From Forest Nursery Notes, Summer 2008

40. Understanding plant nutrition: an introduction. Argo, B. and Fisher, P. Greenhouse Grower 26(1):34, 36, 38, 40, 42. 2008.

Jan. 2008 26(1): 34, 36, 38, 40, 42.

Understanding Plant Nutrition: An Introduction

In a year-long series, Argo and Fisher take a microscope to the details that can help growers make informed decisions on nutrients.

By BILL ARGO and PAUL FISHER

UNDERSTANDING nutrient management can help you prevent both crop quality and environmental problems. When nutrient imbalances arise, deficiencies or toxicities affect plant quality and profitability. The use of high fertilizer concentrations (300 to 400 ppm N) combined with heavy leaching is no longer environmentally acceptable because of the potential runoff of fertilizers, chemicals and water resources.

Our goal in this series is to help you make informed decisions about the nutritional program you use to grow the crop. We will explain how different management factors influence plant nutrition, how to develop an overall fertilizer strategy that minimizes risk and outline actions you can take to recognize and correct common nutritional problems.

Common nutritional problems found in container grown plants.

Nitrogen deficiency on vinca

Iron/manganese toxicity on marigolds

In this first article, we describe the essential nutrients for plant growth. These nutrients must be provided from some source (such as fertilizers, media components or irrigation water) for healthy plant growth. Future articles will expand on each of these nutrients, describing fertilizer sources, available forms such as water-soluble and controlled-release fertilizers, and explain how these nutrients interact with other production factors.

General Plant Nutrition

Plants are mostly water. If we place 100 pounds of healthy living plant material into a drying oven to remove all the water, we will have only about 10 pounds of dry plant material left. Most plants are about 90 percent water and 10 percent dry matter.

The 10 pounds of dried plant material is made up of the "organic" components of carbon, hydrogen, oxygen and a number of "inorganic" ions such as nitrogen, phosphorus and potassium. Plants obtain most of their organic carbon, hydrogen and oxygen from water and air.

If we take the 10 pounds of dry plant material and remove all the carbon, hydrogen and oxygen, only about 1 pound of ash remains. Therefore, print nutrition using fertilizers directly manages only about 1 percent of the plant by weight.

The plant ash is composed of plant nutrients that are essential for normal growth, metabolism and flowering. However, these nutrients are not all taken up at the same rate. Essential plant nutrients can be separated into two groups, termed macronutrients and micronutrients. Macronutrients are found at relatively high concentrations in the plant tissue and include nitrogen, phosphorus, potassium, calcium, magnesium and sulfur. Micronutrients are found at much lower concentrations in the tissue than macronutrients and include iron, manganese, zinc, copper, boron and molybdenum (Table 1).

These 12 essential plant nutrients are commonly provided by various fertilizer sources applied during crop production. There are several other


Phosphorus deficiency on pansy

nutrients that are considered as essential for normal growth, including sodium, chloride, nickel and possibly chromium. However, these later four essential plant nutrients are often found as contaminants in a number of different fertilizer sources, growing media components or irrigation water. It is not normally necessary to apply extra of these nutrients.

Nutrient Uptake By The Plant

Plants can only take up nutrients that are dissolved in the soil solution. When fertilizer salts dissolve in water, they break apart into positively charged cations or negatively charged anions. For example, potassium nitrate (KNO_3) dissolves in water into a positive K^+ cation and a negative NO_3^- anion. The same chemical reaction occurs when fertilizers are mixed with water in a stock tank or when they are applied as a dry granular fertilizer to the soil and are watered in.

Plant roots cannot maintain an overall positive or negative charge like the electrodes in a battery, so they interact with and change the soil solution in order to balance the uptake of cations and anions. When a cation (like potassium, K+) is taken up by the plant, its charge can be balanced either by the plant also taking up an anion (like nitrate, NO_3-) or by exuding another cation (like an acid hydrogen (H+) ion). When an anion (like nitrate) is taken up by the plant, its charge can be balanced by taking up a cation (like potassium) or by releasing another anion (like a basic hydroxide (OH-) or bicarbonate (HCO_3-) ion). This "charge balance" is one way that plant roots can make the soil pH more acidic or basic.

Plants use energy to selectively and actively take nutrients up from the soil solution. If energy is limiting (such as under low light conditions), then nutrient uptake can be reduced. Therefore, providing plants with adequate light energy is important for having healthy nutrient uptake. Plant roots also need air to "burn energy" in active nutrient uptake. A waterlogged soil can reduce nutrient uptake by starving roots of air, and can also lead to root disease.

Water uptake also helps drive nutrition. For example, the rate of uptake of calcium and boron is largely based on water moving into the plant for transpiration (evaporation of water from leaves). Any factor that limits water uptake will limit uptake of calcium and boron. Growing plants in high air humidity or excessively dry soil both reduce uptake of water and therefore nutrients.

Plants do not passively take up nutrients at the same concentration as found in the soil solution, but within limits they can actively take up the ions they need for growth. This helps us in growing crops — nutrient concentration in the soil solution does not have to exactly match the nutrient levels in the plant. As long as the nutrients are available within an acceptable range, meaning that they are present in sufficient concentration and are in a soluble form, plants can remain healthy.

Table 1: Essential Fertilizer Nutrients, Chemical Abbreviation, And Typical Concentrations Found In Dried Plant Material

(Percent of leaf dry weight) 1 percent is equivalent to 10,000 ppm.

Nutrients	Form Absorbed	Conc. In Tissue	Primary Role In The Plant	Mobility In The Plant
Macronutrients				
Nitrogen (N)	NO_3-, NH_4+	4.0%	A component of chlorophyll, nucleic acids, proteins and enzymes	High
Phosphorus (P)	H_2PO_4-, HPO_{42}-	0.5%	Required to store and transport energy	High
Potassium (K)	K+	4.0%	Acts as a osmotic regulator in water absorption and loss by the plant	High
Calcium (Ca)	Ca_{2}+	1.0%	Cell structure, secondary plant hormone	Low
Magnesium (Mg)	Mg_{2}+	0.5%	Central ion in the chlorophyll molecule	High
Sulfur (S)	SO_{42}-	0.5%	A component of nucleic acids and proteins	Low to moderate
Micronutrients				
Iron (Fe)	Fe_{2}+	200 ppm	Required for chlorophyll synthesis and energy transferring pathways	Low
Manganese (Mn)	Mn_{2}+	200 ppm	Required for chlorophyll production and energy transferring pathways	Low
Zinc (Zn)	Zn_{2}+	30 ppm	Activates enzymes	Low
Copper (Cu)	Cu_{2}+	10 ppm	Involved in respiration and oxidation/reduction reactions	Low
Boron (Bo)	$H2BO_3$-	60 ppm	Essential for cell division and differentiation of young tissue	Low
Molybdenum (Mo)	MoO_4-	1 ppm	Involved in nitrogen metabolism	Low
Nickel (Ni)	Ni_{2}+	?	Nitrogen fixation	?
Others				
Sodium (Na)	Na+	500 ppm	Osmotic regulator	High
Chloride (Cl)	Cl-	0.1%	Required for photosynthesis	High

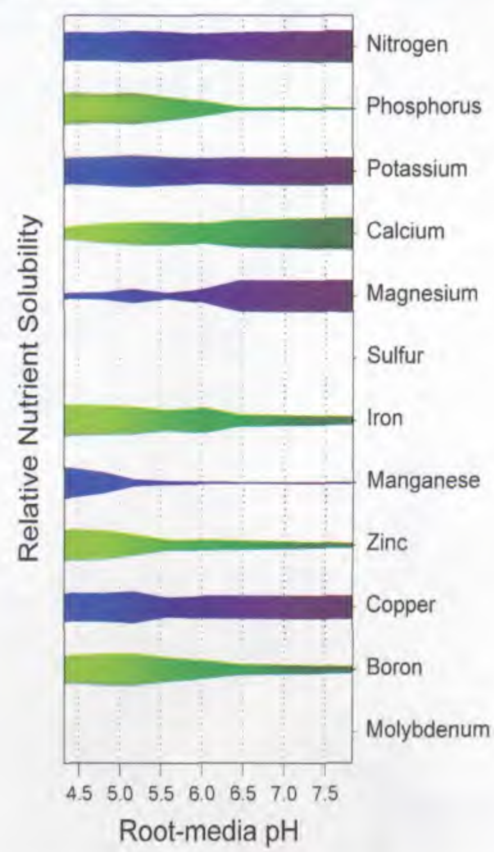
Cobalt and silicon are also sometimes listed as beneficial nutrients but little information exists about their absolute requirements in floricultural crops.

pH Effects On Nutrient Solubility, Availability And Uptake

Because plants can only take up nutrients that are dissolved in the growing medium, and pH affects nutrient solubility (Figure 2), then the media pH affects nutrient management. For example, iron solubility (and uptake) generally decreases with increasing pH because iron precipitates out of the soil solution at higher pH levels. Phosphorus also precipitates out of solution at higher pH levels. Phosphorus uptake will be further reduced above pH 7.2 because any phosphorus left in solution is converted into a less available form. Nitrogen uptake can be indirectly affected by media pH because low pH decreases nitrification (conversion of ammoniacal nitrogen to nitrate nitrogen) or the conversion of urea to ammoniacal nitrogen.

Plant species differ in their ability to take up nutrients at a given pH level. For example, geraniums and African marigolds are very efficient at taking up soluble iron and manganese from the soil solution. The most common nutritional problems with these "iron-efficient" crops occur when too much iron and manganese is taken up into the plant, causing a toxicity. In comparison, calibrachoa and petunias are very "iron inefficient," and so at high pH they often cannot take up enough iron into the plant, resulting in a deficiency.

Figure 2. Relative solubility of nutrients at different pH levels in one peat-based media (graph based on research by John Peterson).



Growers have learned to manipulate the acceptable pH range for these crops in order to optimize iron nutrition. For example, the acceptable pH range for growing iron-efficient crops tends to be higher (6.0 to 6.6) than the "average" crop in order to limit iron and manganese solubility (lower solubility, less uptake). In comparison, the acceptable pH range for growing iron-inefficient crops is lower (5.4 to 6.2) to maximize iron solubility (more solubility, more uptake). It can be helpful to understand different plant needs, rather than taking a "one-size-fits-all" approach to fertilizing all crop species.

Providing Essential Nutrients

In the broadest sense, a fertilizer is any material that supplies one or more essential nutrients to the plant. Fertilizers can dissolve easily, such as materials used to make water-soluble fertilizer (for example, ammonium nitrate or calcium nitrate) or they can have limited solubility (gypsum or limestone) and are typically added to the root medium in a granular form prior to planting. Resin-coated fertilizers are soluble fertilizers that are encapsulated to control the release over time.

Components that are used to make the root medium can also supply nutrients to the plant. For example, bark or coir may contain potassium, calcium and some phosphorus. Vermiculite can be a source of magnesium and possibly potassium. Rockwool may contain sulfur. Even peat, after it is limed, can be a source of calcium and/or magnesium, depending on the lime source.

Irrigation water can be another source of essential nutrients. In general, irrigation water does not contain nitrogen, phosphorus or potassium at levels that are high enough to be considered a fertilizer source. However, acidification of irrigation water with a strong mineral acid (sulfuric, phosphoric or nitric acid) to reduce alkalinity concentrations can change the irrigation water into a significant source of nitrogen, phosphorous or sulfur, depending on the acid source. In addition, irrigation water can also be a significant source of calcium, magnesium, sulfur, boron, sodium and chloride.

Successful nutrient management is not complicated. As a grower, you need to ensure that all essential nutrients are supplied in an acceptable amount through either pre-plant or post-plant fertilizers, and that other stresses such as root disease or an excessively high pH do not limit nutrient uptake. GG

About the authors: Bill Argo **(bargo@blackmoreco.com)** is technical manager at the Blackmore Company and Paul Fisher (**pfisher@ufl.edu**) is an associate professor and Extension specialist in the Environmental Horticulture Department at the University of Florida.