PLANT QUIRKINESS AND OTHER WEIRD SCIENCE …

CONSULTING THE NEAREST PLANT NUTRITIONIST… REALLY? (PART 1)

Adapted from the Master Gardener Manual

There is a lot of discussion these days about **proper nutrition** and how without it our health is affected from mild to life threatening conditions. Sadly, the more we learn the more we understand this to be true. And why would this NOT be true for plants? Well, it is and even more so. Plants are unique in that they make their own food, something animals cannot do. So, this concept is key to understanding why the availability of nutrients, in that pot, are so crucial to the health of our trees. And just like us nutrient deficiencies in plants present themselves in all sorts of ways, but more on that later. Let's start the discussion of various nutrients, why they are needed and how their absence affects the plant.

Seventeen elements are considered essential nutrients for plant growth, and 14 of these elements come from the soil (see table at right) If there is a deficiency of any essential element, plants cannot complete their vegetative and reproductive cycles. Some of these nutrients combine to form compounds that make up cells and enzymes. Other nutrients are important for certain chemical processes. And while some of these we understand, others we are still figuring out. The simple concept of "most limiting nutrient" is thought provoking to say the least especially when we keep in mind that WE are growing plants in a pot. So, we can have the best and the worst situations simply by either giving our plants what they need, ignoring them all together, or just sort of doing something and hope for the best. The latter actually has the potential to be the worst because trouble shooting what is "wrong with a plant" becomes difficult to say the least.

So, let's start with the Big N for **Nitrogen**: an essential building block for plant proteins. It is an integral part of chlorophyll and is a component of amino acids, nucleic acids and coenzymes (yes, your plants have those too). So right away we know, oh wow, what's going to happen without chlorophyll? Nitrogen is taken up by plants as nitrate and ammonium. These compounds are present in the soil by the addition of inorganic fertilizer or the conversion of organic matter into those compounds or by microbial action called nitrogen fixation (wisteria). When N immobilization happens, it is available for later use. When it is just "free" in the soil, that is there is nothing to bind it, it can easily leach out. This is why soil components not only play an important function for drainage and O_2 availability, but are directly related to nutrition [future article].

N Deficiency symptoms:

Slow growth and stunting; yellow-green color leaves; "firing" of tips and margins of leaves: Yellowing begins with MATURE leaves.

Fertilizer sources: the first number refers to the pure Nitrogen per 100 pounds of fertilizer.
Calcium nitrate 15-0-0
Potassium nitrate 13-0-14
Sodium nitrate 16-0-0
Ammonium nitrate 34-0-0
or sulfate 21-0-0
Diammonium phosphate 21-53-0
Urea 45-0-0

Do you know what Soil COLOR means?

Black & Brown: very good to good organic matter, well drained

Red: low organic, well drained, color is due to iron content!

Gray: low, poor draining, poor aeration

Yellow: Low organic, well drained.

Plant Nutrient/Source

1. **Carbon/air**
2. **Oxygen/ air & water**
3. **Hydrogen/ water**

Soil/Primary Nutrient

4. Nitrogen

5. Phosphorus

6. Potassium

Soil/Secondary Nutrient

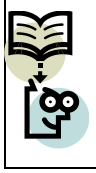
7. Calcium

8. Magnesium

9. Sulfur

Soil/Micronutrients

Boron, Chlorine, Copper, Iron, Manganese, Molybdenum, Nickel, Zinc = 17!



PLANT QUIRKINESS AND OTHER WEIRD SCIENCE …

CONSULTING THE NEAREST PLANT NUTRITIONIST… REALLY? (PART 2)

Adapted from the Master Gardener Manual

There is a lot of discussion these days about **proper nutrition** and how without it our health is affected. And it is even more so for plants. They are unique in that they make their own food, something animals cannot do. So this concept is key to understanding why the availability of nutrients, in that pot, is important. And just like us nutrient deficiencies in plants present themselves in all sorts of ways. (See part one for more intro and all about Nitrogen).

The second nutrient of the big 3 is **Phosphorus (P).** Plants use phosphorus to store and transfer energy throughout the plant. It also uses P to form the nucleic acids of DNA and RNA. Phosphorus promotes early plant growth and root formation by playing a role in the division and organization of all the many types of cells. Including P in your Fall fertilizer applications is very important for healthy roots going into winter and a strong "wake-up" in the spring. Phosphorus is adsorbed by plants in different forms (3) depending on the soil pH. The mobility of Phosphorus is low anyway and deficiencies are common in cool, wet soils. For the best uptake phosphorus should be incorporated into the soil. Deficiency symptoms include:

- Slow growth (stunting)
- Purplish color of foliage in some plants
- Dark green color with tips of leaves dying
- Delayed maturity
- Poor flowers, fruit or seed formation

The second number on the bag refers to the percentage of $P_2 0_5$ by weight. Such as Superphosphate (0-20-0). This nutrient is important for all perennial plants since they continue from season to season.

The last of the big three is **Potassium (K)** And WOW what an amazing nutrient that we don't usually talk about. Potassium is crucial for movement of sugars and the formation of starches (energy and stored energy). It is also important for the efficient use of water as it plays a role in the opening/closing of the stomata (leaf pores). It ALSO increases a plants resistance to diseases and assists in both enzyme activation AND photosynthesis. And if that is not enough, it improves winter hardiness and affects the size and quality of fruit. So it is obviously one of the BIG-Three for lots of very good reasons and SO important for container growing which is what bonsai is all about. Plants take up Potassium in the form of potassium ions (K+). It is relatively immobile in soils but can leach in sandy soils. Potassium fertilizer should also be incorporated into the soil. Deficiency symptoms include:

- Tips & margins "burn"; starts on mature leaves; lower leaves turn yellow
- Plants are weak; slow growth
- Small or no fruits

The third number on the bag refers to the percentage of K_2O by weight. Such as 12-10-20; forms include Potassium nitrate, P-chloride or P-sulfate.

So, following the 3 Primary nutrients comes the SECONDARY nutrients, also 3 in number, and we start our discussion with...

Calcium (Ca). We all know how important Ca is to our bodies; as we grow and throughout our lives. And so, it is for plants and in very similar ways. Calcium provides the building block (calcium pectate) for cell walls and membranes and MUST be present to form new cells. It is also present in important plant carbohydrates, e.g. starch & cellulose. Calcium promotes vigor and rigidity as well as being important to healthy root and stem growth. Plants adsorb Ca in the form of the calcium ion (Ca+).

Deficiency symptoms include:

- "Tip burn" of young leaves
- Terminal bud dieback; root tips are also affected
- Stunted root growth
- Premature shedding of blossoms and buds
- Weakened stems

Some examples of sources specific for Ca: Gypsum, Superphospate and Calcium nitrate.

Next up is **Magnesium (Mg).** The list of benefits may be short but the importance is obvious. Magnesium is a component of the chlorophyll molecule. So without it NO photosynthesis. And if not in high enough amounts, faulty photosynthesis with obvious deficiency. Mg also serves as an activator for many plant enzymes required for sugar metabolism and movement through the plant, as well as various growth processes. Plants take up magnesium as the ion, Mg^{+2}.

Deficiency symptoms include:

- Interveinal chlorosis (yellowing) of older leaves
- Curling of leaves upward along margins
- Marginal yellowing with green along midrib
- Most likely occurs on acid, sandy soils
- Can be induced by high K applications (must be balanced).

Fertilizer sources for Mg are Dolomitic lime and Magnesium sulfate (MgSO4: Epsom salts)

Below: Satsuki azalea; lighter leaves are yellow with red blotches indicating Mg deficiency.

The last of the secondary nutrients is…

Sulfur (S). It is part of three critical amino acids that play an essential role in protein synthesis. (Sulfur also gives garlic & onions their odor.) Plants take up sulfur in the form of sulfate ions (SO_4^{-2}). Sulfur is susceptible to leaching, and sulfur deficiencies can occur in sandy soils low in organic matter.

Deficiencies symptoms include:

- Young leaves are light green to yellowish. In some plants older leaves are affected.
- Small spindly plants
- Retarded growth and/or maturity

Fertilizer sources: Elemental sulfur, Potassium sulfate, Ammonium and Iron sulfate.

Part 3, Zinc and beyond

PLANT QUIRKINESS AND OTHER WEIRD SCIENCE …

CONSULTING THE NEAREST PLANT NUTRITIONIST… REALLY? (PART 3)

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So far we have focused on the primary (macronutrients) and secondary nutrients.
Finally, we will discuss the Micronutrients. It does not mean that they are less important but only that they are needed in MICRO-quantities. They are still very important to the plant, with many functions. For example, we jump to iron deficiency when we see chlorosis, however it's much more complicated as you will see as you read on.

Zinc (Zn) and Beyond.

Zinc is an essential component of several enzymes in plants. It controls the synthesis of an important plant growth regulator (indoleacetic acid), and involved in the production of chlorophyll and protein. Zinc is taken up as the Zinc ion (Zn^{+2}). Zinc deficiencies are more likely to occur in soils low in organic matter. High soil pH (alkaline) causes the solubility of zinc to decrease and becomes less available. Zinc and phosphorus have antagonistic effects in the soil. So soils high in phosphorus can cause Zinc to become less available. Wet and cold soil conditions also promotes Zinc deficiency because of slow root growth and slow release of zinc from organic matter.

Deficiency Symptoms:

- Shortened stem length/rosetting of terminal leaves
- Reduced fruit bud formation
- Dieback of twigs after first year
- Mottled leaves and interveinal chlorosis

Examples of fertilizer sources are, Zinc sulfate, Zinc oxide, Zinc chloride, and chelating agents such as EDTA help make certain nutrients more available to plants.

Iron (Fe): Iron is taken up by plants as ferrous ion (Fe^{+2}). Iron is required for the formation of chlorophyll in plant cells. It serves as an activator for processes such as respiration, photosynthesis and symbiotic nitrogen fixation. Ornamentals and certain trees (and turf) are especially susceptible to iron deficiency. Symptoms of iron deficiency occurs in soils with pH greater than 7.0. Specific needs can be determined visually (and soil test and tissue test).

Deficiency Symptoms:

- Interveinal chlorosis of young leaves. Veins remain green except in severe cases.*
- Twig dieback
- In severe cases, death of limbs

Examples of fertilizer sources include, ferrous sulfate and ferrous ammonium sulfate with a chelating agent (EDTA) also helpful.

Manganese (Mn):

Manganese serves as an activator of enzymes used in plant growth. It also assists iron in chlorophyll formation. It is picked up by the plant in the form of manganous ion (Mn^{+2}). Manganese deficiency can occur in soils with a pH of 8. When soil is very acid (i.e. 4.5) manganese can increase to toxic levels.
Deficiency Symptoms:

- Interveinal chlorosis of young leaves
- Gradation of pale green color with darker color next to veins.

*No sharp distinction between veins and interveinal areas as with iron deficiency.
Examples of fertilizer sources include Manganous oxide and sulfate, and Manganese oxide.

Copper (Cu): Copper is an activator of several enzymes. It may play a role in the production of vitamin A. Deficiency interferes with protein synthesis which can have a major impact on plant growth and development.

Deficiency Symptoms:

- Stunted growth
- Dieback of terminal shoots, especially in trees
- Poor pigmentation
- Wilting and eventual death of leaf tips.

Fertilizer sources include Copper sulfate, Cupric and Cuprous oxide and chelating agents (EDTA) can be helpful.

Boron (B): Boron regulates the metabolism of carbohydrates in plants. It is ESSENTIAL for the cells that divide (meristem cells) to be able to differentiate into specific tissues (stems, leaves, etc.). With boron deficiency, plant cells may continue to divide, but structural parts are not differentiated and tissue growth/development stops. Boron is taken up as the borate ion (BO_3^-). Plants differ in their boron needs. Boron can be limiting in soils low in organic matter, but do not over apply as toxicity can occur.

Deficiency Symptoms:

- Death of terminal buds, causing lateral buds to develop and producing a "witches broom".
- Thickened, curled, wilted and chlorotic leaves.
- Soft or necrotic spots in fruit
- Reduced flowering or failed pollination

Fertilizer sources include granular borax, and Solubor.

Molybdenum (Mo):

Molybdenum is taken up as molybdate ions (MoO_4^-). It is an ESSENTIAL micronutrient that enables plants to make use of nitrogen. Without it, plants cannot transform nitrate nitrogen to amino acids and some species (legumes) cannot fix atmospheric nitrogen. A molybdenum deficiency can occur in acidic (< pH6), sandy soils. Soil applications as well as foliar applications are effective.

Deficiency Symptoms:

- Stunting, lack of vigor. Similar to nitrogen deficiency due to its key role with N use by plants.
- Marginal scorching and cupping or rolling of leaves.

Fertilizer sources include Sodium and Ammonium molybdate.

Chlorine (Cl): Chlorine is required in the photosynthetic reactions. Deficiency in nature is rare due to its universal presence in nature. However inorganic, artificial soils are suspect. Plants take up chlorine as the chloride ion (Cl^-).

Deficiency Symptoms:

- Wilting followed by chlorosis (yellowing).
- Excessive branching of lateral roots.
- Bronzing of leaves

Fertilizer sources include Calcium, ammonium, and potassium chloride.

Nickel (Ni): Nickel is taken up as Ni^{+2}. Nickel is a component of the enzyme urease, which is needed to prevent toxic accumulations of urea, a natural by-product of nitrogen metabolism in plants. It is also essential for seed development. High levels should be avoided as it can induce zinc or iron deficiency by competing for uptake.

Deficiency Symptoms: Interestingly, nickel deficiency is only reported for plants growing under hydroponic conditions. Nickel deficiency causes urea accumulation in the leaf tips which causes necrosis.

Fertilizer sources: There are no known sources of nickel fertilizer for soil.

AND to bring it altogether:

Soil Organic Matter, or humus, is the partially decomposed residue of plants, animals and other organisms and refers to all organic material in soil. Organic matter improves soil structure by acting as a bonding agent that holds soil particles together as aggregates. Good soil structure promotes water movement and root penetration while reducing soil crusting and erosion.

Organic matter provides plant nutrients, mainly nitrogen and sulfur and smaller amounts of phosphorus. Organic matter is a primary reservoir for available forms of micronutrients (mainly zinc and boron).

Soil organic matter also improves the cation exchange capacity (CEC), its ability to hold positively charged molecules, or ions, of mineral nutrients. CEC is a measure of the total amount of exchangeable cations (positively charged ions) a soil can absorb. Nutrient cations in the soil include calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^+), sodium (Na^{+}), and hydrogen (H^+). The cations in the soil are in equilibrium with those in the water in the soil. As plants remove nutrients (cations) from the soil solution, they are replenished from the adsorbed (soil) cations, which are then available for plant uptake. The higher the CEC the more cations a soil can retain.

Soil	CEC
Sand	2-5
Sandy Loam	5-12
Loams	10-18
Silt/silt-clay loam	15-30
Clay/clay loams	25-40