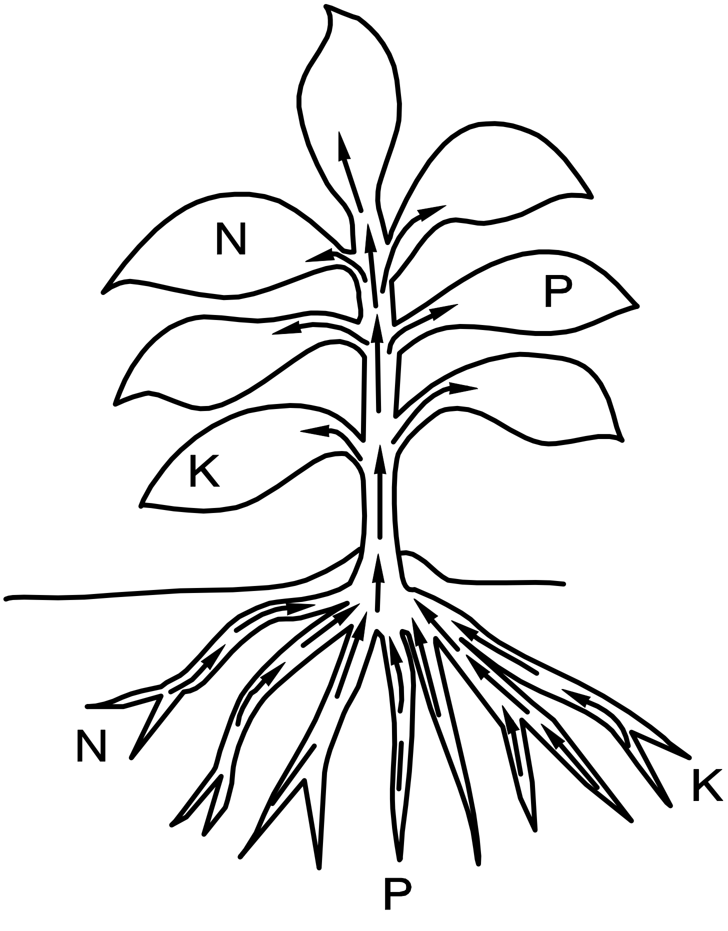
Soil Fertility
and
Plant Nutrition 1



Soils 446

Course Module
Lecture Note Packet

University of Idaho
College of Agriculture

Outline of Course
Soils 446
Module 1: Soil Fertility and Plant Nutrition 1

Lesson 1: **Soil Fertility and Plant Nutrition**

Lesson 2: **Essential Elements**

Lesson 3: **Essential Elements; Current Issues**

Lesson 4: **Nutrient Mobility in Soils**

Lesson 5: **Ion Exchange**

Lesson 6: **Soil pH and its Management**

Lesson 7: **Soil pH and its Management**

Lesson 8: **Soil pH and its Management; The Nitrogen Cycle**

Lesson 9: **The Nitrogen Cycle; Nitrogen Fixation**

Lesson 10: **Forms of N in the Soil; Mineralization and Immobilization Processes**

Lesson 11: **Mineralization and Immobilization Processes; Nitrate and Groundwater**

Lesson 12: **Nitrate and Groundwater; Retention of Nitrogen in the Soil; Leaching**

Lesson 13: **Gaseous Losses of Nitrogen; Plant Response to Nitrogen Fertilizer**

Lesson 14: **Plant Response to Nitrogen Fertilization; Predicting Nitrogen Needs**

Lesson 15: **Predicting Nitrogen Needs; N Fertilizers**

Lesson 16: **N Fertilizers; Fertilizer Recommendations**

Table of Contents

Page #

Appendix Materials

CIS 811 ***The Relationship of Soil pH and Crop Yield in Northern Idaho***

CIS 787 ***Liming Materials***

CIS 838 ***Inoculation of Legumes in Idaho***

EPA's National Pesticide Survey

CIS 872 ***Nitrate and Groundwater***

CIS 962 ***BMPs for Nitrogen Management to Protect Groundwater***

Bull. 704 ***Soil Sampling***

CIS 453 ***Winter Wheat Fertilizer Guide***

CIS 372 ***Irrigated Field Corn for Silage or Grain***

CIS 911 ***Northern Idaho Lawns***

LESSON 1
Soil Fertility and Plant Nutrition

A. Soil Fertility Defined

***SOIL FERTILITY* — is the status of a soil with respect to its ability to supply elements essential for plant growth without a toxic concentration of any element.**

◆

***SOIL PRODUCTIVITY* — is a measure of the soil's ability to produce a particular crop or sequence of crops under a specified management system.**

◆

- ◆ **All productive soils are fertile for the crops being grown, but many fertile soils are unproductive because they have a poor climate.**
  - ▶
  - ▶
  - ▶
  - ▶

B. Historical Development of Soil Fertility

◆ **Writings back to 2,500 BC mention the link between annual floods of the Tigris, Euphrates, and Nile rivers and the fertility of the soils.**

◆

◆ **Canals built in ancient Athens to move sewage from cities to farmland.**

◆

◆ **By 100 BC legumes were being grown to enrich farm soils. Clovers and beans were widely sowed.**

◆

◆ **Woodashes and saltpeter were used by the first century.**

◆

◆

◆ **Justice van Leibieg, a German chemist, improved our understanding of soil fertility in the 19th century.**

◆ **“Law of the Minimum”**

◆

◆ **1862 Morril Act; 1888 Hatch Act; 1919 Smith Lever Act.**

- **Between 1940 and 1970 average yeilds of U.S. crops increased between 100 and 400%.**
- **Over 30% of this increase is attributed to soil fertility.**
-

C. Essential Elements Required for Plant Growth

- **There are currently 17 elements considered essential for plant growth. They include:**

Element	Symbol
Carbon	
Hydrogen	
Oxygen	
Nitrogen	
Phosphorus	
Potassium	
Sulfur	
Calcium	
Magnesium	
Boron	
Chlorine	
Copper	
Iron	
Manganese	
Molybdenum	
Nickel	
Zinc	

Of these essential 17 elements

- **Of these essential 17 elements**
  - **3 are derived from the air**
  - **14 come primarily from the soil**
- **The 14 soil derived nutrients are often split into two or three distinct groups:**

Macronutrients (6):

Micronutrients (8):

Primary Macronutrients (3):

Secondary Macronutrients (3):

MACRONUTRIENTS:

Nitrogen: (N)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficienty Symptoms in Plants:

Phosphorus: (P)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficienty Symptoms in Plants:

LESSON 2
Essential Elements

Potassium: (K)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficienty Symptoms in Plants:

Sulfur: (S)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficienty Symptoms in Plants:

Calcium: (Ca)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficienty Symptoms in Plants:

Magnesium: (Mg)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficienty Symptoms in Plants:

MICRONUTRIENTS:

Boron: (B)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficienty Symptoms in Plants:

Chlorine: (Cl)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficiency Symptoms in Plants:

Copper: (Cu)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficiency Symptoms in Plants:

Iron: (Fe)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficiency Symptoms in Plants:

Manganese: (Mn)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficiency Symptoms in Plants:

Molybdenum: (Mo)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficiency Symptoms in Plants:

Nickel: (Ni)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Zinc: (Zn)

Uptake:

Plant Content:

Mobility in the Plant:

Function in the Plant:

Typical Content in Idaho Soils:

Problems in Idaho:

Deficiency Symptoms in Plants:

Ranking the essential elements from greatest to lowest content in plants:

Relative fertilizer usage of essential plant nutrients:

LESSON 3
Essential Elements/Current Issues

Relative crop use of major essential plant nutrients:

Crop	N	P	K	S	Mg
			-----lb/acre-----		
Corn (200 bu)	**322**	**47**	**207**	**44**	**67**
Barley (80 bu)	**151**	**25**	**126**	**25**	**20**
Alfalfa (6 tons)	**338**	**32**	**225**	**34**	**31**
Potatoes (400 bu)	**202**	**24**	**257**	**27**	**24**
Sugarbeets (2800 lb)	**161**	**25**	**212**	**50**	**99**

- **If we make the definition of essential less restrictive ... not required by all plants, but helpful to the growth of some plants, we can add the following:**

Cobalt:

Sodium:

Selenium:

Silicon:

Vanadium:

D. Importance of Fertilizers

- Soils can sustain a low level of crop yeidls for centuries when soil management inputs are minimal. This is in the range of 8 to 10 bushels of wheat per acre.

  these types of yields were common in the old world until the use of fertilizers became routine. On these same soils with fertilizer inputs yields now average more than 45 bu/ac

- Fertilizers account for a large portion of the yield gain during the GREEN REVOLUTION

◆

- Over 75% of the soils in the USA are nitrogen deficient; 50% of the soils are potassium deficient; 40% of the soils are phosphorous deficient

◆

E. Current Issues in Soil Fertility and Plant Nutrition

1. Farm Advising — Consulting

◆ **Plant nutrition is an integral part of crop management; consultants provide an increasingly larger share of the fertilizer recommendations for farmers.**

◆ **Opportunities in soil sampling strategies, plant and tissue testing laboratories, soil test correlation, farm advising.**

◆ **Federal government may someday require nutrient management plans for individual farms; someone will have to write them.**

◆

◆ **Eventually growers will need applicators licesnses to apply fertilizer — just like with pesticides currently.**

2. Integrated Crop Management Systems (ICMS)

◆ **Fertility will become integrated with integrated pest management (IPM) into an integrated crop management system.**

◆

◆ **Computer programs using ICMS systems will need to be developed and interpreted.**

3. Water Quality

◆ **Major national issue with implications for fertilizer management.**

◆ **Nitrates are mobile in soils and can leach into groundwater when poorly managed.**

◆

- **Best management practices (BMPs) are currently being developed for fertilizer use.**

4. Urban Soil Fertility

- **Large amounts of fertilizers are used in urban settings — lawns, gardens, golf courses, etc.**

◆

- **Urban areas tend to be more environmentally sensitive than rural areas (groundwater as a drinking water source).**
- **Regulations may limit fertilizer availability to the general public in the future.**
- **Opportunities for licensed chemical applications or educators to provide training.**

5. Sustainable Agriculture/Forestry

- **Sustainable agriculture can be defined as a long-term goal to adequately support agriculture and forestry indefinitely.**
- **Sustainable agriculture may actually be a high input form of agriculture; high input from a knowledge basis.**
- **Sustainable agriculture should consider seven goals:**

  a. Provide a safe, abundant, high quality supply of food and fiber products

b.

c. Conserve soil, water, air, and mineral resources both on and off the farm

d.

e. Be socially acceptable to the politically powerful groups that affect farm policy (in the United States it is the urban population)

f.

g. Be environmentally acceptable (conserve biodiversity)

6. Forest Nutrition

- **The greatest gains in soil science in the next 15 years will be made in forest plant nutrition.**
- **As we learn the best way to enhance tree growth, a knowledge of soil fertility will cause increased fertilization in forest ecosystems.**

7. Agroforestry Systems

- **From an international standpoint, intercropping situations provide the greatest opportunity to increase food and fiber supply.**

◆

- **A knowledge of how to fertilizer more than one crop at a time is needed.**

8. Economic Efficiency

- **Currently, only about 50% of the nitrogen fertilizer applied to crops actually ends up in the plant.**

◆

- **To stay competitive, farmers will have to get more out of the fertilizers they apply.**

LESSON 4
Nutrient Mobility in Soils

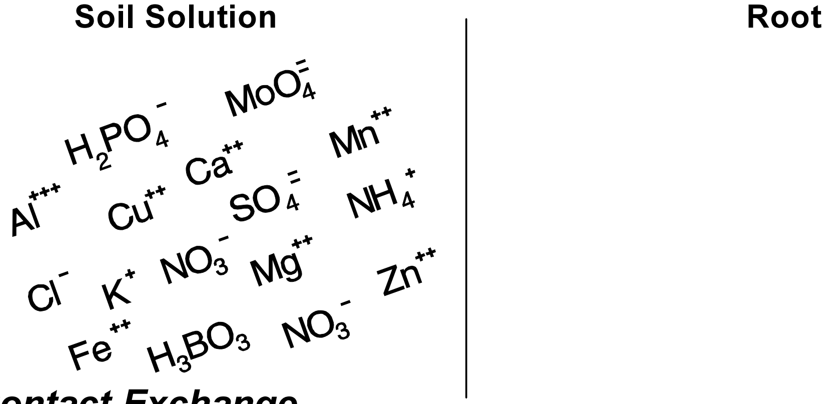
Nutrient Mobility in Soils

- There are three major processes by which nutrients get to the roots of plants. These include:

1.

2.

3.



1. Contact Exchange

- Also refered to as root interception and root exploration
- Is the volume of soil explored by the plant
- Nutrient requirement met by this process:

Nutrient	Available in Soil (lb/a)	Amt Req by Plant	Amt Root% Gets	Requirement
N	200	150	2	1.3
P	250	30	2.5	8
K	160	110	1.6	2
Ca	800	100	8	8

2. Mass Flow

- **Defined as:**

- **Amount of nutrients reaching plant roots by mass flow depends on:**

-

-

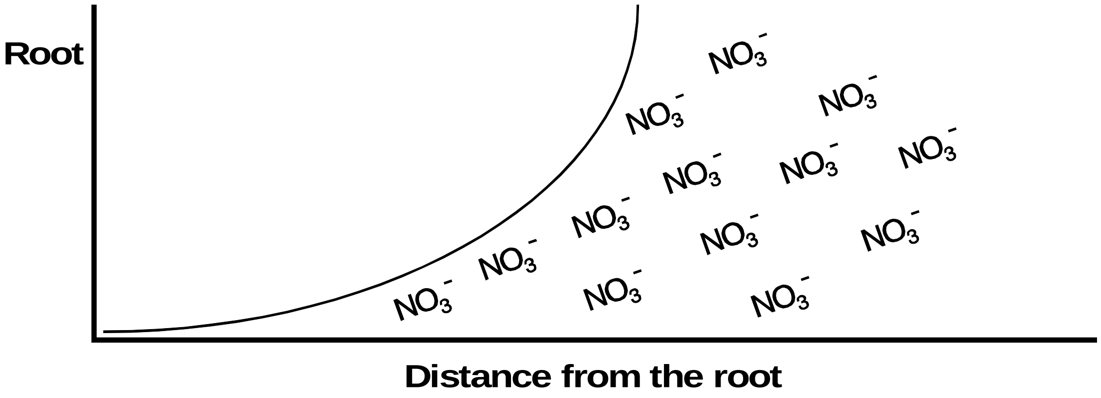
- **Nutrient requirement met by mass flow using a corn plant as an example:**

Nutrient	Content of Corn (ppm)	Soil Soln Ccn (ppm)		Amount Trans (ppm)	% Supplied	
Mg	**1,800**	**8**	**x 500**	**4,000**	**220**	**excess**
Ca	**3,000**	**20**		**10,000**	**300**	**excess**
S	**1,700**	**200**		**EXCESS**		**excess**
N	**30,000**	**20**		**10,000**	**33**	
K	**20,000**	**4**		**2,000**	**10**	
P	**2,500**	**0.2**		**1,000**	**4**	

3. Diffusion

- **Defined as:**

- **Illustration:**



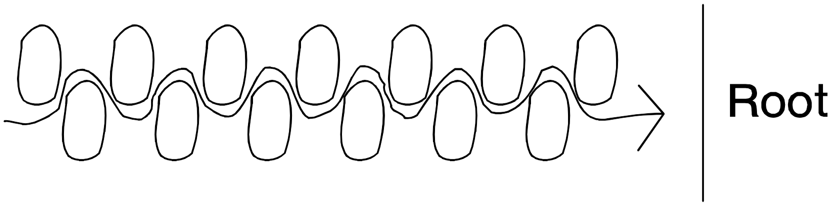
- **So diffusion is movement due to a concentration gradient; get movement from a zone of high concentration to a zone of low concentration**

- **Diffusion parameters:**

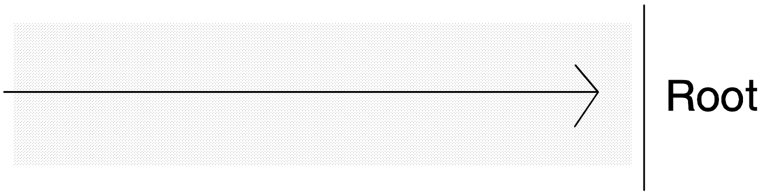
$De = D\theta fy(c1/c)$

D = diffusion in water
θ = volumetric water content
f = tortuosity factor

Sandy soil:



Clay soil:



Shorter path in clay soil:

y = negative adsorption (replusion) and water viscosity

c_1 = concentration of ion at the root surface

c = concentration of the ion in bulk solution

c_1/c = buffering capacity (ability to replace ions in solution)

Rules of thumb:

f - greater in sandy soils than clay soils

θ - higher water holding capacity in clay soils compared to sandy soils

c_1/c - soils with higher clay contents would have higher buffering capacities

D is a factor . . . . . .

θ, f, y, c1, c are factors . . . .

Values of De (cm2/sec):

NH_4^+ -

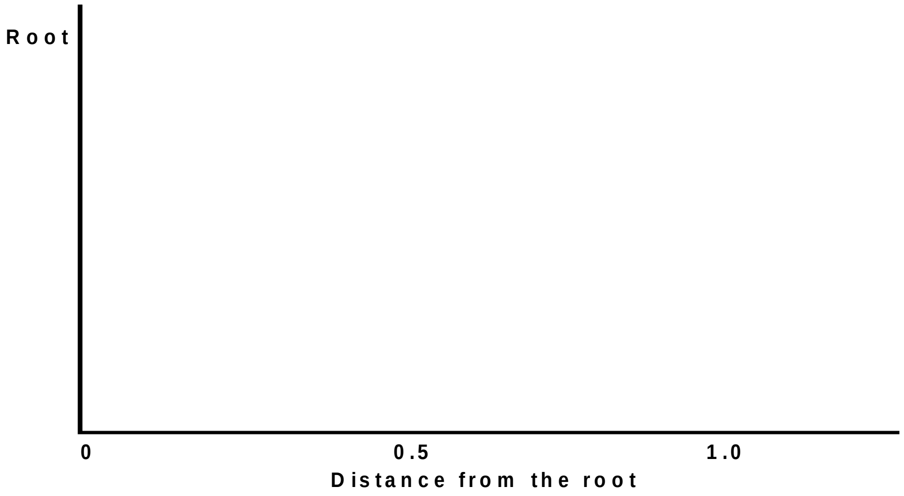
K^+ -

NO_3^- -

$H_2PO_4^-$ -

Movement:

Average distance of diffusion to the root:



So, NO_3^- -

K^+ -

$H_2PO_4^-$ -

Phosphorus movement to roots in the soil:

Example — corn root system

So, actual movement during a growing season is:

LESSON 5
Ion Exchange

Soils are composed of three forms of matter:

1. **Solids**
2. **Liquids**
3. **Gasses**

The solid phase is very important in soil fertility and is composed of:

1. **Inorganic material**
2. **Organic material**

◆ **Cation exchange capacity is primarily composed of clays, organic matter and small silts**

◆ **Because cations are positively charged, they are attracted to surfaces which are negatively charged**

a. Definitions:

***Cation exchange* — the interaction between a cation in solution and another cation on the surface of any surface - active material such as clay or organic colloids.**

***Cation exchange capactiy (CEC)* — the sum total of exchangeable cations that a soil can adsorb. Sometimes called total exchange capacity, base-exchange capacity or cation - adsorption capacity. Expressed in milliequivalents per 100 grams of soil.**

b. The most important factors which influence ion exchange in soils are:

1. **Amount of organic matter present**

   In general — the more OM the higher the CEC

2. **Amount of clay present**

   The more clay → the higher the CEC

3. **Type of clay present**

   Kaolinite
   Illite
   Hydrous Oxides

   Vermiculite
   Montmorillonite

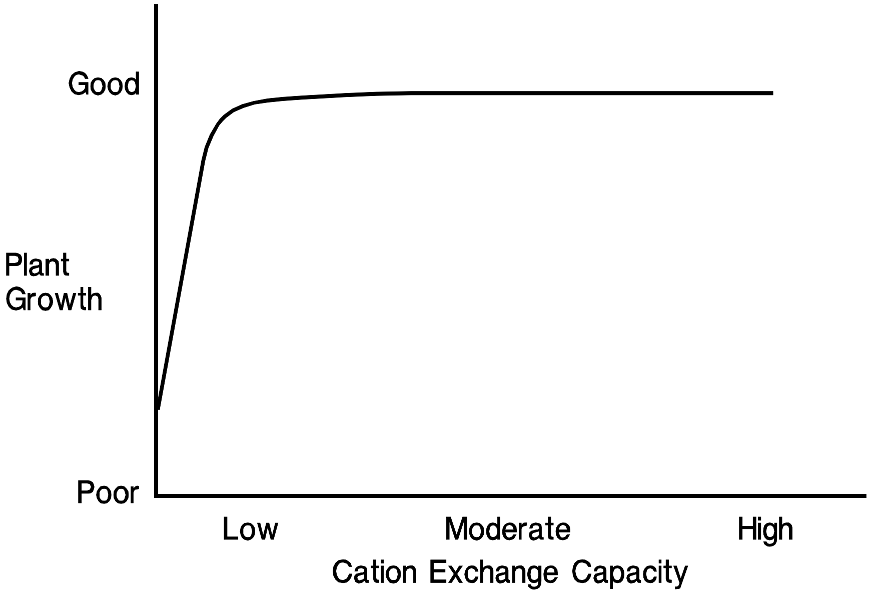
4. **pH of the soil**

   With OM — the higher the pH the more (greater) the CEC

5. **CCN of ions in solution**

   Influence ion exchange — not CEC

c. **There is a relationship between the soils' CEC and its ability to support plant growth**



CALCULATIONS

Basic definitions for calculations:

1. **Equivalent weight — weight of an element that will replace 1.008 grams of H or combine with 1.008 grams of H.**

$$\frac{\text{Atomic weight}}{\text{valence}} = \textbf{equivalent weight}$$

$H = \frac{1}{1}$, $K = \frac{39}{1}$, $Ca = \frac{40}{2}$, $Mg = \frac{24}{2}$, $Al = \frac{27}{3}$

2. Milliequivalent weight — is 1/1000 of an equivalent wt.

$$\text{meq of K} = \frac{39}{1000} = 0.039\text{g}$$

$$\text{meq of Mg} = \frac{24}{2 \times 1000} = 0.012 \text{ g}$$

3. Conversion of meq/100 grams to lbs/acre:

$$1 \text{ meq of Ca per } 100 \text{ g} = \frac{0.020 \text{ g of Ca}}{100 \text{ g of soil}}$$

$$= \frac{.02}{100} \quad @ \quad \frac{x}{2{,}000{,}000} \text{ lbs per 6 inch slice}$$

$$x = \frac{40{,}000}{100}$$

x = 400 lbs of Ca/acre

CLAYS — CEC

CLAY	CEC (meq/100 g)
Hydrous Oxides	3
Kaolinite	10
Illite	30
Montmorillonite	100
Vermiculite	150
Organic Matter	200

Sample Calculation Problems:

1. **Calculate the CEC of a soil when given the clay mineral content and humus content or the quantity of each cation adsorbed on the clay**

a. **What is the CEC of a soil containing 100% clay of which 50% is kaolinite and 50% vermiculite?**

b. **What is the CEC of a soil containing 50% clay of which 40% is kaolinite, 30% illite and 30% montmorillonite?**

c. What is the CEC of a soil containing 3% organic matter and 8% clay which is illite?

2. Calculate the quantity of each cation (in pounds) for an acre furrow slice (AFS) when the quantity of each cation per 100 g of soil is known.

a. For 1 meq of Mg (atomic weight = 24):

b. For 6.5 meq of Ca (atomic weight = 40):

c. For 3 meq of K (atomic weight = 39):

3. **Given an appropriate procedure determine the CEC of this selected soil horizon:**

Sum of cations method:

	meq/100 g
Ca	**8**
Mg	**4**
K	**2**
Al	**3**
Na	**0.2**
H	**0.1**

Determine the soil CEC:

BASE SATURATION

Bases — Ca^{++}, Mg^{++}, K^{+}, Na^{+}, NH_4^{+}

Non-bases — Al^{+++}, H^{+}
(Exch. Acidity)

$$\text{\% Base Saturation (\%BS)} = \frac{\text{meq basic cations x 100}}{\text{TOTAL CEC of soil (or sum of all cations)}}$$

Calculate % Base Saturation for the following:

Given:	**6**	**meq Ca^{++}**
	5	**meq Mg^{++}**
	0.6	**meq K^{+}**
	0.2	**meq Na^{+}**
	3	**meq Al^{+++}**
	1	**meq H^{+}**

CALC of % B.S.

% ALUMINUM SATURATION

$$\text{Al Saturation (Al Sat)} = \frac{\text{meq Al}}{\text{Total CEC of soil}} \times 100$$

without H^{+} in system ($pH > 4.5$):

% Al Saturation = 100% - %BS

% Base Saturation = 100% - Al Saturation

Given:

4 meq Ca^{++}
2 meq Mg^{++}
1 meq K^+
0.5 meq Na^+
0.8 meq NH_4^+
3 meq Al^{+++}

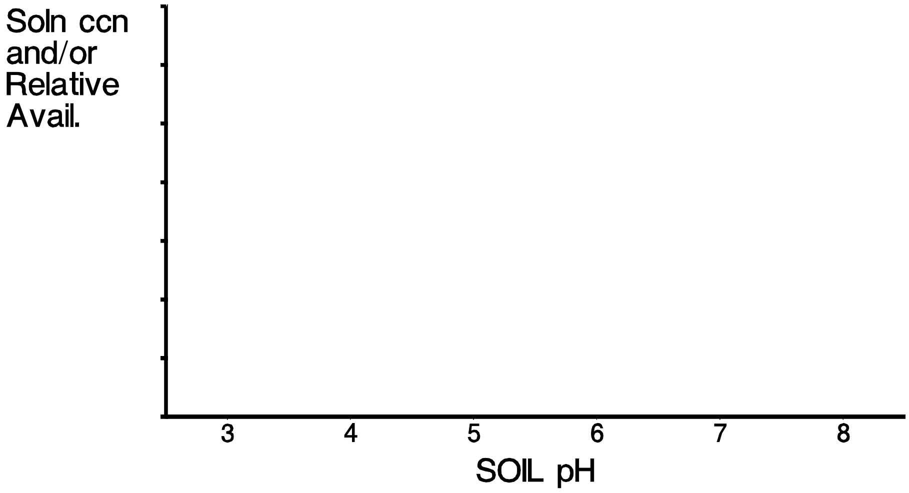
a. Calculate CEC

b. Calculate %BS

c. Calculate % Al Saturation

LESSON 6
Soil pH and its Management

A. Effect of Soil pH on Nutrient Availability



B. Acid Soils

1. Origin of Soil Acidity

a. Removal of Ca^{++} and Mg^{++}

i. Leaching

ii. Crop Removal

▶

- ▶

b. Addition of H^+ to System

i. Decomposition of Organic Matter

- ▶

ii. Roots Emitting H+ for Charge Balance

- ▶

iii. Nitrogen Fixation

- ▶

iv. Acid Rainfall

- ▶

v. Acidity Generated from Ammonium Based Nitrogen Fertilizers

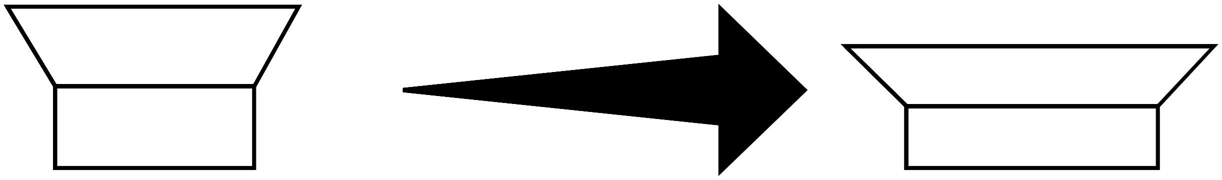
Reaction:

- For every lb of N applied as NH_4^+ → need to add 1.87 to 3.57 lbs of $CaCO_3$ to neutralize the acidity generated
- On a nitrogen basis the most acidifying fertilizers are:

2. Kinds of Soil Acidity

a. Exchangeable Acidity

- Is acidity we can actually measure
- Extract soil with a neutral unbuffered salt solution (KCl, $CaCl_2$)
- Exchangeable acidity is measured from mineral soils
- The chemistry for measurement is as follows:



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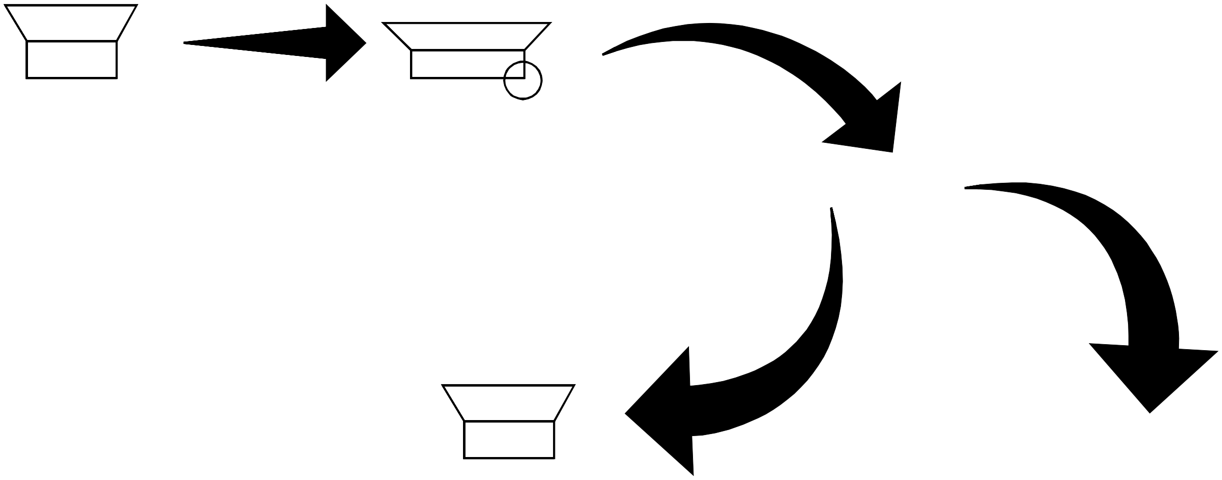
- **The formation of exchangeable acidity is as follows:**



b. Non-exchangeable acidity

- **Organic matter related**

3. Distribution of Soil Acidity

a. World-wide

- **Humid areas of the world tend to be acid; where precipitation exceeds evapotranspiration**

b. United States

i. Eastern United States

ii. West of the Cascades in Washington and Oregon

iii. Acidity Induced by Long-Term Fertilization

- ▶

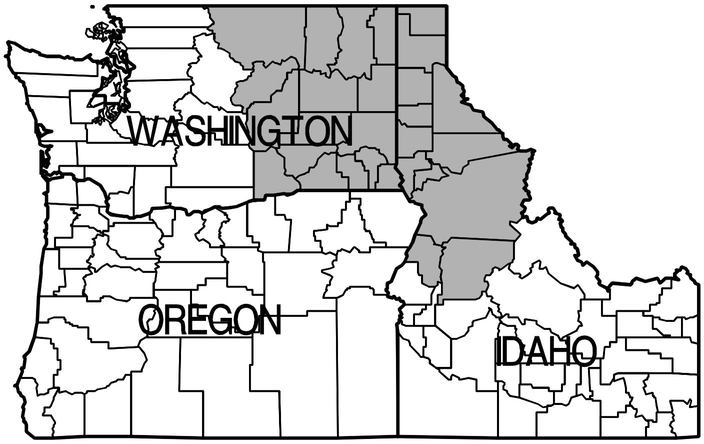
- ▶

4. Soil Acidification Induced by Man

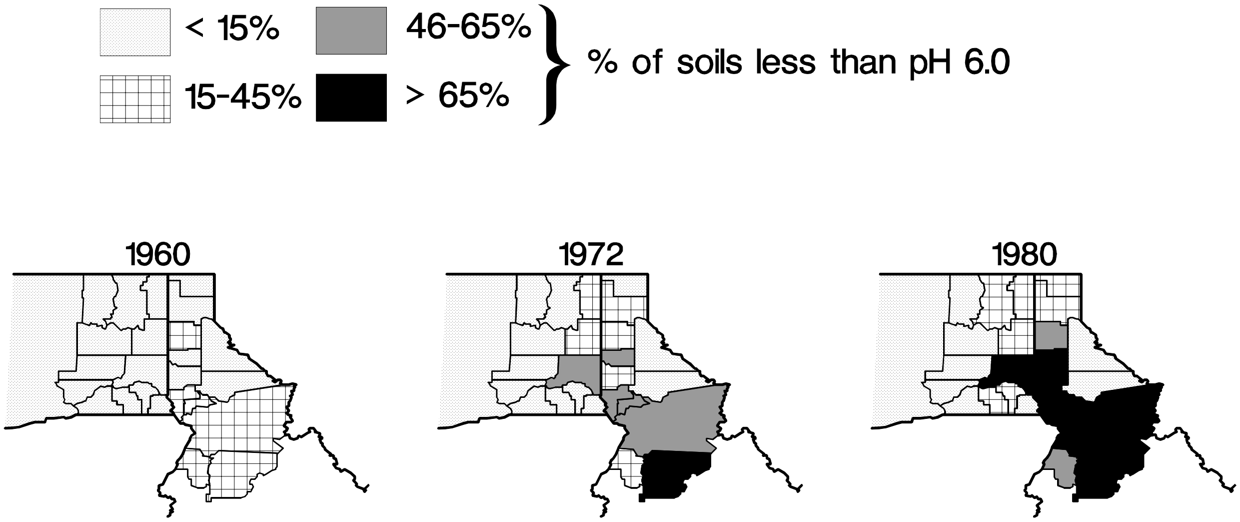
Reading Assignment UI CIS 811

a. Acidification of Soils in Northern Idaho and Eastern Washington

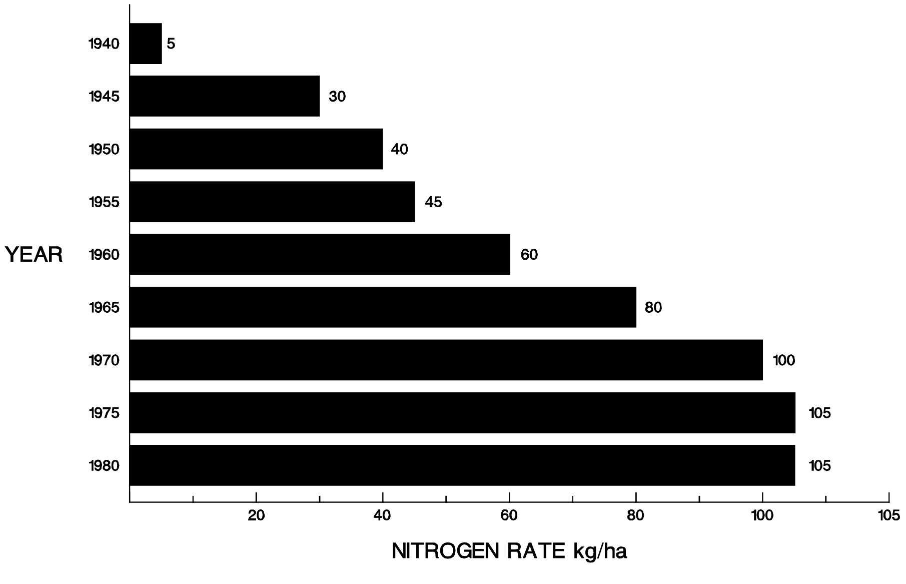
i. The Region



ii. Soil pH Shift Since 1960

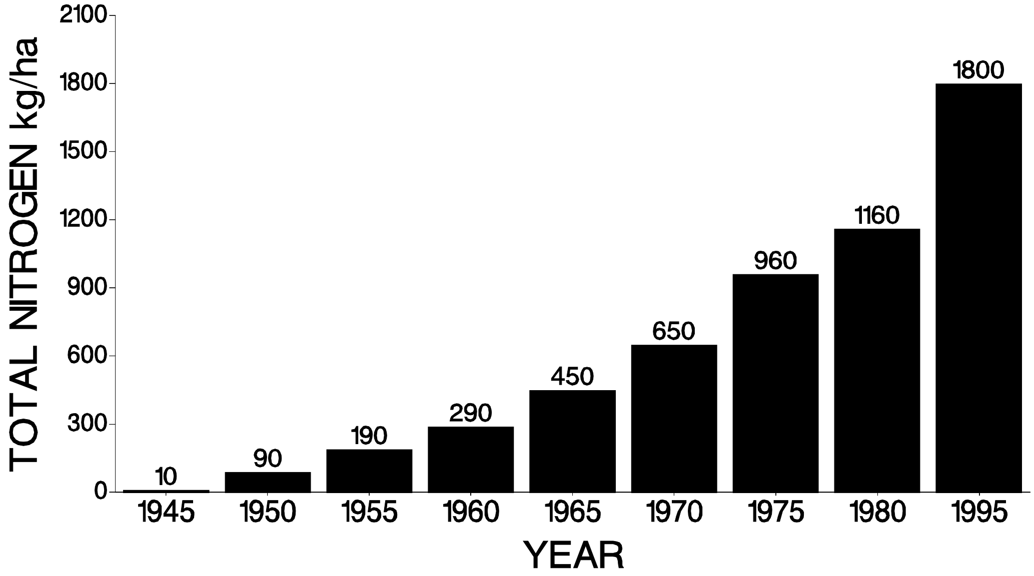


iii. Historical Nitrogen Use



Historic use of N fertilizer on a typical field on the Idaho-Washington border near Moscow, Idaho.

iv. Cumulative Nitrogen Use



Sum total amounts of N applied to a typical field on the Idaho-Washington border near Moscow, Idaho.

v. Current Soil pH Distribution in Northern Idaho

Table 1. Results from soil pH survey conducted on agricultural soils in northern Idaho 1982-84.

Soil pH	% of Fields
> 6.4	6
6.0-6.4	11
5.8-5.9	16
5.6-5.7	22
5.4-5.5	18
5.2-5.3	11
5.0-5.1	10
< 5.0	6

5. Cation Saturation of Acid Soils

a. Mineral Soils

LOCATION	Tex	pH	Exchangeable Ca	Exchangeable Al	(CEC) SumCEC	Saturation Ca	Saturation Al	Soil Ca	Soln Al
			----------meq/100g----------			-----%-----			
Idaho	loam	8.0	7.2	0	8.0	90	0	10.0	0.0
Idaho	si l	5.8	12.0	0.01	19.0	78	0	25.0	.01
N Carolina	l s	4.9	0.6	1.43	1.5	5	95	.75	.55
NS Wales	sa l	4.8	0.9	1.44	3.3	28	44	16.4	.92
Puerto Rico	clay	4.1	0.4	5.35	6.9	6	77	3.2	.31
Brazil	clay	4.5	0.45	1.15	1.6	26	70	1.1	.16

Conclusions from table:

1.

2.

3.

4.

5.

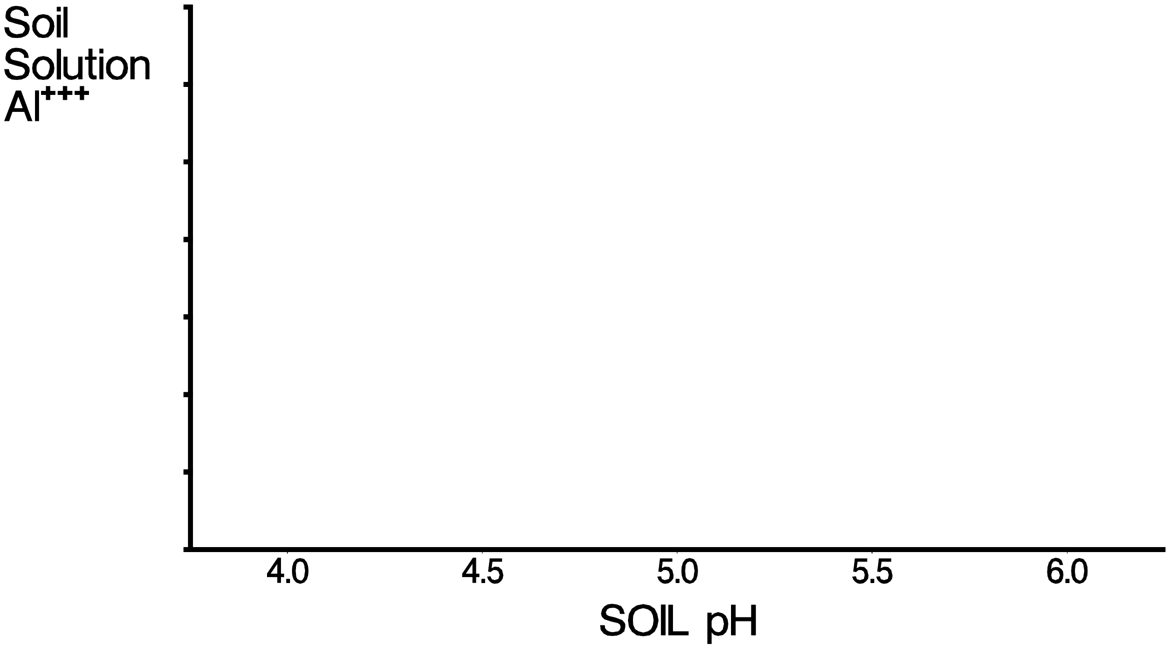
▶

▶

▶

LESSON 7
Soil pH and its Mangement

The influence of soil pH on the quantity of Al^{+++} on the cation exchange sites in a mineral soil:



◆ **As you get to pH 6.0 you have no trivalent Al^{+++} on the exchange sites**

◆

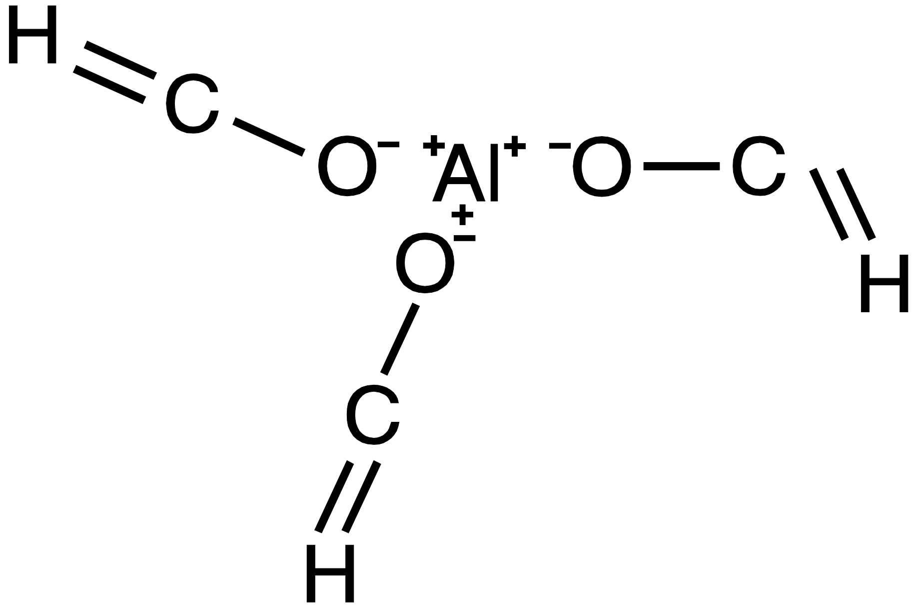
b. Organic Soils (>30% OM)

OM	**pH**	**Exch H**	**Exch Al**
%			
52	**4.1**	**0.78**	**6.82**
52	**4.7**	**0.00**	**2.02**

Why?

- **This is due to the complexing characteristics of Al^{+++} by organic matter**

- **Al^{+++} is bonded to carboxyl as the soil organic matter content increases; the more organic matter the less Al in soil solution:**



6. Aluminum Saturation

- **The calculation of percent aluminum saturation of the CEC is easy and similar to the calculation for base saturation**

$$\% \text{ Al Saturation} = \frac{\text{meq Al} \times 100}{(\text{meq Ca} + \text{meq Mg} + \text{K} + \text{NH}_4 + \text{Na})}$$

- **The calculation of aluminum saturation is important for acid sensitive plants**

Sample Problem:

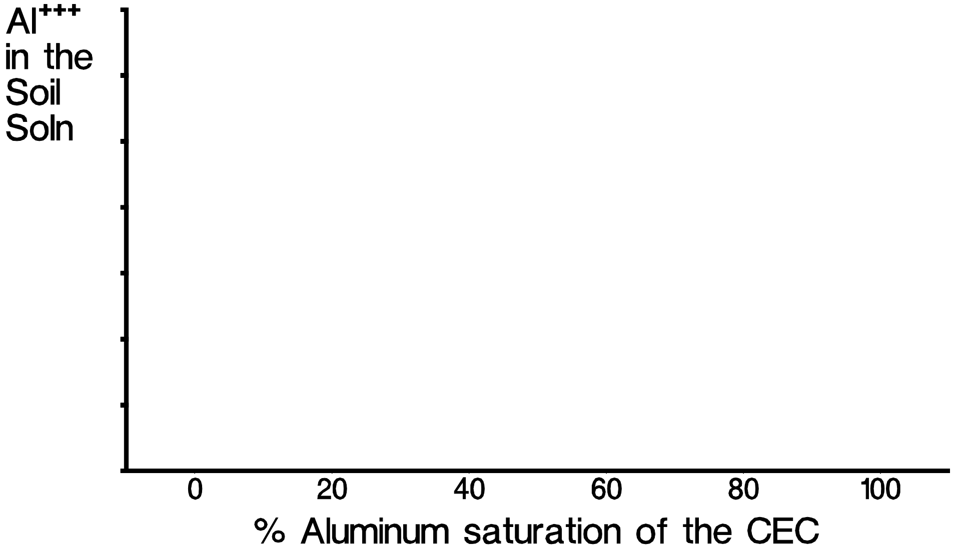
Given: **6 meq Ca**
2 meq Mg
1 meq K
9 meq Al

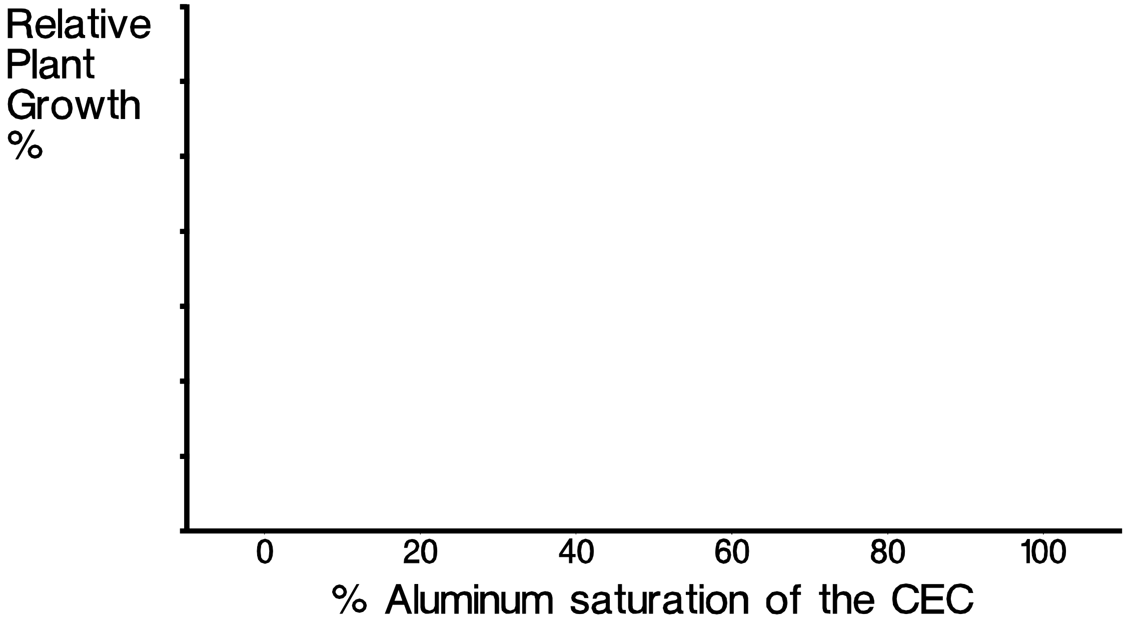
Calculate % Aluminum saturation:

7. Aluminum

◆ **The more Al^{+++} present in the soil the greater the chance of encountering problems with plant growth**

◆ **The greater the percent Al^{+++} saturation of the CEC the more soil acidity problems that are encountered**





◆

▶

◆

▶

◆

8. Specific Effects of Al^{+++} on Plant Growth

a. Toxicity

◆

b. Inhibition of Ca Uptake by Plants

SOIL **PLANT**

|

Al |

Al |

Ca^{++} → Al | **Al^{+++} blocks plant uptake of Ca^{++}**

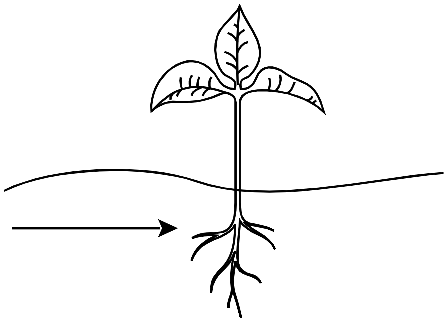
Al^{+++} Al |

Al |

|

- **Physical block**
- **Need at least 15% of the CEC containing Ca for adequate plant uptake; however, high Al saturation can still hurt Ca uptake**

c. Phosphorus Uptake



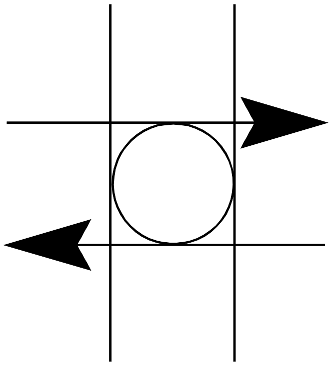
- **Specific effect is precipitation of phosphorus outside the plant root**

9. The Influence of Hydrogen

- **No problems in soils with pH values greater than 4.5**

◆

- The hydrogen interference is not by precipitation; however, it causes irreversible damage to the uptake mechanisms of plant roots:



10. The Influence of Manganese

- In very acid soils there is a potential for toxicity problems
- Note how Mn availability rapidly increases below pH 5.0 — at a much faster rate than any other nutrient (see graph on page 1 on this handout)

11. Other micronutrients

- Most plant micronutrients including Cu, Fe, Mn, and Zn become more available with decreasing soil pH; potential for toxicity of some in very acid soils
- Molybdenum is more available in high pH soils; deficiency problems in acid soils
- Relationship between boron availability and soil pH is not well understood

C. Base Saturation

1. Relationship Between Base Saturation and Plant Growth

- Inverse relationship to percent aluminum saturation
- The higher the base saturation the better the plant growth for most species

- **With legumes you want a base saturation greater than 75%; Conversely you want an aluminum saturation less than 20%**

- **With non-legumes you want a base saturation greater than 45% and an aluminum saturation less than 50%**

- **In most cases (when hydrogen is not present):**

  100% - % Base Saturation = % Al Saturation

D. Liming Acid Soils

1. Problems Associated with an Acid Soil

a. Aluminum Toxicity

b. Calcium Deficiency

c. Magnesium Deficiency

d. Phosphorus Deficiency

e. Micronutrient Toxicity (Mn . . .)

f. Lack of Microbial Activity

- **Is this problem associated with all plants?**

  NO. Some plants like acid environments. These include:

  ▶

  ▶

▶

▶

▶

2. Liming Compounds

◆ **Lime is any material that contains Ca and/or Mg that will neutralize soil acidity**

$CaSO_4$ —

▶

NaOH —

◆ **There are three groups of liming materials:**

1

2

3

◆ **The chemical reaction associated with liming materials:**

LESSON 8
Soil pH and its Management
The Nitrogen Cycle

Soil pH and its Management

a. Carbonates

- **Are the liming materials most available and most widely used**
- **Calcitic Limestone —**
- **Dolomitic Limestone —**
- **An advantage of $CaCO_3$ is that it is more soluble and it reacts quicker than dolomite**
-
- **Marl — naturally occuring low quality $CaCO_3$; contaminate with some clay**
- **Oyster Shells — are $CaCO_3$**

b. Oxides

Calcium Oxide — CaO

Magnesium Oxide — MgO

- **Oxides are manufactured by heating $CaCO_3$ to drive off CO_2**

- **Reaction:**

- **Oxides are also known as:**

c. Hydroxides

- **Water is added back to oxide materials**

$CaO + H_2O \longrightarrow Ca(OH)_2$

$MgO + H_2O \longrightarrow Mg(OH)_2$

- **Also known as:**

F. Soil Alkalinity

◆ **High soil pH can be detrimental to plant growth**

1. Reasons to Decrease Soil pH

- **Improve nutrient availability**
- **Decrease soil diseases**
- **Improve microbial activity in soils**

2. Materials Used to Decrease Soil pH

- **Elemental S**
- **Sulfuric acid**
-

-

- **Reaction using a material to decrease soil pH:**

NITROGEN

A. Humans Need Nitrogen

1. Human requirement

Protein requirement of humans

-

Efficiency of N use:

- **On that basis it takes 38 lbs N/person/year to supply our portein needs;**
- **In temperate areas of the world it takes about 2 acres of land to do this**

2. Rates of Nitrogen Used Worldwide

Country	**Fertilizer N (lb/acre)**	**persons/cult acre**
Netherlands		
Belgium		
Japan		
USA		

Why this distribution?

3. Importance of Nitrogen in Agriculture

- **N is most important nutrient**
- **N is most widely deficient; most widely applied**
- **> 70% of the USA's cropland soils are N deficient**
- **N is the limiting nutrient in many forest soils**

B. The Nitrogen Cycle

- **79% of the atmosphere is N_2**
- **Haber-Bosch process — chemical fixation of nitrogen:**
  - **makes synthetic fertilizers possible**
  - **before the process was invented we relied on legumes for nitrogen**
- **Nitrogen inputs into the biosphere:**

Input Source	millions of metric tons	
BNF	140	
Terrestrial		(40)
Legumes		(90)
Marine		(10)
Synthetic N Fertilizers	77	(10.1 in USA)
Atmospheric Fixation	8	
Juvenile Additions	0.2	

Are synthetic N fertilizers good or bad???

Question for discussion:

- ◆ **What would happen if everyone in the world would stop adding synthetic fertilizers to their crops and decide to become purist organic farmers?**

  1.

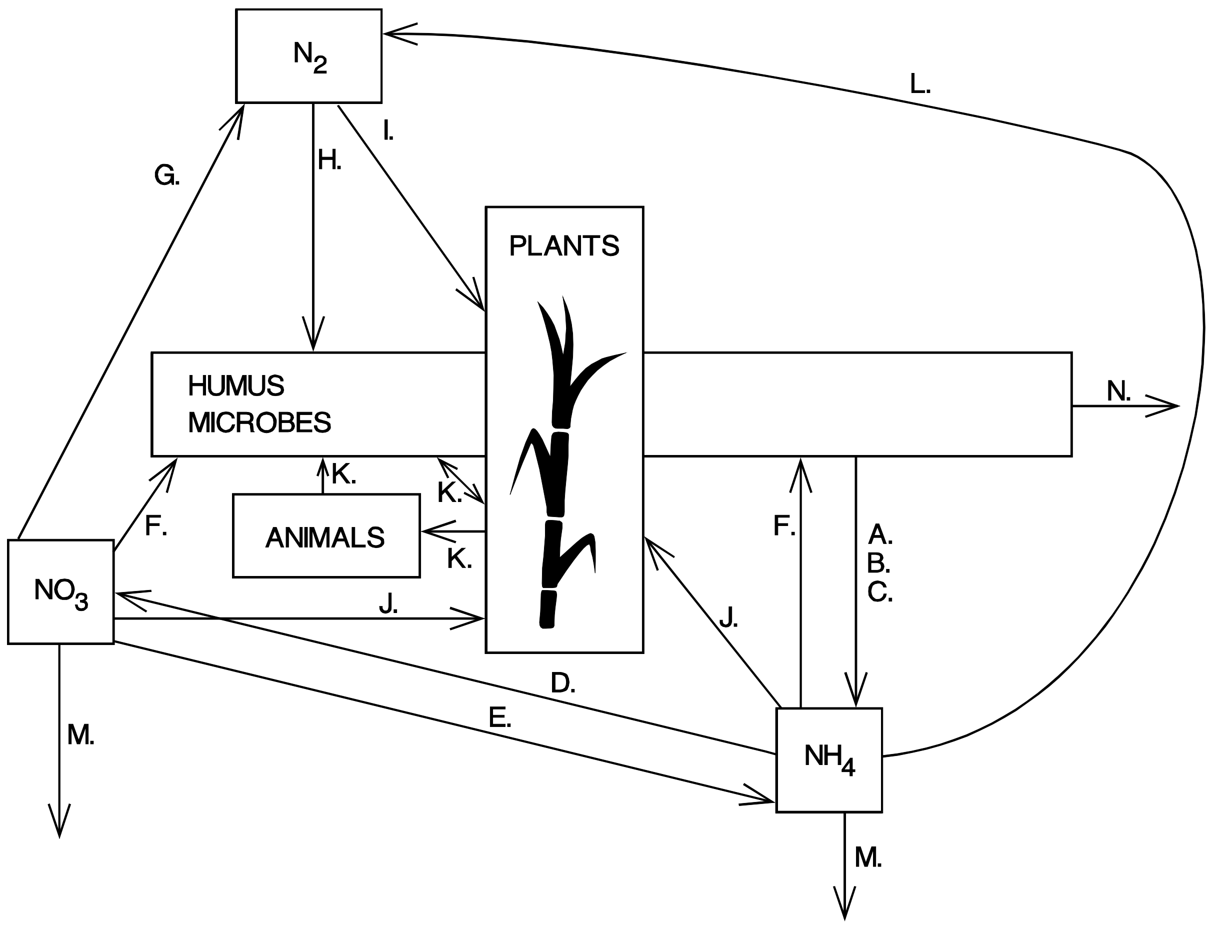
  2.

  3. Marginal lands converted into crop production

  - ▶ **loss of biodiversity**
  - ▶
  - ▶

LESSON 9
The Nitrogen Cycle
Nitrogen Fixation

The Nitrogen Cycle



KEY:

A. ______________________

B. ______________________

C. ______________________

D. ______________________

E. ______________________

F. ______________________

G. ______________________

H. ______________________

I. ______________________

J. ______________________

K. ______________________

L. ______________________

M. ______________________

N. ______________________

C. Nitrogen Fixation

Assignment: CIS 838 — *Inoculation of Legumes in Idaho*

$N_2 \longrightarrow NH_4^+$ (plant usable form)

There are four ways that N_2 can be converted to plant usable form:

1.

2. N_2 fixation by free-living soil microbes

3.

4. Industrial fixation of N_2

Important microbes in nitrogen fixation:

Organism	Description/Properties	Use in Ag/For
Azobacter		
Azospirilla		
Rhizobium	**Symbiotic with legumes**	**Increases legume production up to 300 bls N/acre**
Actinomycetes ***Frankia***		
Blue-green algae ***Anabaena***	**chlorophyll containing aquatic & terrestrial**	**Increase rice production** **Azolla - green manure**

1. Nitrogen Fixation by Symbiotic Microbes

Symbiotic — two organisms living together for the mutual benefit of each other

a. Fixation by Legumes

Legumes:

- ▶ **dicots**
- ▶ **plants of the family Leguminosae**
- ▶ **10,000 species, 200 cultivated by man**
- ▶ **soybeans were the wonder crop of the 1960's; beans the 1990's?**

Amounts of N fixed by legumes:

Legume	Range of N fixed	Typical value
	----------lbs/acre----------	
Alfalfa	150-340	200
Clovers	100-190	130
Kudzu	100-120	115
Soybeans	60-160	100
Cowpeas	80-110	90
Lespedezas	60-90	80
Vetch	60-85	70
Peas	20-80	50
Peanuts	20-70	40
Beans	5-60	30

Important legumes in croplands and forested regions of Idaho:

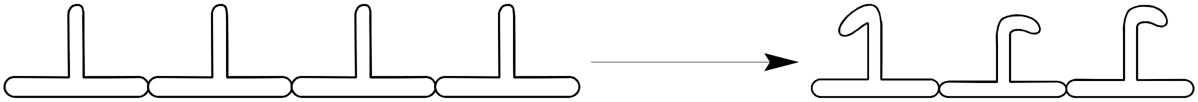
b. Grouping of Legumes

Species	Plants	Cross Inoculation Group
<u>**Rhizobium:**</u>		
R. japonicum		
R. leguminosarum		
R. meliloti		
R. trifolii		
R. lupini		
R. phaseoli		
R. species		

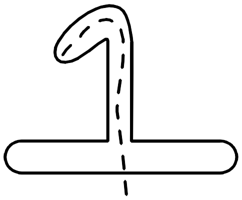
c. Infection and Nodule Formation

(i) increase in the numbers of rhizobia

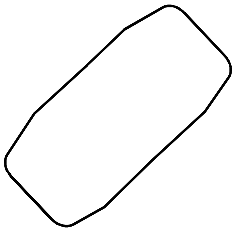
(ii) root hair curls



(iii) infection thread



(iv) bacteria enters the host



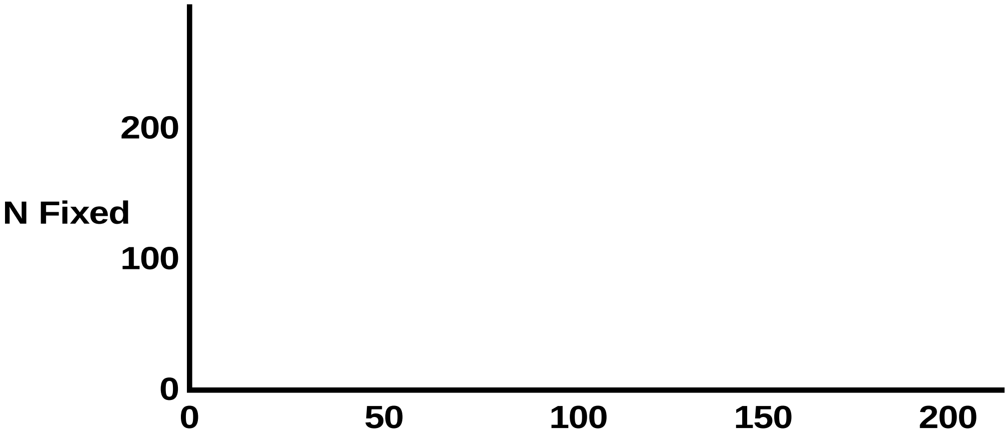
(v) formation of bacteroids

d. Physiological Aspects

(i) the effect of fertilizer N

- **Nitrogen fixation is inhibited by nitrate and ammonium**

If the plant can get N from the soil, the plant will save energy:



(ii) Soil pH

- **Ca deficiency under very low % Base Saturation conditions**
- **Mo deficiencies at low pH values**

(iii) Nutrients

-
-
-

(iv) Moisture

-
- **Range best for plant growth is also best for N2 fixation**

(v) Temperature

- **Most active between 60 and 80° F**
-

e. N_2 Fixation by Leguminous Trees and Shrubs

- **Important in tropical regions, agroforestry systems, forestry**
- ***Mimosa*, *Acacia*, black locust**
- **Alder, Ceanothus in the Pacific Northwest**
    - **Actinomycete — *Frankia***

2. N_2 Fixation by Non-symbiotic Microbes

Asymbiotic — organisms that fix nitrogen without the aid of a host

Blue-green algae

-
-
-

Beijerinckia

Azosprillum

- **root surfaces of corn and grains; grasses**

Azotobacter* and *Clostridium

3. N Additions from the Atmosphere

- **rainfall returns NH_3, NO_2, etc**
- **lightening discharges**

4. Industrial Fixation

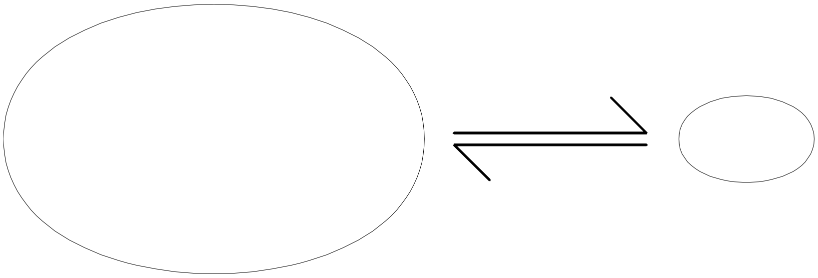
Haber-Bosch Process:

$$3H_2 + N_2 \xrightarrow[\text{catalyst + heat}]{} 2NH_3 \text{ (anhydrous ammonia)}$$

- **$3H_2$ is from natural gas (CH_4)**

LESSON 10
Forms of N in the Soil
Mineralization/Immobilization Processes

D. Forms of Nitrogen in the Soil



Organic nitrogen -

Inorganic nitrogen -

1. Inorganic Forms of Nitrogen

a. Ions

- **ammonium — NH_4^+ plant available**
- **nitrate — NO_3^- plant available**
- **nitrite — NO_2^- - toxic to plants**
- **these three forms comprise 2% of all the N in the soil**

b. Gases

- **N_2**
- **NO**
- **N_2O**

2. Organic Forms

- **95 to 98% of all the nitrogen in the soil**

a. Proteins

b. Amino Sugars

3. Forms of N absorbed by Plants

Only two major forms:

- **ammonium**
- **nitrate**

E. Mineralization/Immobilization Processes

1. Nitrogen Transformations in Soils

a. C:N Ratios, Mineralization, and Immobilization

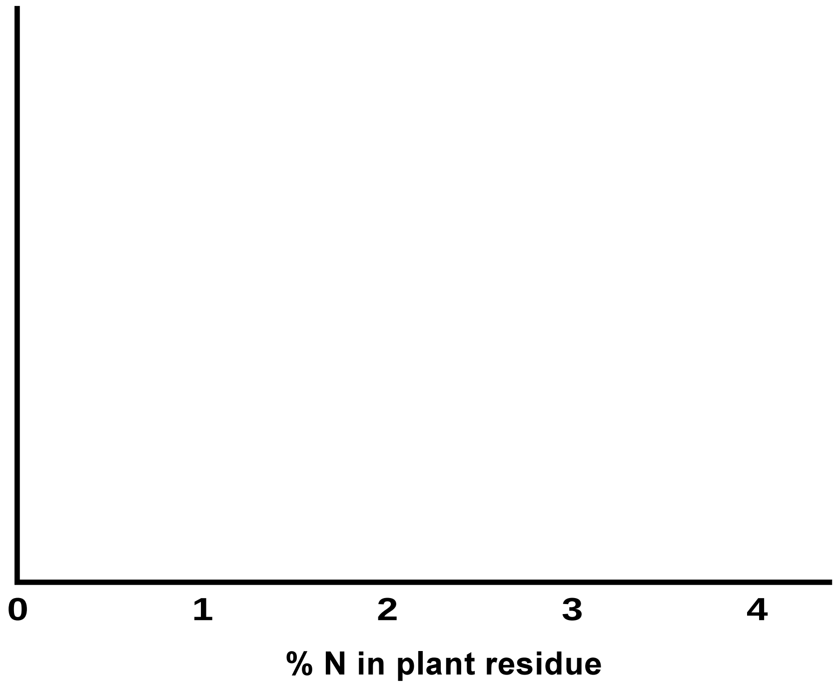
***Mineralization* — the conversion of N from the organic form to an inorganic state as a result of microbial decompostion of organic material**

***Immobilization* — the conversion of N from the inorganic form to the organic form as a result of microbial decomposition, thus rendering the nutrient not available to the plant**

Factors that affect the process:

i. Total N

- **amount of N released is proportional to the quantity of substrate being decomposed**
- **2% N is recognized as being critical; >2% N in material → net mineralization**



ii. Substrate Composition, or C:N Ratio

- ◆ **wide C:N ratio (>30:1) — net immobilization**

- ◆ **narrow C:N ratio (<20:1) — net mineralization**

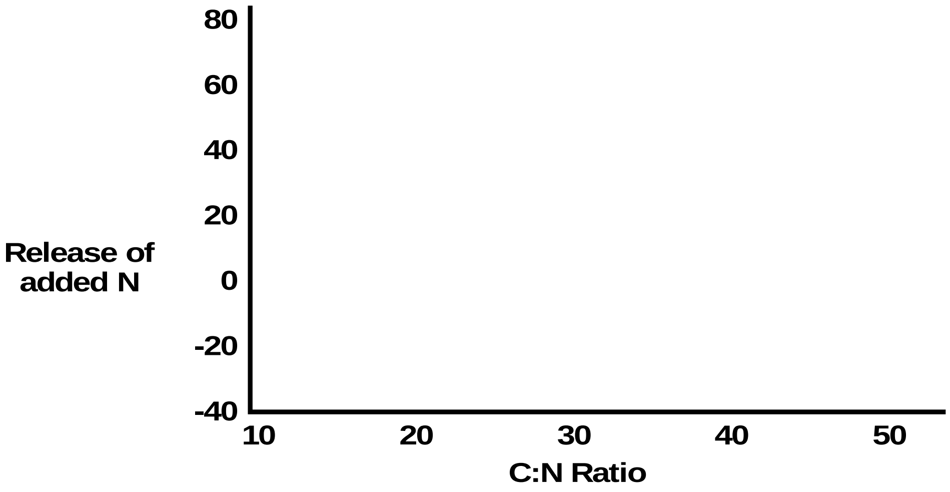
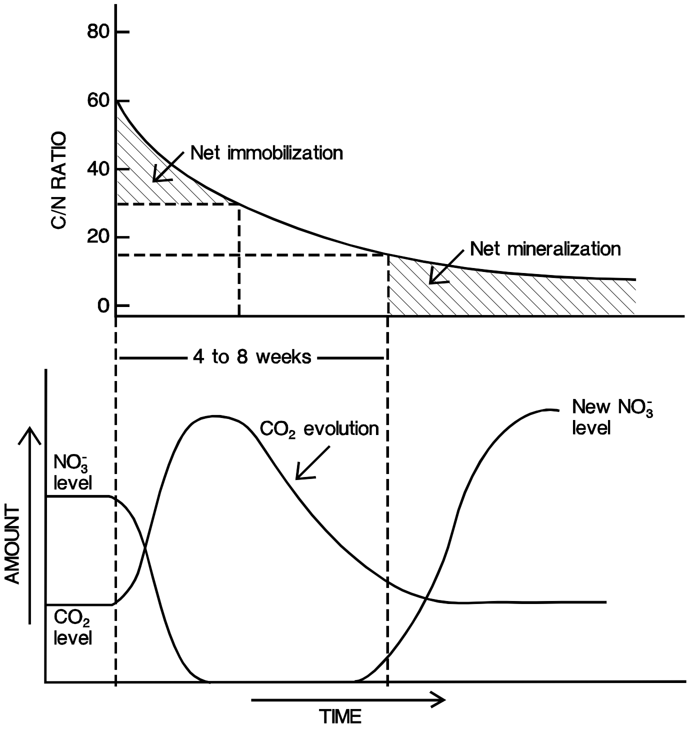


Figure from “Soil Fertility and Fertilizers,” Fifth Edition, 1993; S. L. Tisdale, W. L. Nelson, J. D. Beaton, and J. L. Havlin.



Critical values of %N in C:N ratios: (after Harmsen and Schreven 1955 Adv. Agron. 7:299-398)

Lab data:

Treatment	**-----------------Time of incubation-----------------**			
	0 days	**10 days**	**37 days**	**73 days**
	---------------measured inorganic N---------------			
soil	**52**	**60**	**64**	**67**
soil + alfalfa	**58**	**57**	**70**	**72***
soil + corn stalks	**52**	**48**	**45**	**46****

*** narrow C:N ratio — release of N (mineralization)**

**** wide C:N ratio — good source of energy but low in N — tie up of N (immobilization)**

iii. Other Factors

Time —

Temperature —

pH —

Soil moisture —

iv. Reactions Taking Place

- **Involves microorganisms; organic materials are the source of energy and carbon**

2. Mineralization — the Process

2 step process:
a. aminization
b. ammonification

a. Aminization

- **process carried out by heterotrophic microorganisms**

$$\text{PROTEINS} \longrightarrow \text{R-NH}_2 + \text{CO}_2 + \text{ENERGY} + \text{other products}$$

- **hydrolytic decompostition of proteins and the release of amines and amino acids**

b. Ammonification

- **process carried out by heterotrophic microorganisms**

$\text{R-NH}_2 + \text{HOH} \quad \text{NH}_2 + \text{R-OH} + \text{energy}$

$\searrow + H_2O$

$NH_4^+ + OH^-$

c. Mineralization Rates of Soil Organic Matter

- **Ranges between 1 and 3% per year**

Cool season crops:

Warm season crops:

Very warm season crops:

Temperate forests:

- **basically temperature and moisture determine whether 1, 1.5, 2, 2.5 or 3% of the soil organic matter can be mineralized in a year/season**
- **On the average, soil organic matter contains about 5% nitrogen**

Example Questions:

1. ***How much N will be mineralized over the growing season if the crop is winter wheat and the soil contains 2% organic matter?***

2. ***How much N will be mineralized in a soil containing 3% organic matter and the crop being winter wheat?***

LESSON 11
Mineralization/Immobilization Processes
Nitrate and Groundwater

Mineralization/Immobilzation Processes

d. What about straw additions to the soil?

- **straw additions with wide C:N ratios to soils cause net immobilization;**
  this requires the addition of extra fertilizer N . . . for the microbes
- **rule of thumb is to add 15 lbs of nitrogen per ton of straw up to 50 lbs of N**

Example:

How much N should I add if I plow down 4 tons of corn stubble?

3. Nitrification

Process - mediated by nitrifying bacteria — mainly autotrophs

2 Step Process:

1.

bacteria:

2.

bacteria:

Nitrifying organisms:

autotrophs — bacteria

- **need organic N for energy**
-

heterotrophs —

-

Factors Affecting Nitrification:

a. Supply of NH_4^+

- **need ammonium for nitrification to occur**
- **too much ammonium (>800 lbs/acre) may be toxic to nitrifying microbes, however**

b. Supply of Nitrifying Organisms

- **present in most soils**
- **may be absent if the soil has been recently fumigated**
- **may be absent if a nitrification inhibitor has been recently applied**

c. Temperature

- **significant impact on the speed of nitrification**

Lab study (reference: Frederick 1956 SSSAP 20:496-500):

Temperature °C	°F	Nitrification rate ppm N/week
Initially added 180 ppm N as ammonium phosphate		
2	36	2
7	45	10
15.5	60	45
21	70	60
27	81	90
35	95	120

Conclusions:

Field study (reference: Sabey et al. 1956 SSSAP 20:357-360):

Date applied	**ppm NH_4**	**date sampled**				
		9/28	**10/5**	**10/19**	**10/26**	**11/16**
		ppm ammonium*				
Sept 28	**0**	**5**	**5**	**6**	**-**	**7**
	50	**44**	**34**	**23**	**-**	**17**
	100	**90**	**63**	**51**	**-**	**32**
Oct 26	**0**	**8**			**8**	**7**
	50	**5**			**59**	**51**
	100	**+**			**86**	**91**

***assume that what is not there is now nitrate**

Temperatures: Oct 5 60°F
Oct 19 63°F
Nov 16 43°F

Their conclusion:

d. The Effect of soil pH:

Field study (reference: Frederic last article; Dancer et al. 1973 SSSAP 7:67-69):

-applied 100 ppm of N as ammonium sulfate, incubated soils for 30 days at 24°C and looked at maximum rate of nitrate accumulation:

Field pH	**Maximum rate of nitrate accumulation ppm**
4.6	**2.9**
5.5	**8.4**
6.1	**11.9**
6.3	**19.6**
6.4	**17.4**

Conclusions:

e. Commercial Nitrification Inhibitors

Products available:	**N-Serve (Nitrapyrin)** **AM** **Dwell**

Process:

Desirable traits:

1. **non-toxic to plants**
2. **block conversion of ammonium to nitrite**
3. **not interfere with the transformation of nitrite to nitrate**
4. **be able to move with the fertilizer so that it will be distributed uniformly throughout the soil**
5. **be able to maintain inhibitory action for periods ranging from several weeks to months**
6. **be relatively inexpensive**

Regional success:

Alternative Management Strategies:

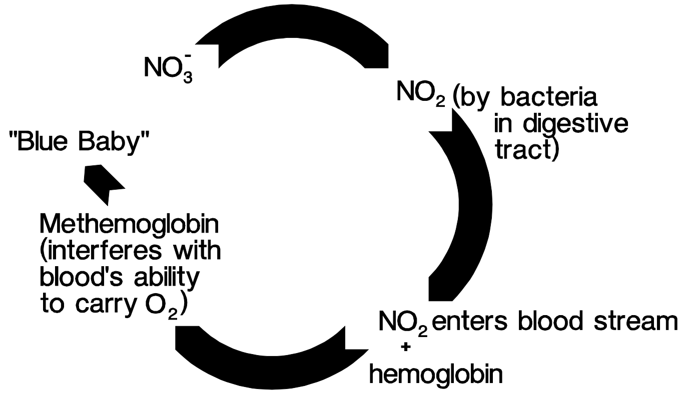
F. Nitrate and Groundwater

- **>50% of the nations drinking water is groundwater**
- **95% of Idahoans rely on groundwater for drinking water**
- **Major potential groundwater contaminant is nitrate**

1. Health Concerns

a. Humans

- **Ingest nitrate in food and water**
- **In older children and adults, nitrate is ingested, absorbed from the digestive tract and excreted rapidly in the urine**
-
- **Effects of long-term consumption of high levels of nitrate are uncertain**
- **Infants are the problem! (less than 6 months old)**
- **Bacteria present in their digestive systems at birth can change nitrate to toxic nitrite**
-
- **Nitrite is absorbed and enters the bloodstream; reacts with oxygen carrying hemoglobin and forms methemoglobin**
- **Interferes with the blood's ability to carry oxygen**
  -
- **Called "Blue Baby Syndrome"**



- **Infant deaths are rare; but only a few cases are documented**
-

b. Livestock

- **High levels of nitrate in water can be toxic to young livestock**
- **Especially to ruminant animals like cattle and sheep**

c. Nitrate Guidelines

- **Guidelines for use of water with known nitrate-N content:**

  0 to 10 ppm nitrate-N:

  - **safe for humans and livestock**

  11 to 20 ppm nitrate-N:

  -

  21 to 40 ppm nitrate-N:

  - **short-term use acceptable for human adults and livestock unless food or feed sources are very high in nitrate**
  - **long-term use could be risky**
  - **do not use for human infants**

  41 to 100 ppm nitrate-N:

  -

Over 100 ppm nitrate-N:

Do not use!

2. Nitrates in Groundwater

- **Between 1988 and 1990 the US-EPA conducted a national survey on nitrates in groundwater. Over 1300 wells were sampled.**

- **Two well types were evaluated:**

    - **Community Water System Wells (CWS)**
    - **Rural Domestic Wells (RDW)**

- **EPA estimates that nitrate is present, at or above the minimum reporting limit of 0.1 ppm in 52% of the CWS wells, and 57% of the rural domestic wells nationwide.**

- **Nitrate levels exceeded federal health standards 1.2% of the time for CWS wells and 2.4% of the time for RDWs**

- **The EPA concluded that on a national basis our water is safe from toxic levels of nitrates; however, legislation is needed to ensure a safe drinking water supply in the future**

- **See handout for other details on EPA survey and Idaho Wellhead Survey**

LESSON 12
Nitrate and Groundwater
Retention of Nitrogen in the Soil
Leaching

Nitrate and Groundwater

3. Sources of Nitrate in Groundwater

- **Agriculture**
- **Septic Tanks**
- **Forestry**
- **Mining**
- **Industry**

4. Prevention of Groundwater Pollution

- **Adoption of Best Management Practices (BMPs)**
- **Laws for Forestry, Mining and Industry**
- **Voluntary for Agriculture at present time**

a. Examples of BMPs for Agriculture

◆ **Apply nitrogen at recommended rates for crop production**

◆ **Utilize preplant soil profile nitrate testing and soil and plant nitrate testing when appropriate**

◆

◆ **Credit nitrogen contributions from legumes, manure, and other organic wastes**

◆

◆ **Do not apply nitrogen fertilizer in the fall on coarse textured soils or shallow soils over fractured bedrock**

◆ **Utilize nitrification inhibitors to minimize leaching**

◆ **Manage fertigation systems carefully**

◆ **Diversify crop rotations to include crops that can utilize residual nitrogen**

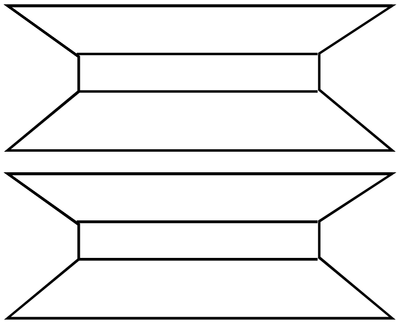
G. Retention of Nitrogen in the Soil

1. Exchange Reactions

2. Nitrogen Immobilization

3. Ammonium Fixation

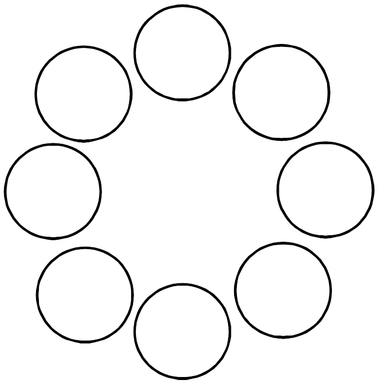
- **Defined as —**
- **Generally restricted to soils of specific mineralogies**
- **Clay minerals with 3 layers can particularly fix ammonium; vermiculite can fix a lot of ammonium**
- **Some fixation with illite**
- **Actual amount of ammonium fixation depends on the amount of K+ in the system in the fixed position**
- **The more K fixed the less ammonium can be fixed**
- **Montmorillonite does not fix ammonium under wet soil conditions**
- **The source of charge on clays is important in determining if ammonium will be fixed:**



- **So a lot of ammonium and K are trapped here in vermiculite**

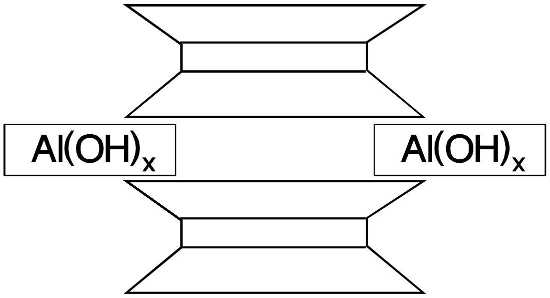
- **Ammonium and K are trapped here in montmorillonite**

- **Fixation occurs because of size of cavity left by oxygen in clays; this hole will hold potassium and ammonium ions but is too small for other ions**



- **Kaolinite does not fix ammonium**

- **Hydrous oxides at low soil pH values do not fix ammonium or potassium because AL(OH)$_x$'s exist in the interlayers; these compounds satisfy the clays' charge and keeps the interlayer propped open, so no fixation occurs:**



H. Leaching

- **Leaching is a major mechanism for loss of nitrogen, particularly nitrate, from soils**

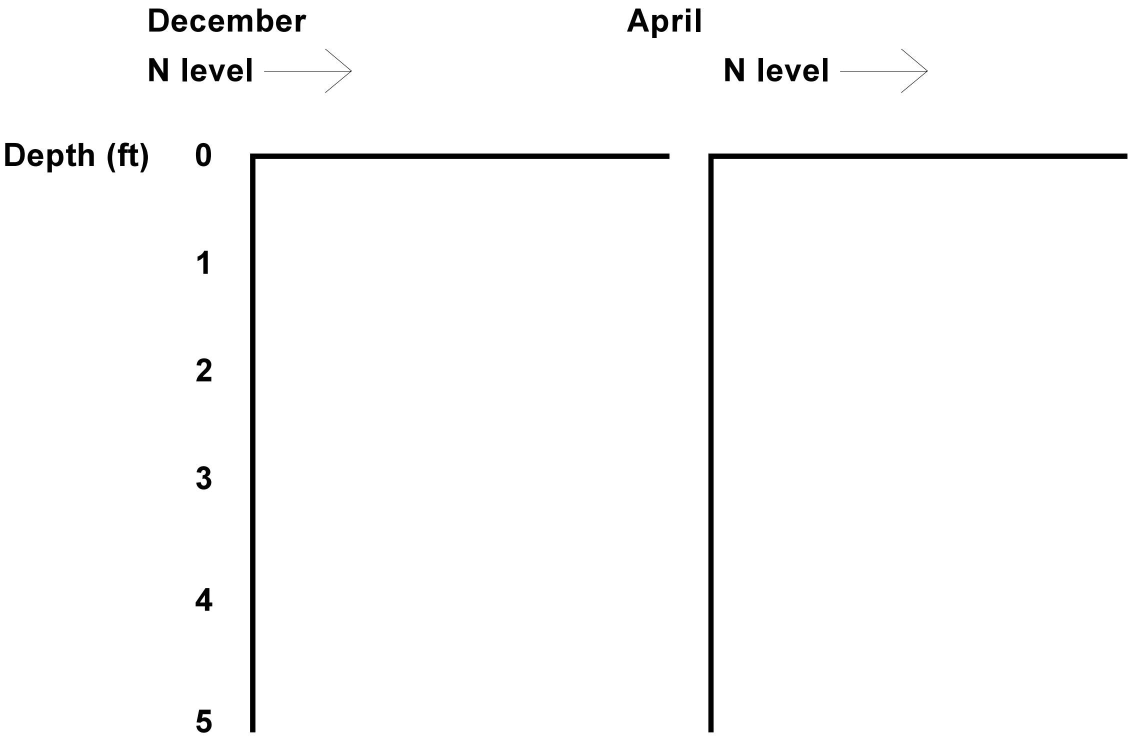
- **Factors that affect leaching include:**

  a. Soil clay content

  b. Soil permeability

  c. Amount of water flowing through soils

1. Difference between Ammonium and Nitrate:



Conclusions from figure:

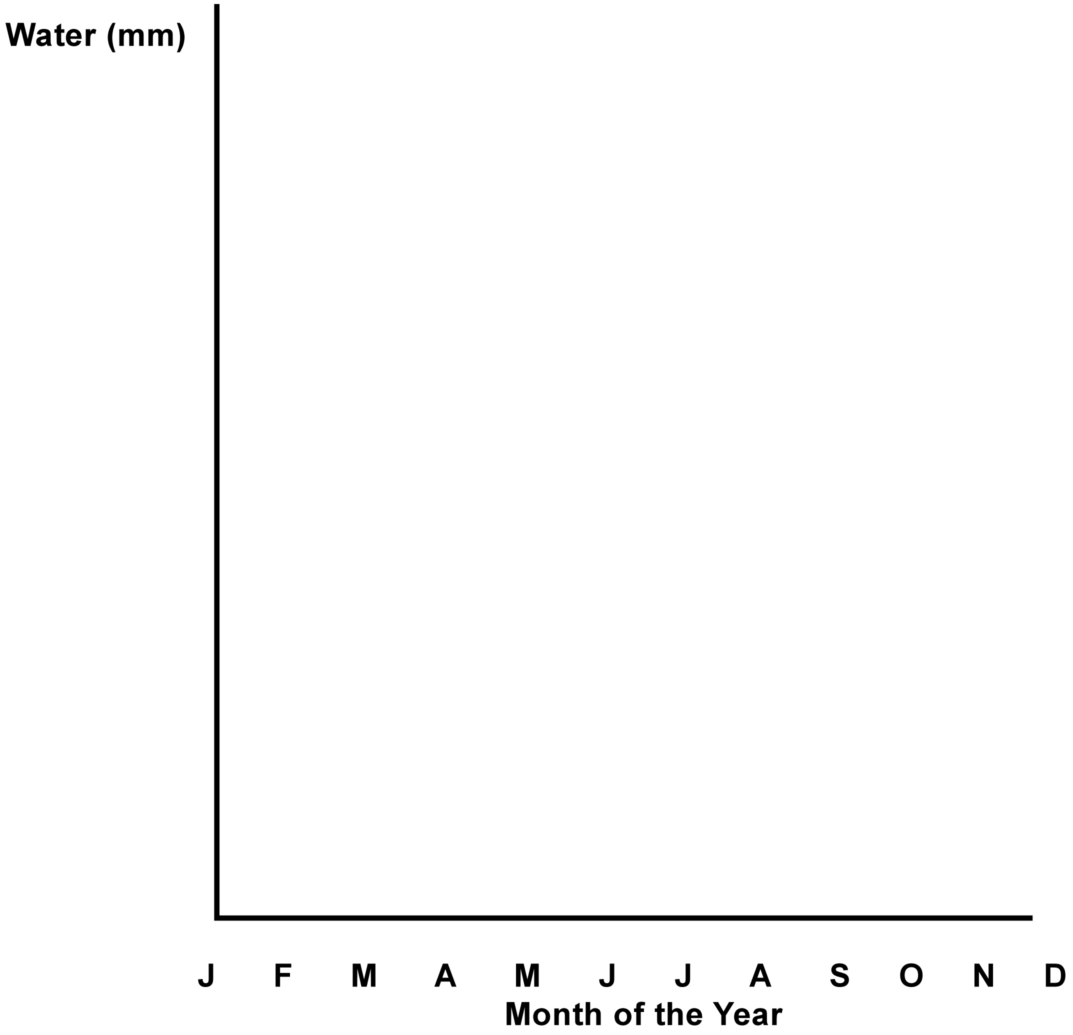
2. Relationship between Evapotranspiration and Rain

Things to consider:

Precipitation

Potential Evapotranspiration

Actual Evapotranspiration



- **Based on the above graph answer the following:**

When is leaching a problem?

When is it safe to apply nitrogen?

When do plants suffer water stress?

LESSON 13
Gaseous Losses of Nitrogen
Plant Response to Nitrogen Fertilization

I. Gaseous Losses of Nitrogen

◆ **Leaching and crop removal are not the only means by which nitrogen can be lost from soils**

1. Denitrification

◆ **Defined as —**

◆ **Organisms involved:**

◆ **Reaction in the soil:**

$$2HNO_3 \xrightarrow[-2H_2O]{+4H} 2HNO_2 \xrightarrow[2H_2O]{+2H} 2NO \xrightarrow[H_2O]{+2H} N_2O \xrightarrow[-H_2O]{+2H} N_2$$

Factors affecting denitrification:

a. Water and Oxygen Supply

- **If you have O_2 you do NOT get denitrification; so microbes will get their oxygen from O_2**
- **If you have less than 0.2 ppm O_2 in the soil water you will get denitrification**

b. Energy Source

- **Need soil organic matter as energy source**
- **Without organic matter you get no denitrification**

c. Soil pH

- **Regulates the speed of denitrification**

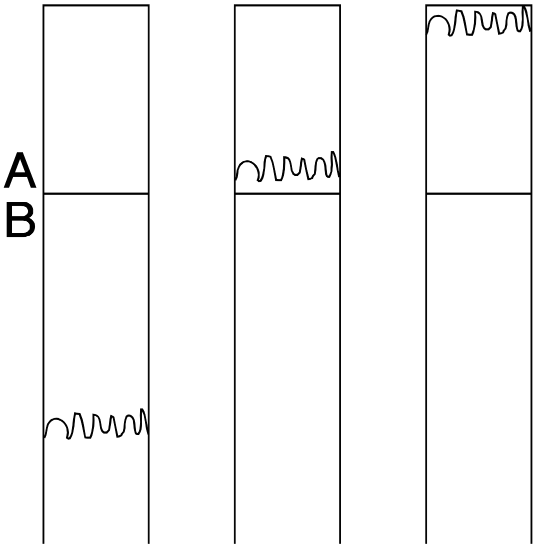
d. Temperature

- **Also regulates the speed of denitrification**
- **The warmer the temperature the faster the rate of denitrification**

Required factors for denitrification:

Examples: Soil profiles

Where will denitrification occur?

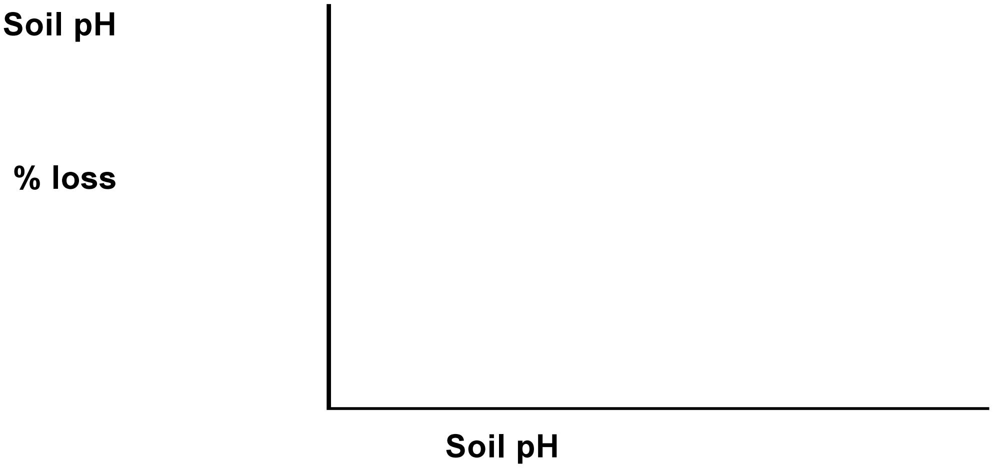


2. Ammonia Volatilization

- **Defined as —**

Factors affecting volatilization

a. Soil pH



b. $CaCO_3$ Content

c. Soil CEC

d. Soil Texture

e. Temperature

f. Soil Moisture

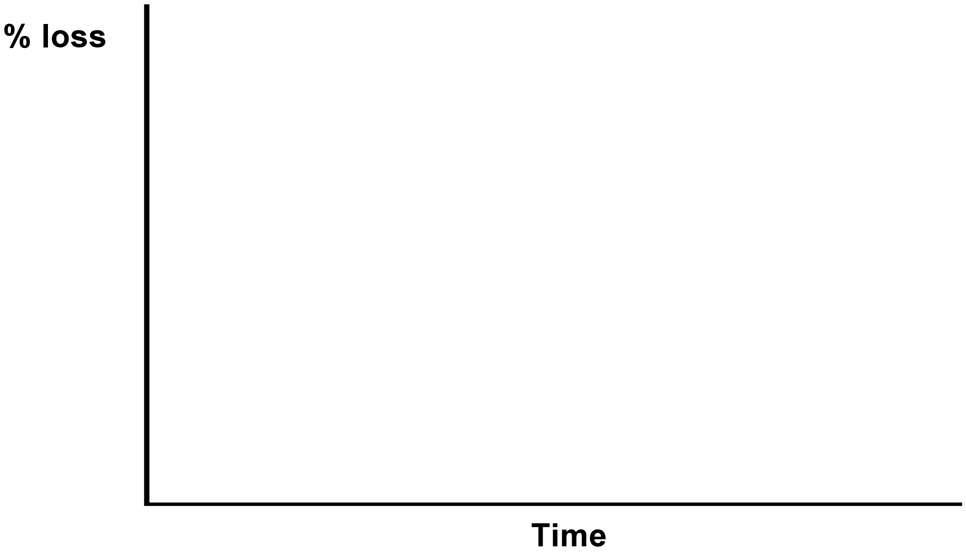
g. Wind

3. Urea — Major Fertilizer Material

◆ **UREA — why is it important?**

a. Reactions in the Soil

b. Management Considerations

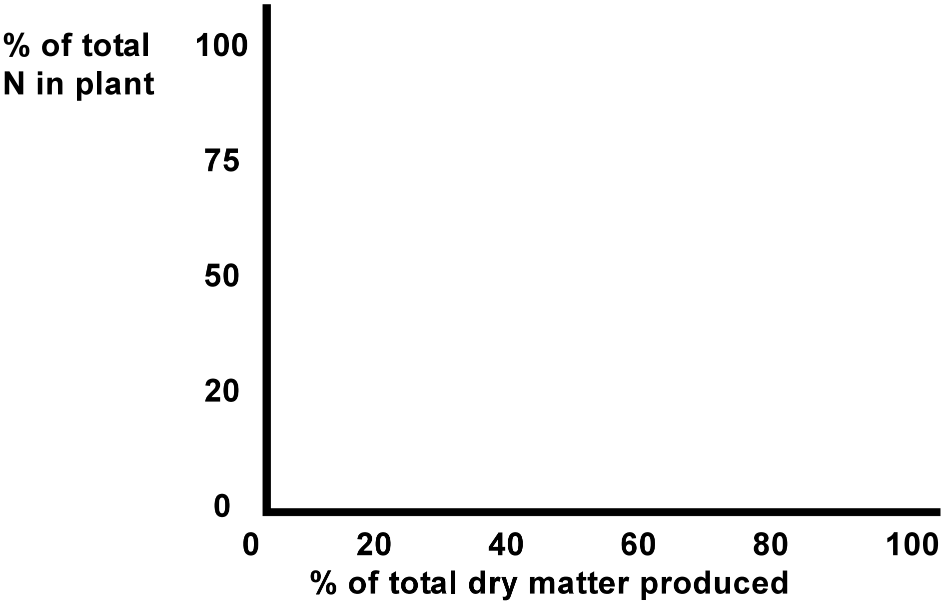


- **Recommendations:**

J. Plant Response to Nitrogen Fertilization

1. Nitrogen Uptake

a. Uptake in relation to dry matter production



Why this distribution?

1. Young plants have a high protoplasm to structural parts ratio

2.

Maximum rates of N uptake:

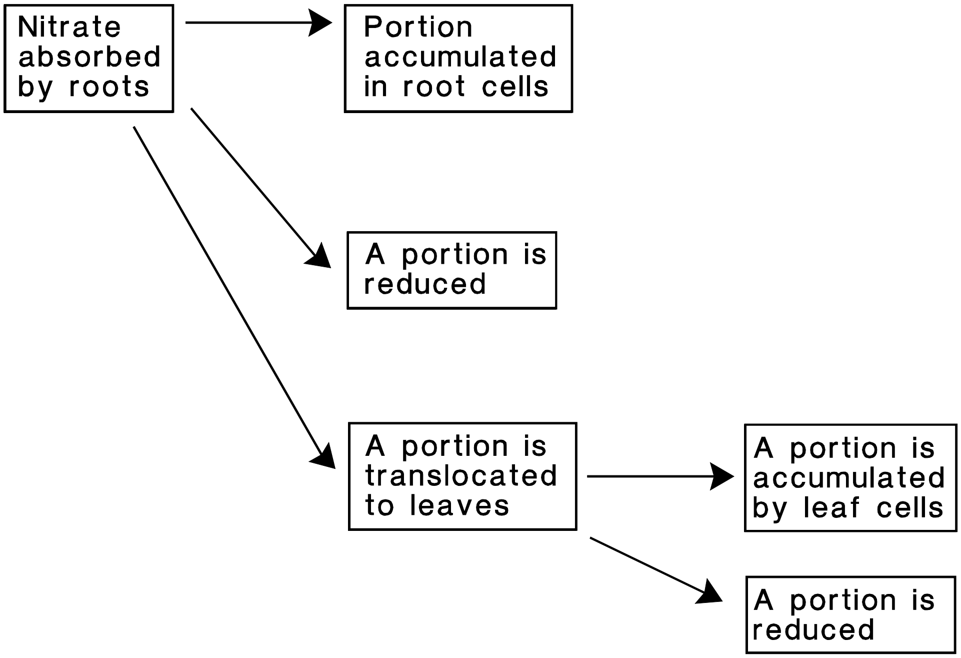
Crop	Total N uptake	Growth Period	N Uptake/day lb N/acre/day
Corn		Just prior to tasseling	
Lettuce		Prior to 1st harvest	
Potatoes		65-76 days after planting	
Cotton		90-105 days after planting	

2. Effect of N Source

a. Nutritional Aspects

(i) Reactions in the plant

NH_4^+	**can enter into organic combinations in plants**
NO_3^-	**must be reduced before plants use it**



(ii) Accumulation

NH_4^+ -

NO_3^- -

(iii) Detrimental Effect of NH_4^+

- **use CHOs to synthesize nitrogenous compounds**
- **so you end up with less CHOs for plant growth**
- **so for effective NH_4^+ use by plants you need plenty of CHOs**

LESSON 14
Plant Response to Nitrogen Fertilization Predicting Nitrogen Needs

Plant Response to Nitrogen Fertilization

b. Growth of Plants on Ammonium and Nitrate

Ref: Barker et al., Crop Sci. 5:439-444

Treatment	Roots	Tops
	g/plants	
Ammonium sulfate	3.1*	5.5
Calcium nitrate	25.0	27.5
	glucose equivalents mg/g	
Ammonium sulfate	3.84	7.61
Calcium nitrate	4.35	10.93

*** So plant was using CHOs to get rid of ammonium instead of growing**

Work with tobacco: Skogley & McCants 1963 SSSAP 27:391-394

Measured growth:

NITROGEN FORM	TIME IN DAYS 4	12	15	21
	grams			
NH_4^+	12	18	23	25
NO_3^-	13	36	49	76

(i) Under Field Conditions
Exceptions to problems with NH_4^+

◆

◆

◆

Conditions where ammonium will not give us good growth as nitrate:

(a) LOW CARBOHYDRATE RESERVES

(b) WHERE NITRIFICATION IS INHIBITED

3. Nitrogen Effect on Root Development and Top to Root Ratio

a. Limited N

- **Root growth — rate of growth is relatively greater than shoot growth**

b. Adequate N

- **Shoot growth is greater than root growth**
- **If you have plenty of CHOs in tops — additional N will increase top growth; less N available for root growth**

c. Banding

4. Yield as Related to N Content

Yield as a function of N in a given plant part:

CROP	DIAGNOSTIC TISSUE
Corn	
Cotton	
Potatoes	
Sugarbeets	
Trees	
Wheat	

5. Recovery of Fertilizer N

a. Coastal Bermudagrss

Ref: Woodhouse 1989. Agron. J. 61:251-256.

Deep Sandy Soil

N RATE	DRY MATTER	RECOVERY OF FERT. N
lb/ac	lb/ac	%
0	2,200	—
56	5,000	60
112	9,400	90
224	14,200	90
448	14,000	60

Conclusions:

b. Corn

N RATE lbs/a	% N RECOVERY Soil I	 Soil II
75		
150		
225		

K. Predicting Nitrogen Needs

1. Predicting N Fertilizer Needs

The following are needed for an accurate N recommendation:

1.

2.

3.

4.

5.

A good recommendation is based on the following:

$$\text{N FERTILIZER REQUIRED} = \frac{\boxed{\text{N REQUIRED IN PLANTS}} - \left(\boxed{\text{MINERALIZABLE N}} + \boxed{\text{SOIL N}} \right)}{\text{EFFICIENCY OF PLANT UPTAKE}}$$

Where do we get this information?

1 →

2 →

3 →

4 →

#1 — Nitrogen Required in the Plant:

$$\boxed{\begin{array}{c}\text{\% N IN CROP}\\ \text{FOR BEST YIELD}\end{array}} \quad \text{X} \quad \boxed{\begin{array}{c}\text{TOTAL YIELD OF}\\ \text{PLANT DRY MATTER}\end{array}}$$

- **get from research**
- **some varieties differ in optimum N content of optimum dry plant matter yield**
- **research is an ongoing process as new varieties are released**

#2 — Nitrogen mineralized from organic matter over the growing season

$$\boxed{\text{K}} \quad \text{X} \quad \boxed{\text{Np}}$$

fraction mineralized	mineralization potential

Np = % ORGANIC MATTER X AFS X % N in OM

% ORGANIC MATTER	AFS	% N in OM
?	**2,000,000**	**0.05**

? from soil test

K = 1% for cool season crops

2% for warm season crops

3% for tropical crops

SAMPLE PROBLEM:

Soil contains 3% organic matter (OM)
Crop: Winter wheat
What is the mineralization potential?

#3 — Residual Soil Nitrogen:

— this is available N in the soil profile to the crop's rooting depth

— Soil test for NH_4^+ and NO_3^-

PROBLEMS:

◆

◆

◆

LESSON 15
Predicting Nitrogen Needs
Nitrogen Fertilizers

Predicting Nitrogen Needs

#4 — Efficiency of Plant Uptake:

Estimated at only 40-55% in Idaho

Factors affecting efficiency:

- ▶
- ▶
- ▶
- ▶
- ▶
- ▶
- ▶
- ▶
- ▶
- ▶
- ▶

Efficiency range in Idaho:

With the above 4 factors we can determine the amount of N needed for optimum yields.

We also need to consider plowed down (turned under) straw

STRAW: for every ton of straw turned under — add 15 to 18 lbs of N for the microbes to decompose the straw (up to 50 lb/ac)

EXAMPLE: If by your calculations 115 lb N/ac was required to produce your crop and you plowed down 2 tons of straw, your recommendation would now be:

SAMPLE PROBLEM:

a. How much extra N do you need to add when 60 bushels of wheat straw are plowed into the soil prior to planting potatoes?

b. How much extra N do you need to add when 1.3 tons of alfalfa are plowed into the soil prior to planting wheat?

- **The material presented above is valid when other environmental factors are not limiting yield. In parts of Idaho however, soil moisture is often limiting. In such cases other variables need consideration.**

L. Nitrogen Fertilizers

1. Gas Forms

a. Anhydrous Ammonia NH_3 = 82% Nitrogen

- **due to high vapor pressure at normal temperatures it is transported in pressurized containers**
- **cheapest form of N fertilizer**
-
- **need 2,960 lbs of $CaCO_3$ to neutralize the acidity generated by 1 ton of NH_3**

2. Solid Forms

a. Ammonium Nitrate NH_4NO_3 34% N 34-0-0

- **manufactured by reacting nitric acid with ammonia**
- **$HNO_3 + NH_3 \longrightarrow NH_4NO_3$**

- use:

- need 1,180 lbs of $CaCO_3$ to neutralize the acidity generated by 1 ton of ammonium nitrate

- traditionally most widely used source of nitrogen in the United States

- use is down due to:
  - ▶
  - ▶
  - ▶

- on a pound for pound basis ammonium nitrate is more expensive to manufacture than anhydrous ammonia

b. Urea $(NH_2)_2CO$ 45% Nitrogen 45-0-0

- rapidly replacing AN as the leading fertilizer N source in the United States because:
  - ▶
  - ▶
  - ▶

- **to manufacture you need NH_3 and CO_2**

- **sold as a granular or prilled fertilizer**
-

c. Ammonium Sulfate $(NH_4)_2SO_4$ 21%N, 24% S

- **white crystalline material**
- **manufactured by:**

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

-

- **also popular in high pH and neutral soils of the West and Texas, Louisiana and Arkansas**
- **need 2,200 lbs of $CaCO_3$ to neutralize the acidity generated by 1 ton of $(NH_4)_2SO_4$**

d. Other Solid Forms of Nitrogen Fertilizers

Calcium cyanamite —

Nitrate of Soda —

Sodium potassium nitrate —

Calcium nitrate —

Ammonium nitrate limestone —

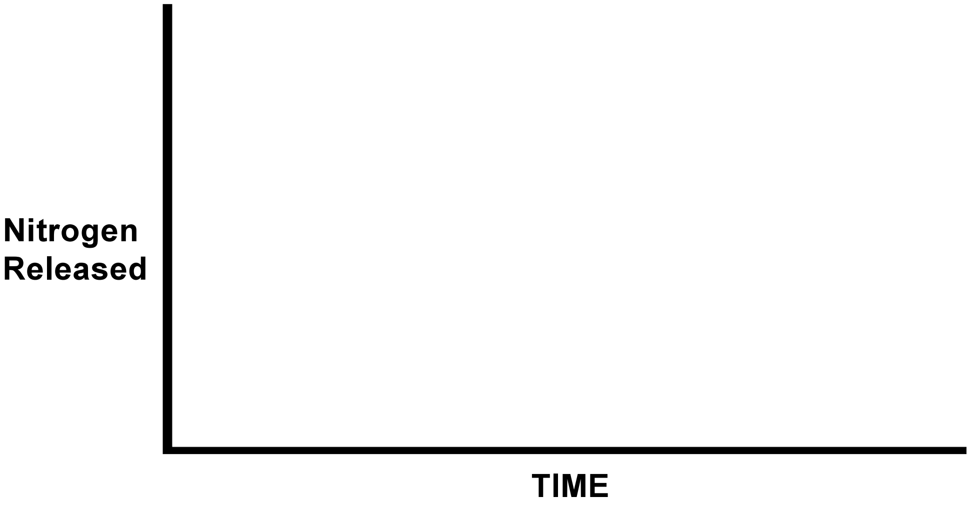
Ammonium chloride —

3. Slow Release N Fertilizers

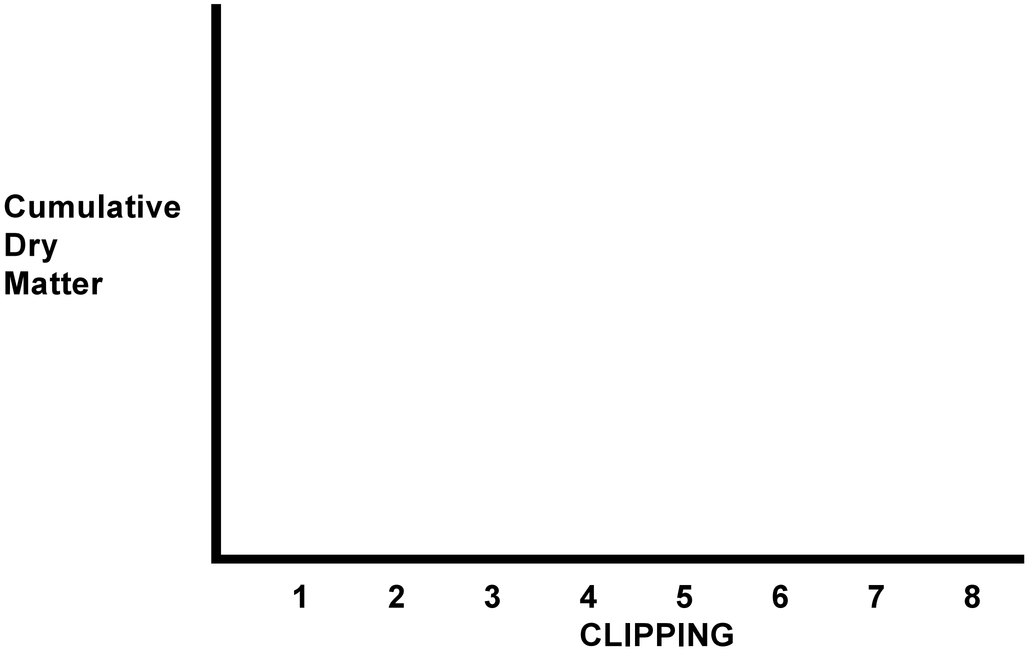
a. Objectives

- **Reduce N leaching losses**
-
- **Release N at the rate that is optimum for crop growth**

b. Release Pattern



c. Properties of Controlled-Release Fertilizers



d. Examples of Controlled Release Fertilizers

◆

◆

◆

◆

e. Economics of Use:

4. Nitrogen Solutions

a. General Properties

b. 6 basic Groups

- **Ammonia-ammonium nitrate**
- **Ammonia-urea**
- **Ammonia-urea-ammonium nitrate**

- **Ammonium nitrate**

- **Ammonium nitrate-urea**

- **Misc. aqua ammonia, others**

PRESSURE SOLUTIONS:

NON-PRESSURE SOLUTIONS:

LESSON 16
Nitrogen Fertilizers
Nitrogen Recommendations

Nitrogen Fertilizers

COMMON TERMINOLOGY:

Advantages:

5. Sample Problems

1. I want to add 130 lbs of N per acre to my soil. How much fertilizer do I add with each of the following sources:

a. ammonium nitrate

b. ammonium sulfate

c. urea

d. sulfur coated urea (36% N)

M. Nitrogen Fertilizer Recommendations

1. Fertilizing Crops

- **All fertilizer guides are based on extensive research — both field and greenhouse research**
- **Soil test calibration data is developed by the University of Idaho**
- **All consultants in Idaho use UI data; differences in recommendations . . . UI is much more conservative than consultants**

Using Fertilizer Guides

- **Fertilizer guides suggest fertilizer rates based on research results for above average yields**
- **Recommendations assume good management**
- **Recommendations assume that other factors are not limiting yield**
- **The efficiency of nutrient use is already taken into account by the fertilizer guidelines (N efficiency estimated at 55%)**

Fertilizer guides are accurate if:

1.

2.

3.

Recommendations can be based on:

1.

2.

3.

4.

Making Recommendations — Examples

a. See Soil Test Report #1

Provide a N fertilizer recommendation for Barry Jones for winter wheat. Barry lives in Troy, ID (north Idaho). Show all calculations.

FLY-BY-NITE SOIL TESTING LABORATORY
SOIL TEST REPORT

Name: Barry Johnson

Address: Troy, Idaho

Field Information (Fill in completely)			
Rotation	Crop	N Fertilizer Applied lbs/N	Yield (measured or anticipated)
Next Crop	W. Wheat		90 bu
Previous Crop	W. Wheat		80 bu residue
199_			returned
199_			

Anything unusual about field?

Soil: Severely Eroded

Cation Content ☐ **; Sampling Depth: ___ inches**

Cation	meq/100g
Calcium	
Magnesium	
Potassium	
Sodium	
Aluminum	

Check Tests Desired

Standard Test ☒ **; Soil Sampling Depth: 12 inches**

Soil pH	5.8
Available P (ppm P)	1.6
Available K (ppm K)	120
Organic Matter (%)	3.6

P/K test: [✓ NaOAc] NaHCO$_3$

Nitrogen Test ☒ ;

Soil Depth (inches)	Nitrate (ppm)	Ammonium (ppm)
0-12	8	0.6
12-24	1.2	0.3
24-36		
36-48		
48-60		

Sulfur	☒	Result	4 ppm
Boron	☒	Result	0.6 ppm
Copper	☐	Result	___ ppm
Iron	☐	Result	___ ppm
Manganese	☐	Result	___ ppm
Zinc	☒	Result	0.6 ppm
Total Salts	☐	Result	___ ppm
Lime Requirement	☐	Result	___ t/acre

Soil Fertility Guide:

Pounds per acre:						
N	P	K	S	B	Zn	Other:

Nitrogen:

b. See Soil Test Report #2

Provide a fertilizer recommendation for Ben Casey. Ben lives in Twin Falls and wants to grow field corn. Show all calculations.

Nitrogen:

FLY-BY-NITE SOIL TESTING LABORATORY
SOIL TEST REPORT

Name: Ben Casey

Address: Twin Falls

Field Information (Fill in completely)			
Rotation	Crop	N Fertilizer Applied lbs/N	Yield (measured or anticipated)
Next Crop	field corn		
Previous Crop	beans		
199_			
199_			

Anything unusual about field?

Cation Content ☐ **; Sampling Depth:** ____ **inches**

Cation	meq/100g
Calcium	
Magnesium	
Potassium	
Sodium	
Aluminum	

Check Tests Desired

Standard Test ☒ **; Soil Sampling Depth:** 12 **inches**

Soil pH	7.6
Available P (ppm P)	9.4
Available K (ppm K)	150
Organic Matter (%)	1.5

P/K test: NaOAc [✓ $NaHCO_3$]

Nitrogen Test ☒ **;**

Soil Depth (inches)	Nitrate (ppm)	Ammonium (ppm)
0-12	1	3.6
12-24	2.5	1.7
24-36		
36-48		
48-60		

Sulfur	☒	Result	16 ppm
Boron	☒	Result	0.5 ppm
Copper	☐	Result	____ ppm
Iron	☐	Result	____ ppm
Manganese	☐	Result	____ ppm
Zinc	☒	Result	0.25 ppm
Total Salts	☐	Result	____ ppm
Lime Requirement	☐	Result	____ t/acre

Soil Fertility Guide:

Pounds per acre:						
N	P	K	S	B	Zn	Other:

2. Fertilizing Lawns

Nitrogen

- **Based on lawn growth**
- **Do not use a soil sample**

a. Rule of thumb — Lawns

- **Apply 0.5 lbs N per 1,000 square feet of lawn for each month of active lawn growth**
- **Active lawn growth:**

40 - 80°F

LAWN GROWTH

North Idaho:

- **active growth starts in early to mid-April; growth stops mid-October**

South Idaho:

- **active growth starts in early March; growth stops in mid-November**

Example:

How much N would a lawn need if active growth ranged from April 1st until October 15th?

b. When to Apply the N

- **Take total amount N needed and:**
- **If you use a slow-release fertilizer take your amount and divide by 2.**
    - **Apply ½ around Easter**
    - **Apply ½ around Labor Day**
- **Take total amount N needed and:**
- **If you use a regular N fertilizer take your amount and divide by 4.**
    - **Apply ¼ around Easter**
    - **Apply ¼ around Memorial Day**
    - **Apply ¼ around Labor Day**
    - **Apply ¼ around Halloween**

c. Amount to apply

$$\frac{\text{lb nutrient recommended per 1,000 ft}^2 \times 100}{\text{\% nutrient in fertilizer material}} = \text{lbs fertilizer needed per 1,000 ft}^2$$

Example:

To supply 1 lb N per 1,000 ft^2 using ammonium nitrate (34-0-0-):