Plant Nutrition
Part 1: Understanding N-P-K

The first thing to know is that gardeners never provide food for their plants. Plants make their own food from the raw materials (nutrients) in the soil and air using energy from the sun. When we fertilize our plants, we are providing them with some of the raw materials or minerals they need to carry out photosynthesis – the process by which they make their own food. No matter what the label says, it is not plant food. Semantics aside, just what does a plant need to make its food.

Depending on which research you read, there are 16-21 essential plant nutrients. How is an element determined to be essential? 1) a plant cannot complete its life cycle without the element, 2) no other element can perform the function of the element, 3) the element is directly involved in plant nutrition. The number varies between 16 and 21 because there are some elements that have been shown to be essential to some plants but not to others.

Some elements are needed in large amounts and are termed macronutrients. Others are required in smaller amounts than macronutrients but still in fairly large quantities and are termed secondary macronutrients. Others are required in very small amounts and are termed micronutrients.

As gardeners, we often supply these nutrients to our plants in the form of fertilizers. In this series of articles, when I use the term fertilizer, I'm referring to both chemical and organic fertilizers. When I want to address chemical or organic fertilizers specifically, I will refer to them as such. In the U.S., all soil amendments or materials that are sold as plant fertilizers must have an analysis, and have the nitrogen, phosphorous and potassium content on the label. This content must be in the form of three numbers with dashes in between that represent N-P-K. The first number represents the percentage of nitrogen (N) in the fertilizer by weight, the second represents the percentage of phosphate (P_2O_5) in the fertilizer and the third represents the percentage of potash or potassium (K_2O) in the fertilizer.

A "balanced" fertilizer generally refers to one that has equal amounts of N-P-K, a 1-1-1 ratio. Therefore, a balanced commercially available fertilizer would be something like 8-8-8, 13-13-13, or 20-20-20. This is "balanced" in the concept of ratio but doesn't apply in the sense of a plant's needs. The historical theory was that different plants have different nutritional needs so no one level of available nutrients is right for all plants. However, research over the past couple of decades indicates that all plants have basically the same nutritional requirements, at least as far as the

Element	Uptake Form	Source	Element	Uptake Form	Source
CARBON	CO_2	Air & Water	boron	H_3BO_3, $H_2BO_3^-$, HBO_3^{2-}	Soil
HYDROGEN	H_2O	Air & Water	chlorine	Cl^-	Soil
OXYGEN	H_2O	Air & Water	copper	Cu^{2+}	Soil
NITROGEN	NO_3^-, NH_4^+	Soil	iron	Fe^{2+}	Soil
PHOSPHORUS	$H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}	Soil	manganese	Mn^{2+}	Soil
POTASSIUM	K^+	Soil	zinc	Zn^{2+}	Soil
Sulfur	SO_4^{2-}	Soil	molybdenum	MoO_4^{2-}	Soil
Calcium	Ca^{2+}	Soil	nickel, silicon	Ni^+, Si^+	Soil
Magnesium	Mg^{2+}	Soil	sodium, cobalt	Na^+, Co^{2+}	Soil
			vanadium	V_2O_5	Soil

Table 1: List of 20 essential plant nutrients, the chemical form which plants can uptake, and the common source of these nutrients. Nutrients in all caps are macronutrients, ones with the first letter capitalized are secondary macronutrients, those in all lower case are micronutrients.

macronutrients are concerned. Plants can carry out all biological functions and complete their life cycle using the same proportion of nitrogen, phosphorous, and potassium. This proportion translates to a fertilizer N-P-K ratio of 3-1-2. This would mean that using a "balanced" fertilizer (e.g. 13-13-13) would be adding excess phosphorous and potassium that the plant doesn't really need. This is also a waste of money, resources and a possible source of environmental pollution.

Why might this be a problem? Nitrogen is lost quite quickly from soil because it is so water soluble. Potassium is lost more slowly and phosphorus much more slowly. If you add enough "balanced" fertilizer to provide the amount of nitrogen required for optimal growth, your phosphate and potassium levels will accumulate over time. Excessive soil phosphorus reduces the plant's ability to take up required micronutrients, particularly iron and zinc, even when soil tests show there are adequate amounts of those nutrients in the soil. As a result, symptoms of phosphorus toxicity when they do occur are actually symptoms of iron and/or zinc deficiency. Healthy levels of P in soil ranges from 25 to 50 ppm. Healthy levels of potassium in soil range from 40 to 80 ppm. Excess potassium also interferes with nutrient uptake and can induce deficiencies of other nutrients, particularly nitrogen, calcium, and magnesium. A soil test can provide gardeners with accurate concentrations of the available nutrients in the growing medium.

Unless the label indicates otherwise, chemical fertilizers provide only nitrogen, phosphorus and potassium. If other elements are provided, they are listed on the label as well. If you need to add secondary macronutrients or micronutrients, you will need to obtain chemical fertilizers with these elements included. Many organic fertilizers, on the other hand, provide many of the secondary macronutrients and micronutrients depending on their composition. However, this information may not be listed on the label because the manufacturer is only required to list the N-P-K percentages.

More about chemical versus organic fertilizers in the next installment.

~Dr. Joe Willis

Selected References:

Mahler, R. 2004. Nutrients Plants Require for Growth. Univ. of Idaho. pdf version

Nachmansohn, J. 2013. Do Plants Require Nutrients in Similar Proportions? Bachelor's Thesis

Element	% Dry Weight		Element	% Dry Weight
CARBON	45		chlorine	0.01
HYDROGEN	45		iron	0.01
OXYGEN	6		manganese	0.005
NITROGEN	1.5		boron	0.002
PHOSPHORUS	0.2		zinc	0.002
POTASSIUM	1.0		copper	0.0006
Calcium	0.5		molybdenum	0.00001
Magnesium	0.2		nickel, cobalt	??
Sulfur	0.1		sodium, silicon	??
			vanadium	??

Table 2: The average dry weight percentage of the essential plant elements found in living plants.