogen (N_2) into plant-available nitrogen by bacteria that occur naturally in the soil.

However, field soil is rarely used in the commercial greenhouse environment. Instead, growers use soilless substrates (media) that consist primarily of organic matter such as peat or bark, and other inert (unreactive) components such as perlite, rice hulls, or vermiculite that are incorporated for drainage. Compared to soil, these components are much more consistent in their composition, have the necessary aeration and water-holding properties for container production, and are light enough to transport economically.

But soilless substrates do not contain soil, they lack many of the nutrients in sufficient quantity to maximize plant growth and development. Furthermore, because the physical and chemical



GUARANTEED ANALYSIS F1313

Total nitrogen (N)	20%
8.00% ammoniacal nitrogen	
12.00% nitrate nitrogen	
Available phosphate (P_2O_5)	10%
Soluble potash (K_2O)	20%
Magnesium (Mg), total	0.1500%
0.1500% water soluble magnesium (Mg)	
Boron (B)	0.0068%
Copper (Cu)	0.0036%
0.0036% chelated copper (Cu)	
Iron (Fe)	0.0500%
0.0500% chelated iron (Fe)	
Manganese (Mn)	0.0250%
0.0250% chelated manganese (Mn)	
Molybdenum (Mo)	0.0009%
Zinc (Zn)	0.0025%
0.0025% chelated zinc (Zn)	

Derived from: ammonium nitrate, potassium phosphate, potassium nitrate, magnesium sulfate, boric acid, iron EDTA, manganese EDTA, zinc EDTA, copper EDTA, ammonium molybdate

Potential Acidity: 407 lbs. Calcium carbonate equivalent per ton.

Information regarding the contents and levels of metals in this product is available on the internet at: http://www.aapfco.org/metals.html

***Figure 1.** The guaranteed analysis on a fertilizer label includes the percentage of each nutrient it contains.*

properties of soilless substrates differ from soil, they typically do not bind nutrients as strongly as soil particles, which means that excess irrigation can readily leach some nutrients from the substrate.

Consequently, growers must supplement the substrate with water-soluble and/or controlled-release fertilizers to provide plants with essential nutrients. Commercial substrates often contain a starter charge to provide a base level of nutrition, but they are not of sufficient concentration to provide adequate nutrition to finish a greenhouse crop. To ensure optimal plant growth, greenhouse growers typically should begin a fertilizer program immediately after planting.

This publication examines the basics of greenhouse and nursery crop fertilization and provides an overview of the current fertilization methods available for soilless substrates.

Plant Nutrition

The bulk of a plant's total dry weight (89 percent) is composed of carbon (C), hydrogen (H), and oxygen (O). Plants can readily absorb these elements from the air and water, so they are not included in commercial fertilizers.

Commercial fertilizers generally include the other essential elements: primary and secondary essential macronutrients and essential micronutrients. N, P, and K compose just 8.5 percent of a plant's total dry weight, but these nutrients are the primary macronutrients and are included (in varying ratios) in complete fertilizers. For example, a complete fertilizer label may indicate 20-20-20, which means that (by weight) the fertilizer is 20 percent N, 20 percent P (as P_2O_5, which is 44 percent P), and 20 percent K (as K_2O, which is 83 percent K).

The secondary macronutrients, calcium (Ca), magnesium (Mg), and sulfur (S) are not included in this ratio, and may or may not be included in the fertilizer or in sufficient quantities. These macronutrients compose 2 percent of plant's dry weight. Fertilizer labels will list the percentage of these nutrients by weight as part of the guaranteed analysis (Figure 1).

Details about reading a fertilizer label are available in *Understanding the Fertilizer Bag*, (Maryland Cooperative Extension Fact Sheet 862, extension.umd.edu/publications/pdfs/fs862.pdf).

Essential micronutrients may be present in the substrate, in complete fertilizers, or even in clear irrigation water. While essential, plants require micronutrients in much smaller quantities than macronutrients — micronutrients compose just 0.061 percent of a plant's dry weight! The essential micronutrients include iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), chlorine (Cl), and nickel (Ni). Minimal requirements for these nutrients vary by plant species.

Details about fertilizer label information and how to use it can be found in *The Basics of Fertilizer Calculations for Greenhouse Crops* (Virginia Cooperative Extension publication 430.100, pubs.ext.vt.edu/430/430-100/430-100.html).

Controlled-release Fertilizers

Controlled-release fertilizers (CRF) are coated with a substance (often a resin, wax, sulfur, or polymer) that prevents the nutrients it contains from being immediately available to the plant — the result is that nutrients are released over an extended period. Depending on the brand of CRF the release rate (and thus its longevity) is subject to temperature, substrate moisture level, and the type and thickness of the coating.

The most recent technological advances in CRFs involve increased control over the rate and pattern of nutrient release. Complex polymer coatings allow for greater control over release rate. Control over the release pattern becomes possible by varying the thickness of the coatings within the formulation. For example, a high initial release rate can be achieved by having a greater proportion of capsules in the product that have a thin coating.

Manufacturers formulate CRFs to be incorporated into the substrate before planting or topdressed on the surface of the substrate after planting. Growers may then water the pots with clear tap or acidified water, or supplement the substrate with a water-soluble fertilizer, depending on irrigation water quality and plant requirements.

Not only can CRFs be supplemented with water-soluble fertilizer, but a primarily water-soluble fertilizer program can include the use of a topdressed CRF for supplemental fertilization for heavy-feeding crops such as garden mums, poinsettias, or petunias. Growers can customize fertilization to their crops by adding micronutrients to the standard N-P-K CRF, by adding multiple levels of longevity (three to 14 months), and by incorporating various initial release rates (low, standard, or high).

When the longevity of the CRF is greater than the plant production period, CRFs provide the added benefit of supplying nutrients after the consumer buys the plant, often adding to its vigor and visual appeal.

Longevity at the following Average Media Temperature (F)
Longevidad promedio a la siguiente temperature del substrato (F)

60°F (15°C)	**70°F (21°C)**	80°F (26°C)	90°F (32°C)
4 – 5 MONTHS MESES	**3 – 4 MONTHS MESES**	2 – 3 MONTHS MESES	1 – 2 MONTHS MESES

Figure 2. *This label for a controlled-release fertilizer shows the relationship of its nutrient release rate to media temperature.*

Continuing improvements in coating technology will allow growers greater control over nutrient release rates. Longevity is directly related to substrate temperature and moisture and is indicated on the fertilizer label (Figure 2). Being able to control nutrient release is a major advantage to this form of nutrient delivery because nutrient release rate is more in line with plant uptake — the result is that fewer nutrients are lost from leaching. Although CRFs cost more per pound than water-soluble fertilizers, CRFs can compensate for their higher price because plants can use them more efficiently (and thus minimize leaching) and can help growers save on labor because there are fewer applications.

Water-soluble Fertilizers

Water-soluble fertilizers dissolve easily in water and are applied to the crop in the irrigation water. One benefit of this type of fertilization is that growers can easily adjust the nutrient concentrations according to a crop's changing needs over a growing season.

Growers often choose a fertilizer concentration and apply this concentration at every watering. This is called continuous liquid feeding (CLF), or fertigation. By contrast there are fertilization programs in which growers apply higher rates of fertilizer less frequently, and irrigate with clear water between feedings.

Figure 3. *Controlled-release fertilizers (the green circular prills) were incorporated into the substrate of this perennial at transplant.*

Continuous feeding provides a more uniform nutrient supply to the crop over time. However, if crops of varying feeding levels are grown in the same greenhouse, a grower may be forced to adjust the injection system to just one setting. In this case, it would be beneficial to fertigate heavy-feeding plants regularly while irrigating light-feeding plants with clear water in between fertigation.

There are a wide variety of soluble fertilizer formulations available. There may be as many as 50 in a single commercial brand. Although potentially overwhelming, the wide variety of greenhouse crops and regional water quality make these formulations necessary. Multiple formulations allow for the customization that is needed to grow plant material that meets market demand.

For example, petunia may benefit from additional iron in its fertilizer while marigold is sensitive to high iron concentrations. Foliage plants can utilize N that contains a higher percentage of urea, while pansy is sensitive to N in ammonium form. Dark-weather fertilizer formulas (at least 60 percent of N as nitrate) are available for use during periods of cool, cloudy weather when plants may not utilize the ammonium form of N. In addition to avoiding nutrient deficiencies and toxicities, optimizing nutrient concentrations for a specific crop can reduce secondary issues, such as insect and pathogen pressure.

EC, pH, and Alkalinity

Electrical conductivity (EC) indicates soluble salt levels, and subsequently fertilizer salt concentrations, in the growing substrate. An EC test is a simple way to assess whether plants are receiving the right amount of fertilizer at a given time. Growers can find the recommended EC values for particular crops, and then make fertilizer injection adjustments before deficiency or toxicity symptoms are visible.

Table 1. *Electrical conductivity (EC) ranges for three feeding levels of commonly grown greenhouse crops. Recommendations based on the pour-through method.*

Fertility Level	Crop Examples	Growing EC Range mS/cm	Establishing/Finishing EC Range mS/cm
Light-feeding plants	Bedding plants	1.2 to 2.4	0.9 to 1.3
Medium-feeding plants	Zonal geranium	2.2 to 3.3	1.2 to 2.1
Heavy-feeding plants	Poinsettia	2.8 to 4.1	1.9 to 2.7

Adapted from: *Floriculture Principles and Species* (J.M. Dole and H.F. Wilkins, 2005).

Table 2. *Potential acidity or basicity and percent NH_4-N of various commercial fertilizers.*

Fertilizer	Potential Acidity or Basicity A=acid, B=base	% NH_4-N
21-7-7	1560 A	100
20-18-18	710 A	73
24-7-15	612 A	58
21-5-20	418 A	40
17-5-24	125 A	31
20-0-20	0	69
15-5-15	141 B	22
14-0-14	220 B	8
13-0-44	460 B	0

Adapted from *Ball RedBook,Volume 2: Crop Production* (D. Hamrick, 2003).

Refer to Table 1 for general suggestions; however, growers should refer to other publications for EC requirements of specific crops. The *Ball RedBook, Volume 2: Crop Production* (2003) is a good resource (see References). Target EC values vary by crop and growth stage. For example, nutrient requirements are lower at plug and at the end of the finish stage.

In order to prevent the soluble salt concentration from reaching harmful levels in the substrate (which increases the chance of root burn), growers have been encouraged to irrigate to 10 to 15 percent leaching. Although doing so with a CLF program will inevitably leach nutrients (especially N and K), which is costly from both an economic and environmental standpoint, this practice can be necessary to avoid a build-up of nutrients (fertilizer salts) in excess.

Some growers use lower fertilizer concentrations to reduce leaching. This approach is more efficient and economical, but there is a lower margin of error. For short-term crops (with a less than six-week production period), using high quality irrigation water and avoiding excess fertility, leaching may not be necessary. Regular monitoring of substrate EC will indicate when irrigating to leaching to reduce soluble salts is required.

Acidification is an important factor to consider because the pH of the growing substrate greatly affects the availability of various nutrients to the plant, especially micronutrients. An acidic solution (low pH) contains a higher concentration of H^+ ions in the solution. The most acidic solution has a pH of 0, while the most basic solution (high pH) has a pH of 14. A basic solution contains a high level of OH^- ions in solution. Between the two extremes of the pH scale is a neutral solution with a pH of 7.

Most greenhouse crops grow best in slightly acidic soilless substrates with a recommended pH of 5.6 to 6.2. Growers can monitor root zone pH and EC on-site. The same technique is used to sample media for pH as for EC, and the two are often measured simultaneously with a dual pH/EC meter. For more about pH and EC sampling, see *Commercial Greenhouse and Nursery Production: pH and Electrical Conductivity Measurements in Soilless Substrates* (Purdue Extension publication HO-237-W, available from the Purdue Extension Education Store, www.the-education-store.com).

Be aware of the effect each fertilizer formulation has on pH. Fertilizers that provide N primarily with ammonium (NH_4-N) will lower the pH because H^+

ions are released when plant roots absorb ammonia (NH_3^+) ions. Fertilizers that provide N primarily with nitrate (NO_3-N) will increase the pH because OH^- ions are released when plant roots absorb nitrate (NO_3^-) ions.

Therefore, it is possible to acidify your root zone with your fertilizer if you use one that is acidic in reaction (that is, a 21-7-7 fertilizer). Fertilizers can also be neutral (such as 20-0-20) or basic (such as 13-0-44). This information is available from the fertilizer manufacturer and is compiled in charts in references such as the *Ball Redbook*. Another helpful reference is "Understanding pH management and plant nutrition," www.firstrays.com/PDF/Part%203%20-%20Fertilizers.pdf

The alkalinity of irrigation water affects a grower's ability to adjust substrate pH. Alkalinity is determined by measuring the total amount of carbonates and bicarbonates in a solution. This means that the more total carbonates (carbonates, CO_3^- + bicarbonates, HCO_3^-) in the water, the more difficult it is to raise or lower the pH — high-carbonate water can act like liquid lime. Therefore, growers must add more acid to highly alkaline water to lower the pH compared to water with low alkalinity. Test your irrigation water to provide a value (usually given as parts per million (ppm) of equivalent calcium carbonate) to determine whether acid injection or acidifying fertilizers are necessary. Growers can submit samples to a lab or purchase test kits to use in house.

For more information about water alkalinity and fertilization, see *Commercial Greenhouse and Nursery Production: Alkalinity Management in Soilless Substrates* (Purdue Extension publication HO-242-W, available from the Education Store).

ALKCALC (extension.unh.edu/Agric/AGGHFL/Alkcalc.cfm), is a University of New Hampshire Cooperative Extension Web application that can assist you with calculating the amount of acid necessary to neutralize alkalinity. *Greenhouse Substrates and Fertilization* (www.ces.ncsu.edu/depts/hort/floriculture/plugs/ghsubfert.pdf) is a North Carolina State Extension publication that covers greenhouse fertilization and its relationship to substrate pH and alkalinity, with additional information about its relationship to substrates (media) not covered here.

New Hampshire Cooperative Extension also offers an online program called FERTCALC, (extension.unh.edu/Agric/AGGHFL/fertilizercalculator.cfm) that calculates the pounds of fertilizer needed for the size of your stock tank based on the ppm of N, P, or K you wish to deliver with your chosen injector and fertilizer.

Summary

When determining the best fertilizer program for your greenhouse operation, it is important for growers to **(1) sample irrigation water to determine its pH and alkalinity**. The test allows growers to determine if water acidification or acidifying fertilizers will be necessary. The importance of this will increase for long-term crops (such as poinsettia), as substrate buffering capacity decreases over time as the lime charge is leached out or exhausted. A water analysis will also indicate if the Ca level is adequate and indicate the concentration of the other nutrients present.

To make an informed fertilizer selection, growers must **(2) determine the nutritional needs of the crops being grown.** This includes fertility levels during different stages of growth and development, desirable pH range, and specific needs for additional micronutrients.

With this information, growers can **(3) determine if a water-soluble or CRF delivery system will be the most cost-effective program.** This will depend on the degree of mechanization at the facility, the expertise of the labor, the quantity of plant material grown, and the diversity of crops.

Once growers choose a fertilizer, it is wise to **(4) initiate a substrate monitoring program** and sample the substrate solution on a regular basis to track the pH and EC values. This tracking can help prevent any nutrient deficiency or toxicity symptoms due to improper fertilization. Growers should select a diagnostic lab or consultant in advance in case problems arise. Do not wait until there are problems to determine where to submit samples for analysis.

Experience will soon tell that no two growing seasons are alike, so growers should **(5) keep detailed records, about the crop grown, substrate used, temperature set points, light conditions, irrigation frequency, time to finish, and crop quality.** This information will indicate if fertilization adjustments for future crops are necessary and what kind of adjustments will improve results.

When using a new product or fertilization rate, it is important to test it on a small subset of the crop. Growers can also base new programs on manufacturer suggestions, but those should be used only as an initial guideline, as they may be based on different growing conditions. In addition, be aware that crop needs vary in different areas of the country, due to differences in water sources, media, and environmental growing conditions.

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