Module 1: Overview of soil fertility, plant nutrition, and nutrient management

To view the chapter for this topic click here.

Introduction

- Understanding the principles of soil fertility is vital to
  - efficient nutrient management
  - profitable crop production
  - environmental protection

- Seventeen chemical elements are essential for plant growth:
  - are needed in different amounts by the plant
  - vary in mobility within the plant
  - vary in concentration in harvested crop components

- Important aspects to know:
  - amount of each nutrient needed for optimum economic yield
  - amount removed by a crop with harvest
  - nutrient transformations within the soil
  - potential mobility of nutrients that might affect water quality

Essential plant elements

- **Non-mineral**
- **Mineral**
  - **Primary Macronutrients**
  - **Secondary Nutrients**
  - **Micronutrients**

Element	Source	Concentration
Carbon (C)	Air	45%
Oxygen (O)	Air/Water	45%
Hydrogen (H)	Water	6%
Nitrogen (N)	Air/Soil	1-5%
Potassium (K)	Soil	0.5-1%
Phosphorus (P)	Soil	0.1-0.5%
Calcium (Ca)	Soil	0.2-1%
Magnesium (Mg)	Soil	0.1-0.4%
Sulfur (S)	Soil	0.1-0.4%
Chlorine (Cl)	Soil	0.01-0.1%
Iron (Fe)	Soil	50-250ppm
Manganese (Mn)	Soil	20-200ppm
Boron (B)	Soil	6-60ppm
Zinc (Zn)	Soil	25-150ppm
Copper (Cu)	Soil	5-20ppm
Molybdenum (Mo)	Soil	0.05-0.2ppm
Nickel (Ni)	Soil	0.1-1ppm

Essential plant elements

- To be classified as essential, the element needs to meet the following criteria:
  - the plant cannot complete its life cycle (seed to new seed) without it
  - the element's function cannot be replaced by another element
  - the element is directly involved in the plant's growth and reproduction

Plant uptake of nutrients

- Each nutrient is taken up in an ‘ionic’ or charged form.
- Knowing what form of a nutrient the plant absorbs helps us to better understand on what controls the cycling and movement of that nutrient in soil.
- Understanding nutrient functions and mobility within the plant are useful in diagnosing nutrient deficiencies.
- Nutrient uptake by roots is dependent on:
  - root growth and soil exploration
  - the ability to absorb nutrients
  - the nutrient concentration at the root surface
- Nutrients are in contact with roots by three mechanisms:
  - root interception
  - diffusion
  - mass flow

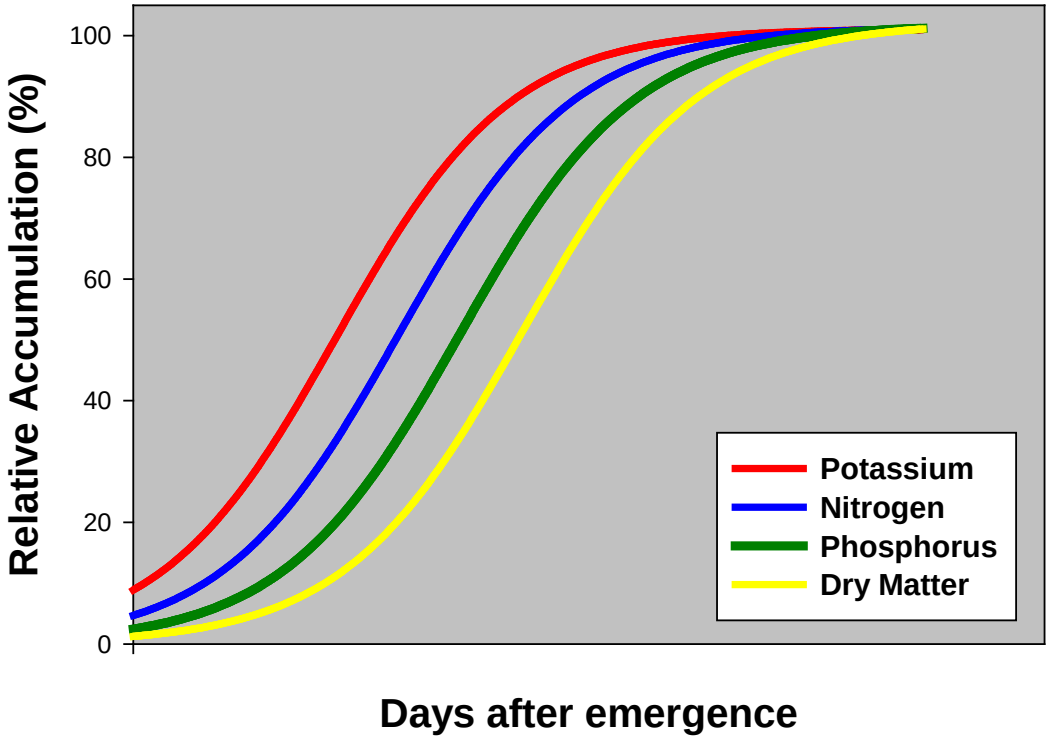
Plant Uptake of Nutrients

Element	Form
Nitrogen (N)	NO_3^- (nitrate), NH_4^+ (ammonium)
Potassium (K)	K^+
Phosphorus (P)	$H_2PO_4^-$, HPO_4^{-2} (phosphate)
Calcium (Ca)	Ca^{+2}
Magnesium (Mg)	Mg^{+2}
Sulfur (S)	SO_4^{-2} (sulfate)
Chlorine (Cl)	Cl^- (chloride)
Iron (Fe)	Fe^{+2} (ferrous), Fe^{+3} (ferric)
Manganese (Mn)	Mn^{+2}
Boron (B)	H_3BO_3 (boric acid), $H_2BO_3^-$ (borate)
Zinc (Zn)	Zn^{+2}
Copper (Cu)	Cu^{+2}
Molybdenum (Mo)	MoO_4^{-2} (molybdate)
Nickel (Ni)	Ni^{+2}

Nutrient Mobility within the Plant

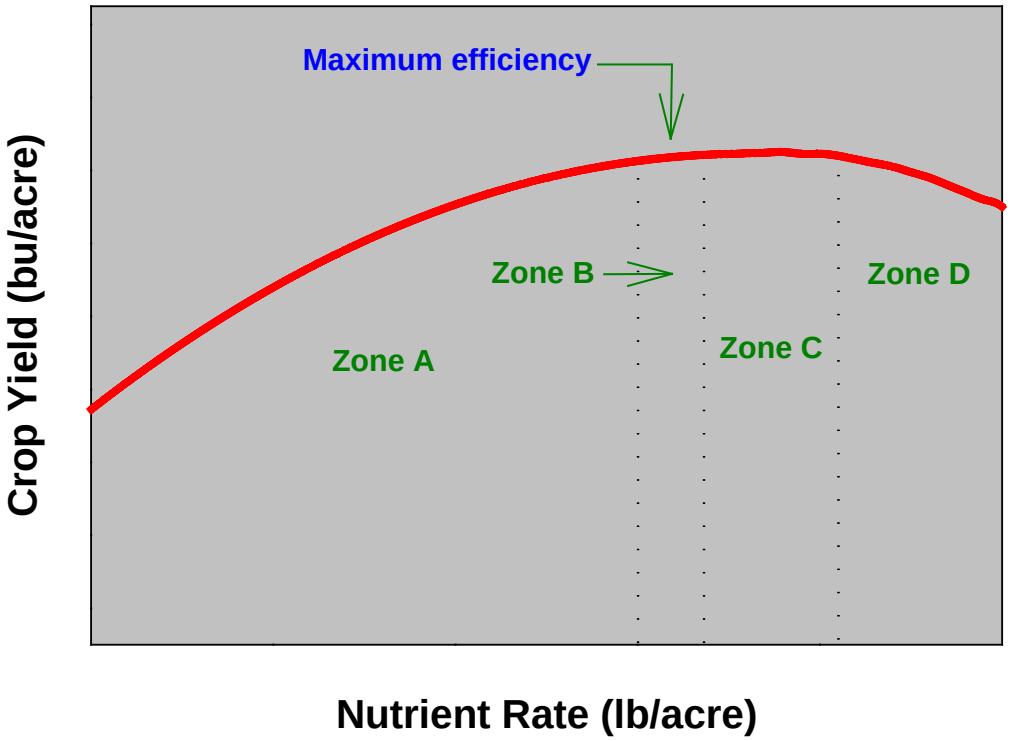
Mobile nutrients	Immobile nutrients
Nitrogen (N)	Sulfur (S)
Phosphorus (P)	Calcium (Ca)
Potassium (K)	Iron (Fe)
Chloride (Cl)	Zinc (Zn)
Magnesium (Mg)	Manganese (Mn)
Molybdenum (Mo)	Boron (B)
	Copper (Cu)
	Nickel (Ni)

Timing of Nutrient Uptake by Plants



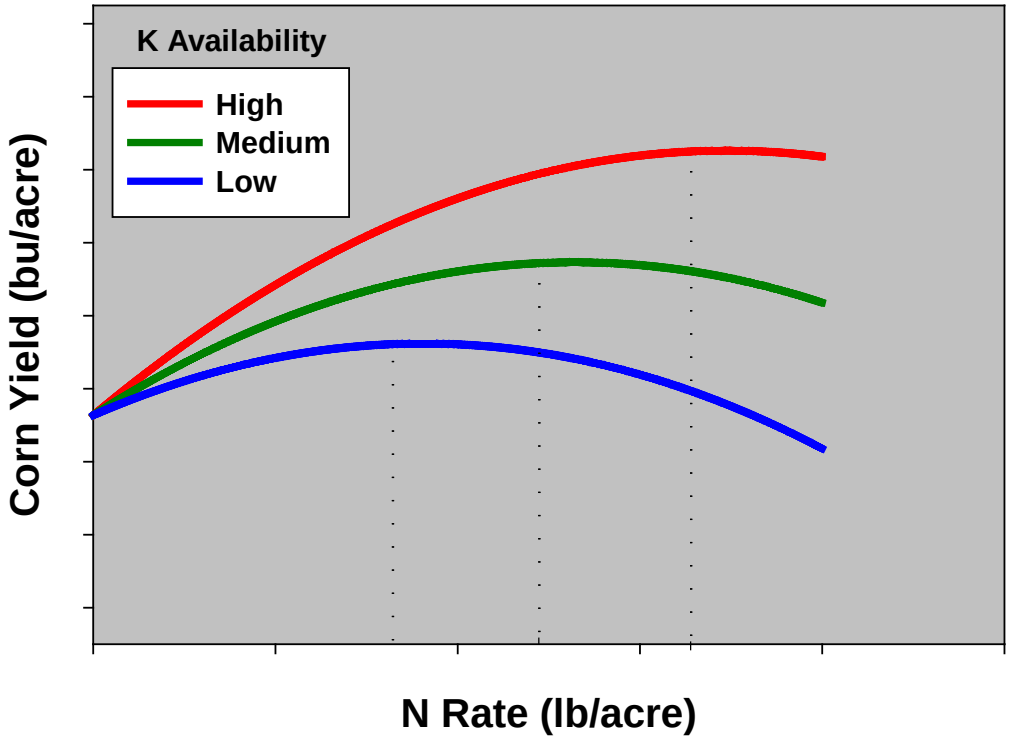
Example: growing season accumulation patterns of K, N, P, and dry mater in corn.

Crop Response to Nutrient Supply



Relationship between crop yield and essential nutrient application rate.

Nutrient Interactions



Potassium improves yield response to N fertilizer and N use efficiency.

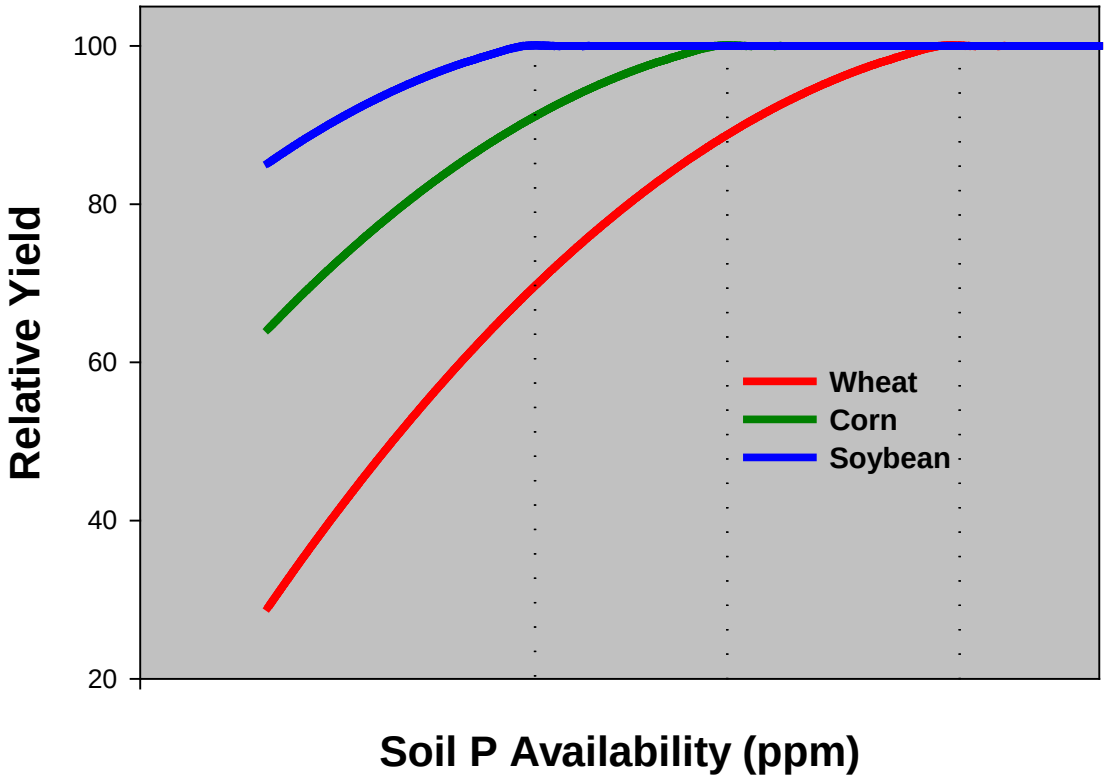
Nutrient Diagnostic Methods: Correlation, Calibration, and Interpretation

- Nutrient diagnostic methods are tools for determining plant nutrient needs:
  - soil testing
  - plant analysis
  - crop canopy sensing

- The development of a diagnostic method for a given nutrient involves three steps:
  - selecting a soil or plant test or analysis or methodology that is related to a specific crop nutrition need or response to application
  - field correlation of test results with crop yield, amount of nutrient taken up by plants, and/or some other desirable crop characteristic
  - field calibrating the test result in terms of its effect on some desirable crop characteristic, such as yield response
  - developing sufficiency interpretations

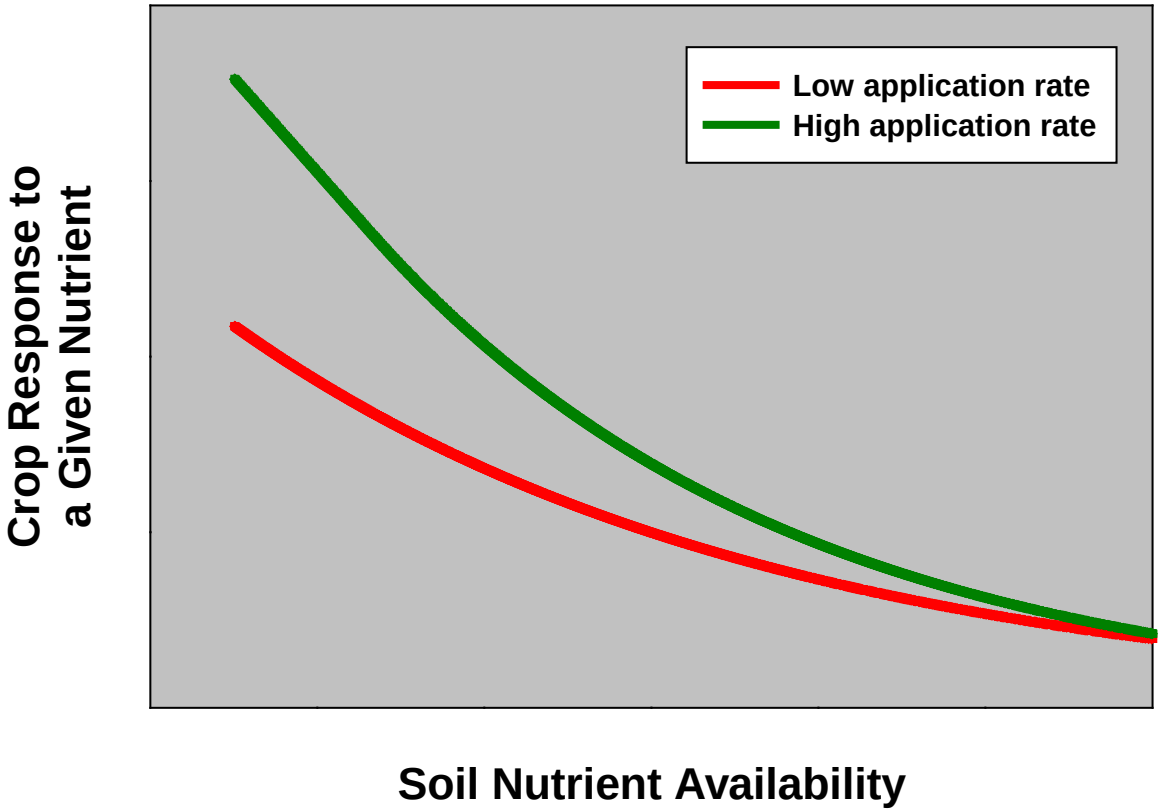
- Fertilizer recommendations are then based on interpretation of test results from calibrated methods and fertilizer response trials.

Nutrient Diagnostic Methods: Correlation, Calibration, and Interpretation



Different crop responses from different soil Bray-1 P levels.

Nutrient Diagnostic Methods: Correlation, Calibration, and Interpretation



Crop yield response to a low and high rate of a given nutrient as related to the original soil nutrient level.

Nutrient Diagnostic Methods: Correlation, Calibration, and Interpretation

Nutrient Index Level	Meaning of Index Level for Crops
	Applying the nutrient will be beneficial …
Very low	over 80% of the time
Low	65% of the time
Optimum	5% of the time
High	less than <1% of the time
Source: Iowa State University Extension publication PM 1688.	

Steps in Nutrient Management Planning

- 1. Obtain accurate soil information for each field or management unit within a field.
- 2. Estimate realistic crop yield potential based on soil productivity or yield mapping, crop rotation and intended management.
- 3. Calculate plant nutrient applications required.
- 4. Determine the plant-available nutrients in any livestock manure or other by-product amendments.
- 5. Estimate any applicable residual nutrient contributions from fertilizer or manure applied in previous seasons, or previous legume crop effects on soil N supply.

Steps in Nutrient Management Planning

- 6. Determine need for purchase of off-farm nutrients, such as fertilizer or manure.
- 7. If necessary, use an applicable environmental risk assessment tool (mainly for N and P).
- 8. Apply animal manure and commercial fertilizer to supply nutrients only when needed and using practices that ensure high use efficiency.
- 9. Keep records of nutrient sources, application dates, rates, and methods.
- 10. Remember that nutrient management plans need to be accurate, understandable, and defendable.