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Nutrients Plants Require for Growth

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Plants require 17 essential elements for growth: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn). These 17 essential elements, also called nutrients, are often split into three groups (fig. 1). The first group is the three macronutrients that plants can obtain from water, air, or both— carbon (C), hydrogen (H) and oxygen (O). The soil does not need to provide these nutrients, so they are not sold as fertilizers.

The other 14 essential elements are split into two groups—soil-derived macronutrients and soil-derived micronutrients. This split is based on the actual amount of nutrient required for adequate plant growth. The soil-derived macronutrients are nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), and magnesium (Mg). The soil-derived micronutrients are boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Zn).

Soil-derived macronutrients

The six soil-derived macronutrients are present in plants at relatively high concentrations—normally exceeding 0.1 percent of a plant's total dry weight. This translates into a minimum need of 20 pounds of each macronutrient per acre each year.

Nitrogen—Plants require large amounts of nitrogen for adequate growth. Plants take up N from the soil as NH_4^+ (ammonium) or NO_3^- (nitrate) (table 1). A typical plant contains 1.5 percent nitrogen on a dry weight basis, but this can range from 0.5 percent for a woody plant to up to 5.0 percent for a legume.

Nitrogen is a component of amino acids, which link together to form proteins. Nitrogen is also a component of protoplasts and enzymes (table 2). Once in the plant, N is mobile—it can move from older plant tissue to new tissue. Consequently, if N is deficient in plants, the older leaves often turn yellow-green or yellow first. As the deficiency progresses the entire plant yellows.

The major natural source of N in soils is organic matter (table 3). Nitrogen is the nutrient generally most limiting in agronomic, horticultural, and home and garden situations in the Pacific Northwest.

Phosphorus—A typical plant contains 0.2 percent P on a dry weight basis (table 1); however, depending on the plant species this value can range from

Table 1. Uptake form and typical plant content of the 14 soil-derived essential nutrients.

Essential nutrient	Uptake form	Plant content (dry weight) Average	Range
		%	
Nitrogen	NO_3^- ,NH_4^+	1.5	0.5-5.0
Phosphorus	$H_2PO_4^-$,HPO_4^{2-}, PO_4^{3-}	0.2	0.1-0.5
Potassium	K^+	1.0	0.5-5.0
Sulfur	SO_4^{2-}	0.1	0.05-0.5
Calcium	Ca^{2+}	0.5	0.5-5.0
Magnesium	Mg^{2+}	0.2	0.1-1.0
		ppm	
Boron	H_3BO_3, $H_2BO_3^-$ HBO_3^{2-}	20	2-100
Chlorine	Cl^-	100	80-10,000
Copper	Cu^{2+}	6	2-20
Iron	Fe^{2+}	100	50-1,000
Manganese	Mn^{2+}	50	20-200
Molybdenum	MoO_4^{2-}	0.1	0.05-10
Nickel	Ni^+	<<<0.0001	?
Zinc	Zn^{2+}	20	10-100

Table 2. Function and mobility within plant tissue of the 14 soil-derived essential nutrients for plant growth.

Essential nutrient	Mobility in plant	Function of plant
Nitrogen	good	proteins, protoplasts, enzymes
Phosphorus	good	ATP,ADP,basal metabolism
Potassium	good	water relations, energy relations, cold hardiness
Sulfur	fair/good	proteins, protoplasts, enzymes
Calcium	very poor	cell structure, cell division, cell elongation
Magnesium	good	chlorophyll, enzymes
Boron	very poor	sugar translocation, cell development, growth regulators
Chlorine	good	photosynthesis
Copper	poor	enzyme activation
Iron	poor	chlorophyll synthesis, metabolism, enzyme activation
Manganese	poor	Hill reaction-photosystem II, enzyme activation
Molybdenum	poor	nitrogen fixation, nitrogen use
Nickel	unknown	iron metablism
Zinc	poor	protein breakdown, enzyme activation

0.1 to 0.5 percent. Plants take up P as an anion (ion with a negative charge)—$H_2PO_4^-$,HPO_4^{2-}, or PO_4^{3-}. The actual form of the anion is dependent on soil pH.

Phosphorus is mobile within plants and can travel from old plant tissue to new plant tissue on demand (table 2). P deficiency in plants is hard to diagnose by eye because deficiency symptoms are not commonly visible. A phosphorus-deficient plant is likely to be dark green but have stunted growth. Phosphorus is essential for ADP, AMP, and basal metabolism in plants.

Phosphorus deficiencies in soils can be diagnosed with a soil test. Phosphorus availability is related to soil pH. In general, soils with pH values between 5.5 and 6.5 have adequate levels of plant available

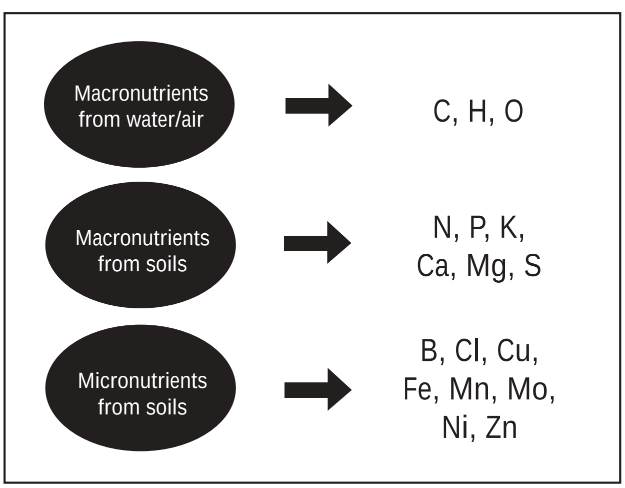

Figure 1. There are 17 essential plant nutrients required for plant growth.

P. However, P availability is much lower in soils with pH values below 5.5 or above 6.5 (table 3).

Potassium—Plants typically contain 1.0 percent K on a dry weight basis (table 1). This value can range from 0.5 to 5.0 percent depending on the plant species. Potassium is held by the clays in soils and is taken up by plants as K^+.

Potassium is mobile in plants (table 2). Potassium deficiencies can be diagnosed by looking at the older plant tissue. Deficiencies appear along the outer margins of older leaves as streaks or spots of yellow (mild deficiencies) or brown (severe deficiencies). Potassium plays several roles in plants. It is important for water and energy relationships and has been linked to improved cold hardiness.

Soils in the Pacific Northwest generally contain adequate amounts of potassium (table 3). Deficiencies are isolated to soils where alfalfa and potatoes have been grown for several decades.

Sulfur—Plants take up S from the soil as SO_4^{2-}, (sulfate) (table 1). Because the plant-available form of S is negatively charged, it can be leached out of plant root zones with precipitation or irrigation. A typical plant contains 0.1 percent S on a dry weight basis, but this can range from 0.05 to 0.5 percent S.

Sulfur, like N, is a component of some amino acids that link together to form proteins. Sulfur is also a component of plant protoplasts and enzymes (table 2). Once in the plant, sulfur has only fair mobility. New plant tissue will show a sulfur deficiency first, often turning yellow-green or yellow.

Sulfur is widely deficient in soils in the Pacific Northwest (table 3). Low levels of soil organic matter or excessive watering can produce deficiencies.

Calcium—A typical plant contains 0.5 percent Ca on a dry weight basis (table 1). However, woody plants may contain up to 5.0 percent Ca. Plants take up calcium as Ca^{2+}. Calcium is required for cell division, cell elongation, and cell structure (table 2). Since Ca is not mobile in plants, calcium deficiency symptoms appear at their growing tips.

Soils in the Pacific Northwest contain plenty of calcium (table 3). Consequently, calcium deficiencies in plants grown under agronomic, horticultural, or lawn and garden situations have never been observed in the region.

Magnesium—Plants typically contain 0.2 percent Mg on a dry weight basis (table 1). This value can range from 0.1 to 1.0 percent depending on the plant species. Magnesium is held by the clays and organic matter in soils and is taken up by plants as Mg^{2+}.

Magnesium is mobile in plants (table 2). Magnesium deficiencies can be diagnosed by looking at the older plant tissue. Deficiencies appear as “interveinal chlorosis” in older leaves—the veins of the leaves stay dark green while the areas between the veins appear yellow-green, yellow, or white. Magnesium is a component of chlorophyll.

Most soils in the Pacific Northwest contain adequate amounts of Mg for plant growth (table 3). Magnesium deficiencies are isolated to soils with pH values below 5.2.

Soil-derived micronutrients

The eight soil-derived micronutrients are present in plants at relatively low concentrations—often just a few parts per million (ppm) of a plant’s total dry weight. Even though plants require only small amounts of micronutrients, a deficiency will harm them as much as a lack of N or P. Plants need 0.5 to 2 pounds per acre of most micronutrients per year.

Boron—Plants require about 20 ppm of B (table 1). Boron is taken up by plants as an uncharged molecule (H_3BO_3) or as an anion ($H_2BO_3^-$, HBO_3^{2-}). Since the plant-available form of B is not positively charged it can be leached out of soils and is often lost from the plant root zone by overirrigation or high precipitation.

Boron promotes the translocation of sugars and cell development and is believed to be important for growth regulators (table 2). Boron is not mobile in plants. Consequently, B deficiency symptoms most often appear on the growing tip of the plant. In B-deficient plants, the growing tip is often deformed.

Soils that contain less than 1.5 percent organic matter or are overirrigated tend to be deficient in B (table 3). Boron deficiencies are common on agronomic crops, in fruit trees, and in urban gardens. For additional information on boron, see University of Idaho CIS 1085, *Boron in Idaho*.

Chlorine—Plants generally contain about 100 ppm of chlorine (table 1). Plants take up chlorine as Cl^- and require it for photosynthesis (table 2). Chlorine is plentiful in soils in the Pacific

Table 3. Typical soil content and extent of deficiencies in the Pacific Northwest of the 14 soil-derived essential plant materials.

Essential nutrient	Typical soil content	Extent of deficiencies
Nitrogen	1-2% organic matter*	widespread
Phosphorus	1-4 ppm (Morgan soil test) 4-20 ppm (Olson soil test)	widespread; low pH (<5.5) soils; high pH (>6.5) soils
Potassium	>100 ppm	isolated to potatoes, alfalfa, high pH
Sulfur	<10 ppm	widespread
Calcium	plenty	no problems
Magnesium	plenty	minimal problems
Boron	01.-0.7 ppm	low organic matter soils or high precipitation
Chlorine	plenty	no problems
Copper	1.0-3.0 ppm	soils with over 8% organic matter
Iron	plenty in low pH soils	high pH (>7.5) soils; ornamentals in urban areas
Manganese	plenty	very isolated
Molybdenum	no soil test	when growing legumes in soils with pH <5.4
Nickel	no soil test	no problems
Zinc	0.3-2.0 ppm	where topsoil has been removed

* Each 1 percent of soil organic matter will supply between 20 and 22 pounds per acre N for plant growth.

Northwest. Consequently, Cl deficiencies in plants will not be encountered.

Copper—Copper is taken up by plants as Cu^{2+} (table 1). Concentrations of Cu in plants average 6 ppm, but can range from 2 to 20 ppm. Copper is a component of plant cytochromes and is needed for enzyme activation. Copper is not mobile in plants; deficiencies appear first in the youngest plant tissue (table 2).

Most soils contain adequate levels of copper for plant growth (table 3). Copper deficiencies are most likely on soils that contain more than 8 percent organic matter—only about 1 percent of the soils in the Pacific Northwest. For additional information on Cu, see University of Idaho CIS 682, *Copper in Idaho*.

Iron—Plants take up iron as Fe^{2+} (table 1). A typical plant contains 100 ppm of Fe, but Fe content range from 50 to 1,000 ppm depending on plant species. Iron is needed for chlorophyll synthesis, metabolic processes, and enzyme activation (table 2). Iron is not mobile in plants, so Fe deficiencies first appear on younger leaves. The characteristic deficiency symptom is interveinal chlorosis on the younger leaves.

In general, there is plenty of plant-available Fe in acid and neutral pH soils (table 3). In the Pacific Northwest Fe deficiencies are often observed in fruit trees, golf course greens, and ornamental plantings in urban areas. Iron deficiencies should be corrected with foliar sprays.

Manganese—Manganese is taken up as Mn^{2+} by plants (table 1). Concentrations of Mn in plants average 50 ppm, but can range from 20 to 200 ppm. Manganese is required in the Hill reaction of photosystem II and is important for enzyme activation. Manganese is not mobile in plants, so deficiencies appear first in the youngest plant tissue (table 2).

Most soils contain adequate levels of manganese for plant growth (table 3). Manganese deficiencies are not found in acid or neutral pH soils. The few observed Mn deficiencies in Idaho occur in alkaline soils that have high levels of organic matter (greater than 6%).

Molybdenum—Plants take up molybdenum as MoO_4^{2-} (table 1). A typical plant contains only 0.1 ppm of Mo. However, this small amount of Mo allows plants to utilize N. In addition, legumes require Mo for nitrogen fixation (table 2).

Molybdenum is not mobile in plants, so deficiency symptoms appear in younger plant tissue first. Molybdenum-deficient plants turn yellow-green to yellow. Most Mo deficiencies occur when legumes are grown in soils with pH values less than 5.4. For additional information on Mo, see University of Idaho CIS 1087, *Molybdenum in Idaho*.

Nickel—Nickel was added to the essential element list in 1991. Plants require less than 1 part per billion Ni. Nickel is believed to be important in iron metabolism in plants. Deficiencies have never been observed in the Pacific Northwest.

Zinc—A typical plant contains 20 ppm Zn on a dry weight basis (table 1). Plants take up zinc as Zn^{2+}. Zinc is required for protein breakdown and in enzyme activation in plants (table 2). Zinc is not very mobile in plants; consequently, deficiency symptoms first appear on the youngest plant tissue. Most soils in the Pacific Northwest contain adequate amounts of Zn (table 3). However, Zn deficiencies do occur in soils where the topsoil or organic matter has been removed. For additional information about Zn, see University of Idaho CIS 1088, *Zinc in Idaho*.

Summary

Nitrogen, phosphorus, and sulfur are the macronutrients that will most likely limit plant growth in Idaho. Under certain conditions the micronutrients boron, iron, and zinc may also be deficient. When correcting a micronutrient deficiency, be careful not to overapply and induce a toxicity. The publications referred to in the text are available at the following University of Idaho web site: http://info.ag.uidaho.edu/catalog/catalog.html.

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