Extension
UNIVERSITY OF WISCONSIN–MADISON

Chris Clark, Michael Geissinger & Mimi Broeske
Nutrient and Pest Management Program

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Crop Nutrients 101

In this publication is an overview of essential plant nutrients and the ways they interact with one another. Farmers and agronomists can use this guide as a tool in conjunction with a good soil testing program to help diagnose agronomic problems and consider their nutrient management strategy. For detailed information on a specific plant nutrient and its role in plants, refer to publications located at extension.soils.wisc.edu and ipcm.wisc.edu.

Plant Essential Nutrients

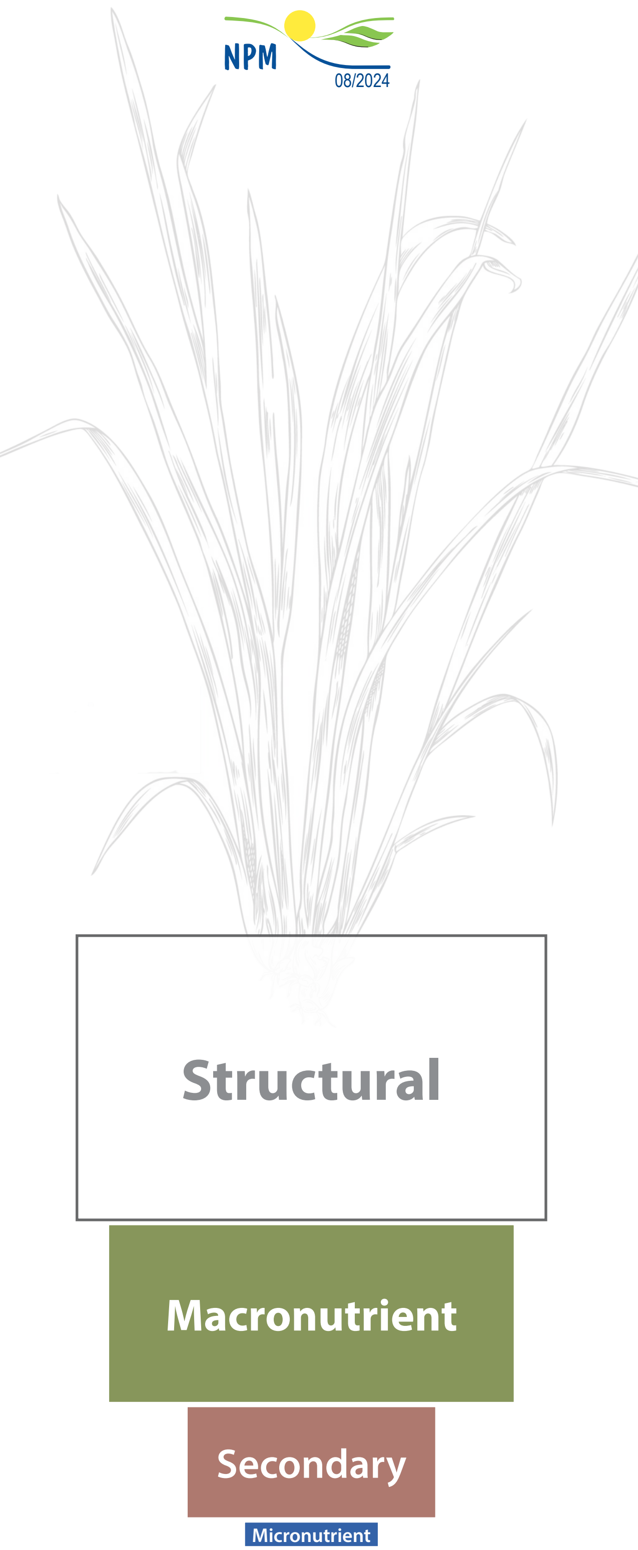
Nutrients that are needed by all plants to complete their vegetative and reproductive life cycles that are irreplaceable by another nutrient are called plant essential nutrients. There are 17 plant essential nutrients, and they are divided into four categories based on the quantity used by the crops: structural nutrients, macronutrients, secondary nutrients, and micronutrients.

Structural nutrients are crop nutrients obtained from air and water. They include carbon (C), hydrogen (H), and oxygen (O).

Macronutrients are needed in large quantities for plants and include some of the nutrients commonly applied with commercial fertilizer. They include nitrogen (N), phosphorus (P), and potassium (K).

Secondary nutrients are needed in medium quantities for plants, in comparison to macronutrients and micronutrients. They include calcium (Ca), magnesium (Mg), and sulfur (S). While calcium deficiencies are rare in Wisconsin, sulfur is often needed in high demanding crops like alfalfa, corn silage, and soybeans, since atmospheric levels of sulfur have decreased in response to clean air efforts.

Micronutrients or trace elements are needed in very small quantities by the plant. They include iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn), molybdenum (Mo), nickle (Ni), and chlorine (Cl).



Understanding Nutrient Availability & Interactions

In addition to soil-derived nutrients, plants utilize nutrients derived from air, water, organic matter, and agricultural inputs like manure. Some nutrients are readily plant-available, while others often need to be assimilated by the plant or broken down by microbes in the soil into plant-available forms. External conditions like the following can affect the availability of nutrients to plants:

- Nutrient availability is restricted for some nutrients at very high or very low pH. Most crop nutrients are readily available at 6.0-7.0 pH.
- Extreme environmental conditions like heavy rainfall or low temperatures that affect factors like soil temperature and oxygen levels can decrease nutrient uptake.
- Variations in soil texture like very low or very high organic matter and sandy soils tend to exhibit more nutrient deficiencies.

In addition to these external factors, sometimes the concentration of certain nutrients will decrease the availability of others, especially if the uptake forms are of similar size, valency, and charge and are competing for the same binding sites in the soil or in the plant. To help consultants and farmers assess nutrient deficiencies and better understand interactions between nutrients when solving agronomic issues, we have developed the following table demonstrating the plant uptake form, ideal soil pH, limiting soil characteristics, and inter-nutrient dynamics for the soil-derived plant essential nutrients.

UNDERSTANDING FACTORS AFFECTING NUTRIENT AVAILABILITY CHART

Content adapted from: *Marschner, H. (2023). Marschner's Mineral Nutrition of Plants (4th ed.). Elsevier* ***and*** *René P. J. J. Rietra, Marius Heinen, Chistian O. Dimkpa & Prem S. Bindraban (2017) Effects of Nutrient Antagonism and Synergism on Yield and Fertilizer Use Efficiency, Communications in Soil Science and Plant Analysis, 48:16, 1895-1920, DOI:10.1080/00103624.2017.1407429*

Category	**Element (symbol)** plant available form	Soil pH	Most common on	Deficiency / Excess
Macronutrients	**Nitrogen (N)** nitrate (NO_3^-) ammonium (NH_4^+)	**Soil pH <5.5 or >8.5** limits uptake	**Most common on** coarse soils	**Deficiency** can result from low soil phosphorus levels can also result from high chlorine **Excess** from high rates of nitrification, mineralization or fertilizer applications can limit K, Ca, or Cl uptake
Macronutrients	**Phosphorus (P)** hydrogen phosphate (HPO_4^{-2}) dihydrogen phosphate ($H_2^+PO_4^-$)	**Soil pH <5.5 or >7.2** limits uptake	**Most common on** poorly drained, wet soils	**Excess** can result from a history of repeated manure applications; it can also limit Zn, Fe, or Cu uptake
Macronutrients	**Potassium (K)** potassium ion (K^+)	**Soil pH <5.5** limits uptake	**Most common on** cold wet soils	**Deficiency** can be caused by excessive N applications or low K fertilization **Excess** can limit uptake of Ca, Mg, or N (especially the NH_4^+ form)
Secondary	**Calcium (Ca)** calcium ion (Ca^{+2})	**Soil pH <6.0** limits uptake	**Most common on** soils with low cation exchange capacity (CEC)	**Deficiency** can be caused by high soil K or N levels **Excess** Ca can limit B, Mg, Cl, or P uptake Note: Samples from old/diseased tissue often test high
Secondary	**Magnesium (Mg)** magnesium ion (Mg^{+2})	**Soil pH <6.0** limits uptake	**Most common on** naturally calcareous soils or low Mg soils with a history of high calcium lime	**Deficiency** can be caused by high soil K, N, Ca, or Mn levels **Excess** Mg can limit Ca, or K uptake Note: Samples from old/diseased tissue often test high
Secondary	**Sulfur (S)** sulfate (SO_4^{-2})	**Soil pH <5.5** limits uptake	**Most common on** low organic matter soils with excessive N applications	**Excess** S can limit K or Mo uptake (or be used to help reduce Mo toxicity) Note: Excess S can also limit selenium (Se); selenium is a soil nutrient needed for animal nutrition
Micronutrients	**Zinc (Zn)** zinc ion (K^{+2})	**Soil pH > 7.5** limits uptake	**Most common on** muck soils, soils with low organic matter, or cool wet soils with corn, which may recover as soil warms	**Deficiency** can be caused by high soil test P levels **Excess** Zn can limit Fe and Mn uptake
Micronutrients	**Manganese (Mn)** manganese ion (Mn^{+2})	**Soil pH > 7** limits uptake	**Most common on** soils with high or very low organic matter, or soils with high moisture	**Excess** Mn can result from recent fungicide applications or high N or P applications on low pH soils; it can also limit Fe, Mo, or Mg uptake
Micronutrients	**Boron (B)** boric acid (H_3BO_3) borate (BO_3^{-3}) borate ion ($B_4O_7^{-2}$)	**Soil pH > 7.5** limits uptake	**Most common on** coarse sandy soils (low organic matter) and heavy clays	**Excess** B can result if soil pH is lowered from 7 to below 6.5 (acidic)
Micronutrients	**Iron (Fe)** ferrus iron (Fe^{+2}) ferric iron (Fe^{+3})	**Soil pH > 6.5** limits uptake	**Most common on** high calcareous soils, soils in regions with high rainfall, or soils with recent heavy lime applications	**Deficiency** can be caused by excessive Zn, P, Cu, or Mn levels **Excess** Fe can result when Zn is deficient; it can also limit Mn uptake
Micronutrients	**Copper (Cu)** copper ion (Cu^{+2})	**Soil pH > 7.5** limits uptake	**Most common on** soils with high organic matter	**Deficiency** can be caused by high Fe or Mn levels **Excess** Cu can result from recent chemical application that contain copper; it can also limit Mo, Fe, Mn, or Zn uptake
Micronutrients	**Molybdenum (Mo)** molybdate (MoO_4^{-2})	**Soil pH ≤ 5.5** limits uptake	**Most common on** soils with high organic matter	**Deficiency** can be caused by high soil test P levels **Excess** Mo can result from soils with pH > 6.0 or K deficiencies; it can also limit Cu or Fe uptake