# Chemistry in Plant Nutrition & Growth

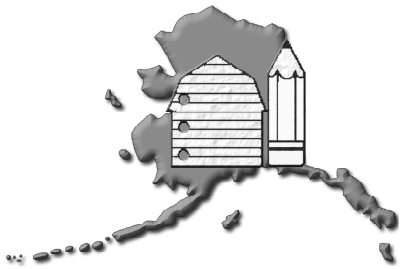
*By Andrew & Erin Oxford, Bethel*

**Objectives**
Review elements of chemistry and apply them to plant nutrition and growth in an agricultural context.

**Suggested grade levels**
9-12

**Alaska Content Standards**
Science D1,D3

**Terms to Define**
organic matter
fertility
radiant energy
toxicity
macronutrient
micronutrient



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## A. Factors Affecting Plant Growth

Plant growth can be defined as the progressive development of the plant. Frequently, the growth term is expressed as the amount of biomass in the plant or plant part (e.g. grain in wheat). Numerous factors affect plant growth. Many of these are related to environmental factors while others are controlled by humans.

- Water supply- amount and distribution
- Radiant energy- quality, intensity, and duration of sunlight
- Air temperature
- Soil temperature – cool soil temperatures often limit plant growth in Alaska by slowing root growth and the recycling of plant nutrients through decomposition of soil organic matter
- Composition of the atmosphere- such as elevated $CO_2$ concentrations- some plants, called $C_3$ plants, produce higher yields with elevated $CO_2$ concentrations while others, called $C_4$ plants, do not benefit from elevated $CO_2$ concentrations
- Composition of the air in the soil
- Competition- from weeds, trees, other grasses or plants
- Pests- presence and absence
- Plant genotypes or varieties
- Soil Fertility- the status of a soil with respect to the ability of a soil to supply elements essential for plant growth without a toxic concentration of any element. All productive soils are fertile for the crops, plants, trees being grown, but a fertile soil may not be productive

Plant nutrition is concerned with the processes affecting the acquisition of nutrient elements by plants, the health of a plant with respect to its supply or content of essential elements, and the functions of those elements in the life of a plant

## B. Essential Elements in Plant Nutrition

Definition or criteria of an essential element (Criteria proposed by Arnon and Stout in 1939)

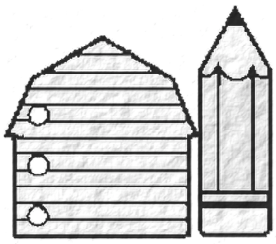
- A given plant must be unable to complete its life cycle in the absence of the mineral element( Life cycle = vegetative state, flower, produce seeds)

- The function of the element must not be replaceable by another mineral element

- The element must be directly involved in plant metabolism or a component of an essential plant constituent (e.g. Nitrogen is a constituent of proteins and chlorophyll)

There are 17 essential elements for plants. The following table lists the essential elements, their source, concentration in the plant, whether they are a macronutrient or a micronutrient, and the form of the element that can be absorbed by the plant. Beneficial nutrients are nutrients that are not needed for the plant to complete its life cycle, but may provide other benefits such as disease resistance, etc. Examples of beneficial nutrients are silicon, cobalt and sodium.

Primary Nutrients — N, P, and K- most common growth limiting nutrients-usually most deficient. Secondary Nutrients — S, Ca, Mg



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| Source | Class | Element | Form Absorbed by Plant | Avg. Concentration in Plant |
|---|---|---|---|---|
| Non-Mineral | Macronutrients (> 1000 ppm) | Carbon (C) | $CO_2$ | 44.0 % |
| | | Hydrogen (H) | $H_2O$ | 6.0% |
| | | Oxygen (O) | $H_2O$, $CO_2$, $O_2$ | 44.0 % |
| Mineral-from soil | | Nitrogen (N) | $NO_3^-$, $NH_4^+$ | 1.5 % |
| | | Phosphorous (P) | $H_2PO_4^-$, $HPO_4^{-2}$ | 0.2 % |
| | | Potassium (K) | $K^+$ | 1.0 % |
| | | Sulfur (S) | $SO_4^{-2}$ | 0.1 % |
| | | Calcium (Ca) | $Ca^{+2}$ | 0.5 % |
| | | Magnesium (Mg) | $Mg^{+2}$ | 0.2 % |
| | Micronutrients (< 1000 ppm) | Iron (Fe) | $Fe^{+3}$, $Fe^{+2}$ | 100 ppm |
| | | Manganese (Mn) | $Mn^{+2}$ | 50 ppm |
| | | Boron (B) | $H_3BO_3$ | 20 ppm |
| | | Zinc (Zn) | $Zn^{+2}$ | 20 ppm |
| | | Copper (Cu) | $Cu^{+2}$ | 6 ppm |
| | | Molybdenum (Mo) | $MoO_4^{-2}$ | 0.1 ppm |
| | | Chlorine (Cl) | $Cl^-$ | 0.2 % |
| | | Nickel (Ni) | $Ni^+$ | 0.5 ppm |

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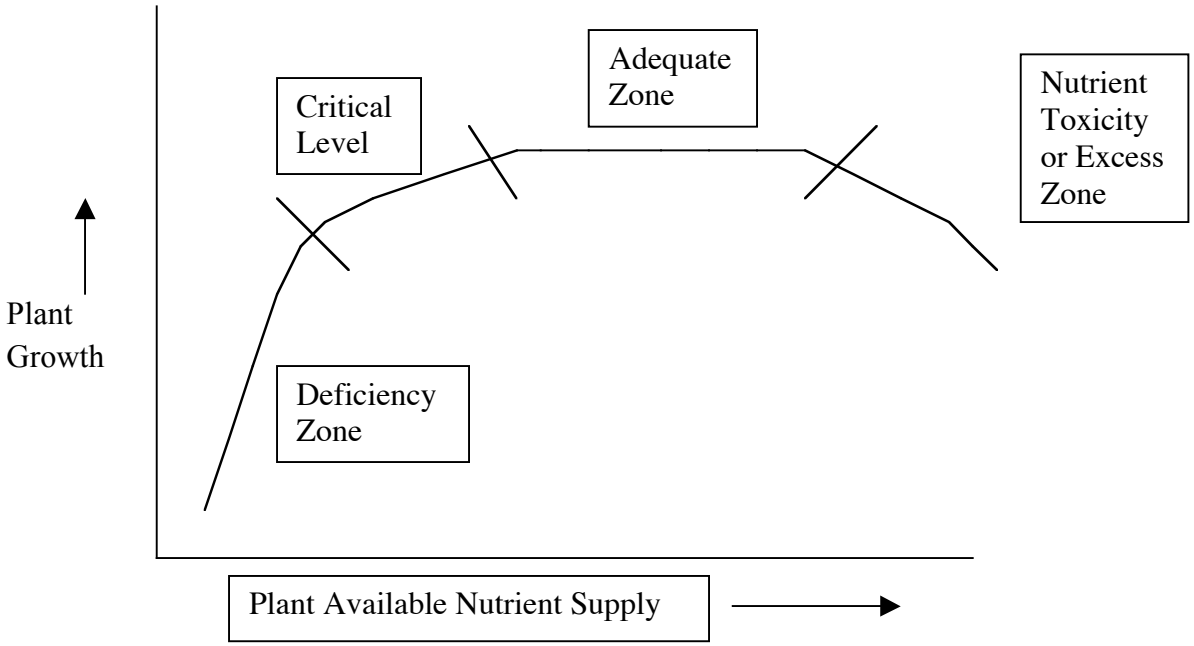
*Peter Bierman, UAF Cooperative Extension Service Land Agent in Palmer, contributed to this lesson.*




Relationships between plant growth and available nutrient supply typically follow a relationship similar to that depicted above. The concept is when equal increments of a nutrient are applied to a crop, the yield response becomes smaller with each increment.
This concept is sometimes referred to as the Law of Diminishing Returns.

**Plant available nutrients:**
• Means a form or forms of nutrients that may be immediately absorbed by the plant roots
• The nutrients are soluble and in the soil solution
• Most of the time, only the inorganic form of the nutrient will be absorbed by the plant root. Organic forms cannot be absorbed.
• The concentration of nutrients in the soil greatly exceeds the annual uptake of the nutrients by the plants because only a portion of the nutrients are in a form that is available for plant uptake.

**Plant Nutrition and Growth Problem Solutions** (see problems on separate student sheet)

1. A given plant must be unable to complete its life cycle in the absence of the mineral element. The function of the element must not be replaceable by another mineral element. The element must be directly involved in plant metabolism or a component of an essential plant constituent.

2. Nutrients may not be plant available- nutrients are in an organic form which cannot be absorbed. Disease, heat stress, competition from other plants, and an inadequate supply of water are other reasons.

3. The product is worthless as a fertilizer because it does not contain any of the essential nutrients except for carbon. In particular, it does not contain the primary nutrients which most often limit plant growth if they are deficient. Three of the other elements in the product are beneficial nutrients (cobalt, sodium, and silicon) that are not needed by the plants to complete its life cycle.

micronutrients are found in plants at a concentration below 1000ppm on a dry weight basis. They are also divided by the quantity or abundance of nutrients the plant needs. Plants need more macronutrients than micronutrients.
Primary nutrients are usually limit plant growth the most and are the most deficient whereas secondary nutrients do not limit plant growth as much and are not as deficient in the soil.



5. Cations: $Cu^{+2}$, $NH_4^+$, $Mn^{+2}$, $Ca^{+2}$, $K^+$, $Mg^{+2}$, $Fe^{+3}$, $Fe^{+2}$, $Zn^{+2}$, $Ni^+$
   Anions: $NO_3^-$, $H_2PO_4^-$, $SO_4^{-2}$, $Cl^-$, $HPO_4^{-2}$, $MoO_4^{-2}$
   Uncharged molecule: $H_3BO_3$, which is boron

6. Water supply, radiant energy, air temperature, soil temperature, composition of the atmosphere, composition of the air in the soil, competition, pests, plant genotypes or varieties, soil fertility

Name _____

# Plant Nutrition & Growth Problems

1. What are the three criteria that must be met for an element to be considered essential for plant growth?

2. A field site that contains a "fertile" soil, one which contains large amounts of nutrients, may not necessarily be a "productive" site, or one that can produce large plants. Why might this be the case?

3. A salesman comes to your door with a new miracle product designed (he claims) to fertilize houseplants and lawns. The product, called Miracle Ash, contains 45% carbon, 10 ppm cobalt, 1000 ppm sodium, 5 ppm silicon, and 300 ppm aluminum. Why is this product worthless as a fertilizer or plant nutrition supplement?

4. What is the basis for dividing the 17 essential plant nutrients into the two classes of macronutrients and micronutrients? What is the basis for dividing the mineral macronutrients into primary and secondary fertilizer nutrients?

5. What essential mineral nutrients are absorbed by the plant primarily as cations? As anions? What mineral nutrient is absorbed primarily as an uncharged ion pairmolecule?

6. What are some factors that affect plant growth?