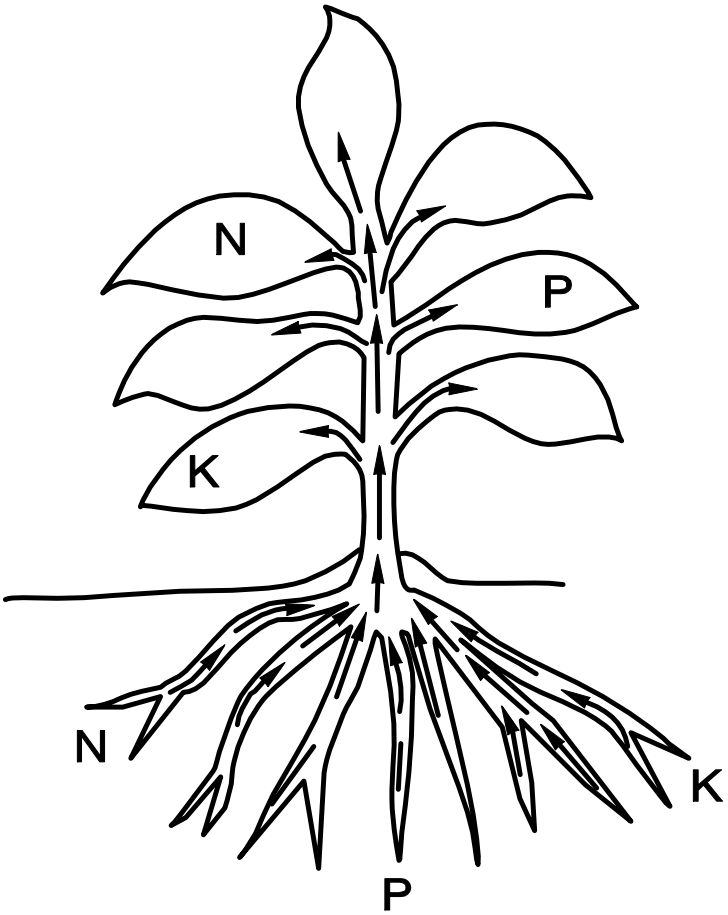
Soil and Plant Diagnostics



Soils 446-03

Course Module
Lecture Note Packet

University of Idaho
College of Agriculture

Purpose of Course

Soil and Plant Diagnostics is a short course consisting of 15 lectures. This short course covers soil sampling, soil test correlation, concepts in soil test interpretation, fertilizer recommendations, and plant tissue diagnostics. Plant tissue diagnostics information includes principles of nutrient deficiency identification, interpretation, and DRIS. The short course also includes a lesson that integrates soil and tissue diagnostics. This course emphasizes principles of soil fertility management, the availability of plant nutrients, and their relationship to plant growth and fertilization practices.

This short course is the third in a series of six modules in soil fertility and plant nutrition offered by the University of Idaho. Your comments on this course will be appreciated.

Outline of Course
Soils 446
Module 3: Soil and Plant Diagnostics

Lesson 1: **Soil Diagnosis; Soil Sampling**

Lesson 2: **Soil Sampling; Specialized Soil Sampling**

Lesson 3: **Specialized Soil Sampling; Soil Test Calibration**

Lesson 4: **Soil Test Correlation; SLAN and BCSR**

Lesson 5: **Specific Nutrients: Liming, Nitrogen**

Lesson 6: **Specific Nutrients: Sulfur, Phosphorus, Potassium**

Lesson 7: **Specific Nutrients: Micronutrients; Fertilizer Recommendations**

Lesson 8: **Fertilizer Recommendations**

Lesson 9: **Plant Tissue Diagnosis**

Lesson 10: **Nutrient Deficiency Symptoms; Tissue Sampling**

Lesson 11: **Tissue Sampling / Diagnosis; Orchards**

Lesson 12: **Tissue Diagnosis: Orchards, Forestry, Interpretation**

Lesson 13: **Interpretation: Onions, Peppermint; Integration with Soil Sampling**

Lesson 14: **Integration with Soil Sampling; DRIS**

Lesson 15: **DRIS**

Table of Contents

Page #

Page #

LESSON 1
Soil Diagnosis
Soil Sampling

Soil Diagnostics

Several factors need to be considered when making fertilizer recommendations. The four most important are:

1.

2.

3.

4.

A. Soil Variability

1. Soil Sampling

(Reading Assignment: Soil Sampling , University of Idaho Bulletin No. 704)

What is a soil test?

- **a chemical evaluation of the nutrient-supplying capability of a soil at the time of sampling**

What does a soil test measure?

-

-

There are four key steps in a good soil testing program:

1. **Taking the soil sample**

2.

3.

4.

However, without a doubt, soil sampling is the most critical step.

SOILS ARE VARIABLE ! ! !

Research data for 25 soil cores:

	-------- P (ppm) --------		-------- NO_3-N (ppm) --------	
Soil	**Mean**	**Range**	**Mean**	**Range**
Palouse	**6.2**	**0.1 - 27**	**5.6**	**0.2 - 36**
Portnuff	**12.6**	**2.0 - 45**	**8.6**	**3.0 - 61**
	-------- S (ppm) --------		**-------- B (ppm) --------**	
Palouse	**4.2**	**0.0 - 45**	**0.5**	**0.0 - 2.0**
Portnuff	**16.4**	**6.5 - 35**	**0.4**	**0.2 - 1.5**

To emphasize the importance of good soil sampling think of it this way:

- **For a P analysis we use 2.5 grams of soil; this represents 2 X 1AFS or 4,000,000 lbs/ac possible from a field as large as 20 acres.**
- **1 AFS = 2,000,000 lbs X 2 (for 1 foot depth) = 4,000,000 lbs**
- **4,000,000 X 454 g/lb = 1,816,000,000 grams**
- **X 20 acres = 36,320,000,000 grams of which we determine P on a 2.5 g sample.**
- **Our sample analysis is 7.883 X 10^{-8} percent of the soil ! ! !**
- **So a representative sample is very important!**

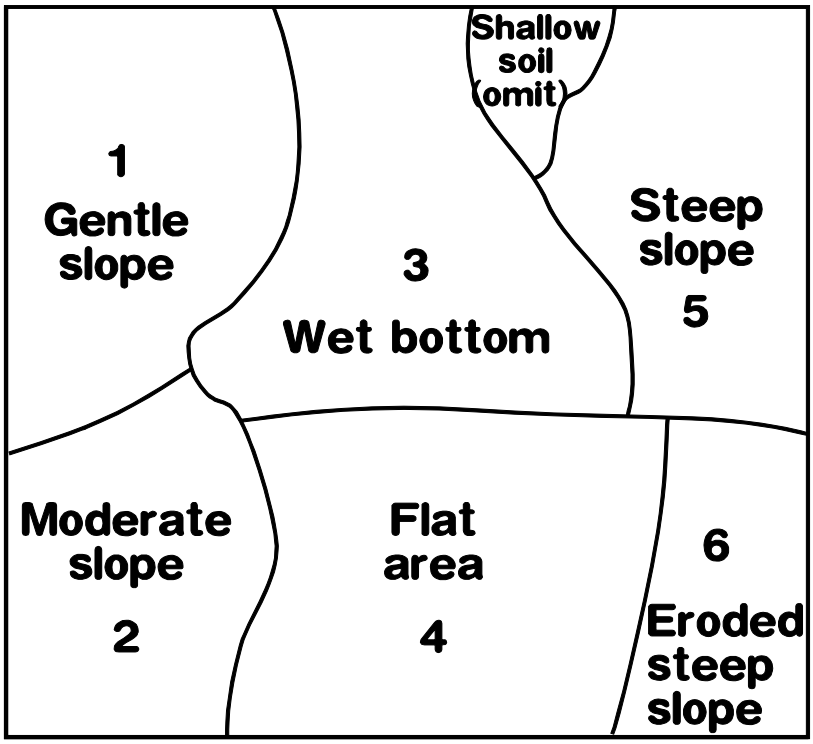
- **An analysis is only as good as the sample collected**

B. Sampling Procedures

1. Getting a Good Soil Sample

a. Map your field

▶



b.

c.

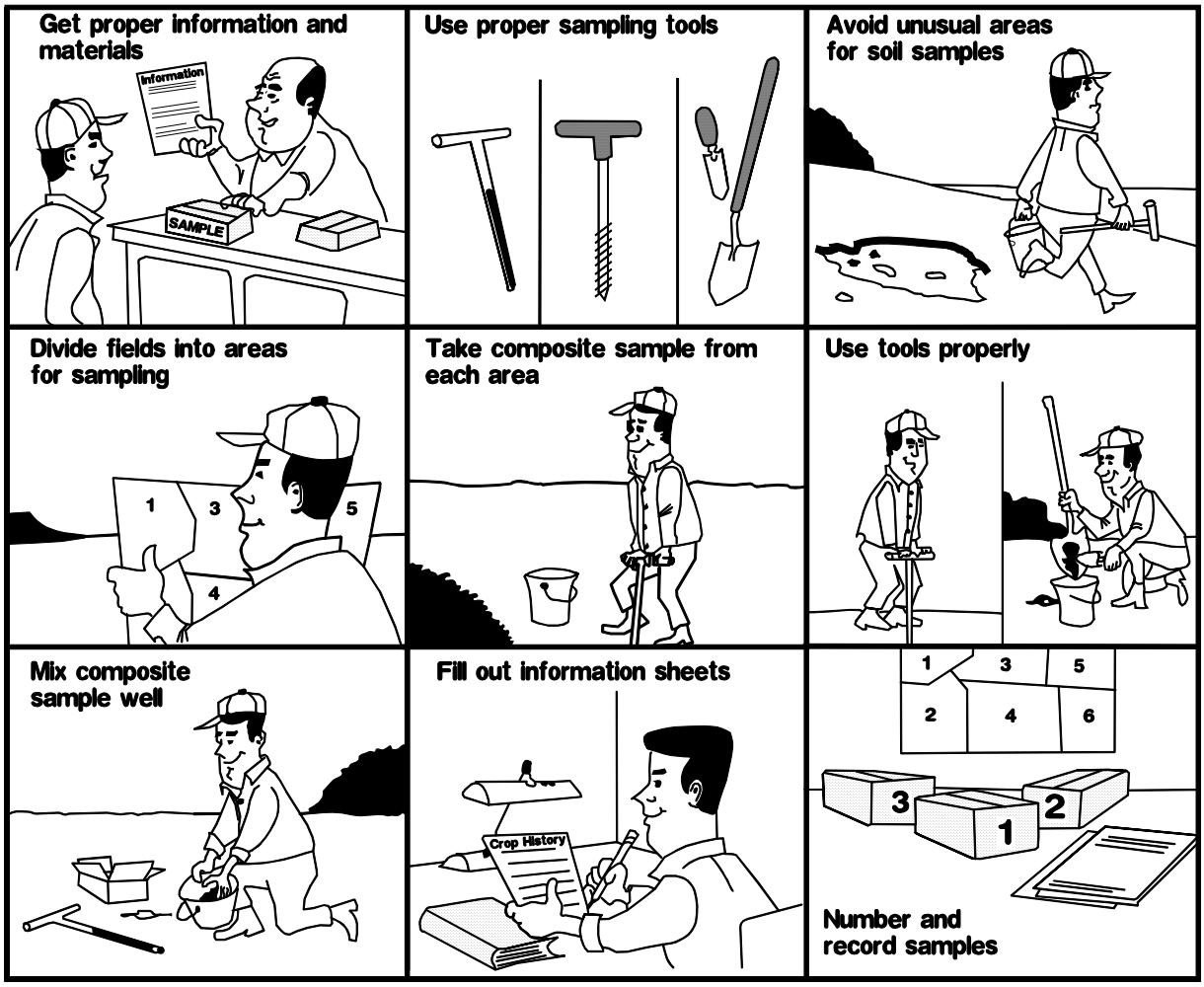
d.

How many samples should I collect?

Recommended number of soil subsamples to collect from different sized areas

AREA	ACREAGE	MINIMUM # OF CORES	REC #
1	20	10	30
2	25	10	30
3	50	20	40
4	35	15	35
5	10	6	25
6	5	4	20

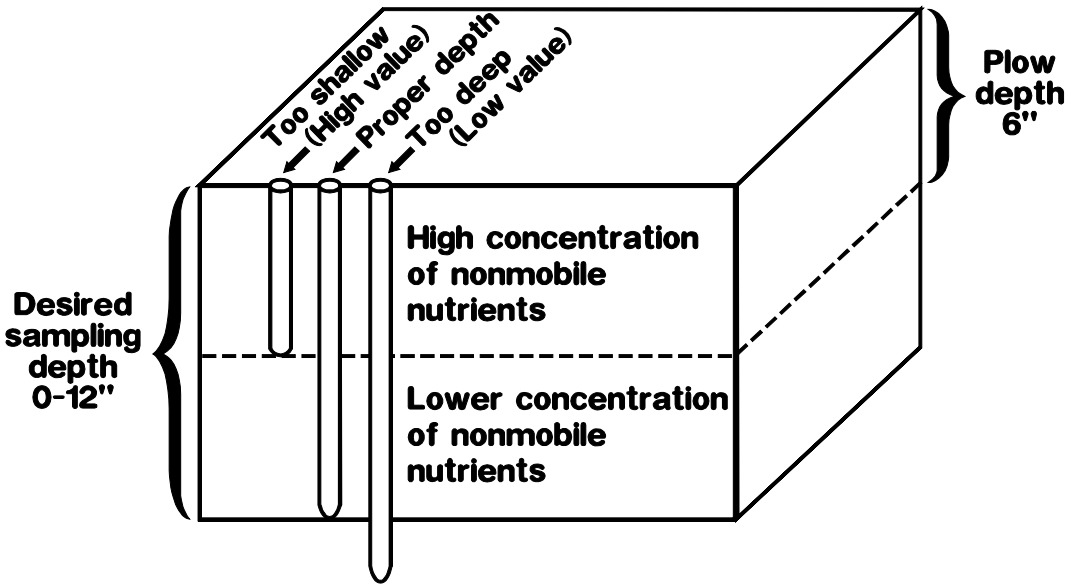
The correct steps involved in soil sampling are illustrated in the figure below:



2. SAMPLING DEPTH

- **Depth of sampling is critical because mobility of nutrients in the soil and tillage can greatly influence nutrient levels in different zones of the soil.**

- **Since the greatest abundance of plant roots, greatest biological activity, and highest nutrient levels occur in the surface layers of the soil, the upper 12 inches of the soil is used for most analysis.**

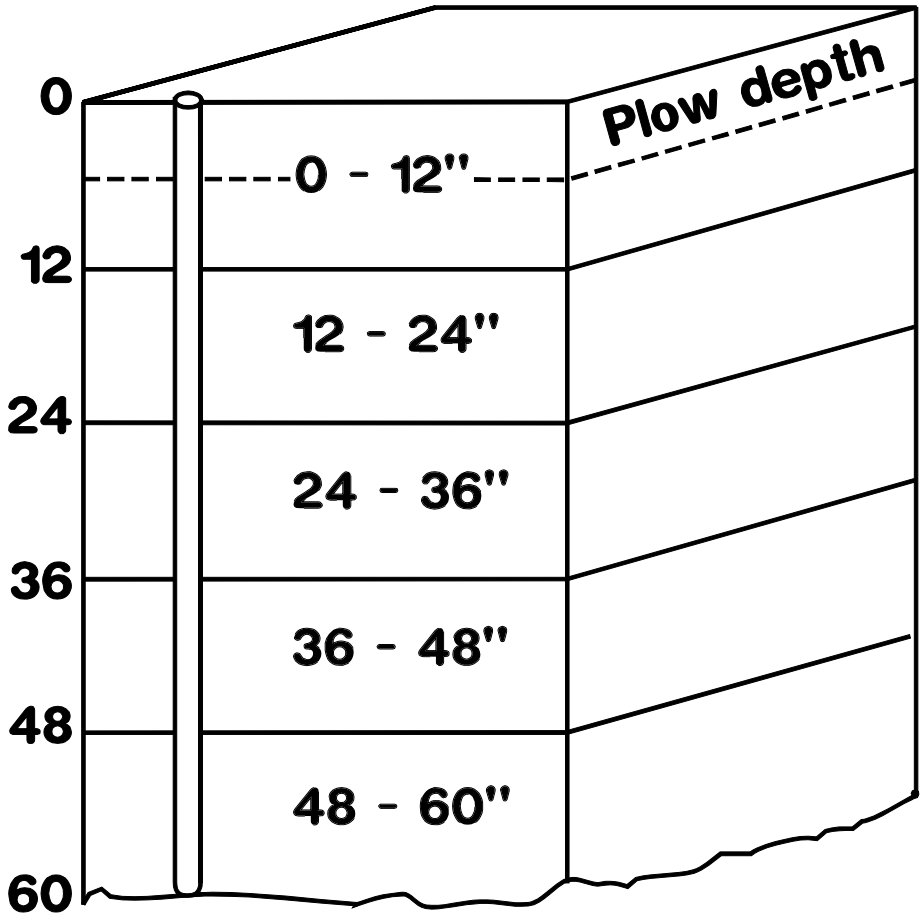


- **Non-mobile nutrients**

-

-

- **When sampling for mobile nutrients take samples by 1-foot increments to the effective rooting depth of the crop.**



Effective rooting depth for some common Idaho crops:

CROP	SAMPLING DEPTH (feet)
Cereals (wheat, barley, oats)	5-6
Corn	5-6
Alfalfa, rape	4-5
Hops, grapes, tree fruits	4-5
Sugarbeets	2-3
Peas, beans, lentils, potatoes onions, mint	2
Potatoes, onions	1-1.5
Vegetable seed	1-1.5
Gardens	1
Ornamentals	1
Forestry - research	1

- **Sample to one foot for the following nutrients:**

- **Sample to crop rooting depth for the following nutrients:**

3. TIME OF SAMPLING

- **Nutrient concentrations vary with season**
-
- **Don’t take samples that are too wet or too dry — tough to get a good representative sample**
-
-

4. SAMPLE HANDLING/SHIPPING

- **When you take samples mix them in a plastic bucket if you are requesting a Zn or Fe test**
-

- **For NO_3 — keep samples cool until they can be dried; if you ship them to a lab — dry them before you ship to prevent denitrification**
  -
  -
-

LESSON 2
Soil Diagnosis
Specialized Soil Sampling

5. NUTRIENT ANALYSIS REQUESTS

- **Only request analyses for nutrients that are known to be deficient in your area. See PNW 276 for details.**
-
- **Micronutrient requests for northern Idaho:**

  B —

  Mn —

  Mo —

  Zn —

  Cl —

  Fe —

- **Micronutrient analyses requests for southern Idaho:**

  B —

Mn —

Mo —

Cu —

Zn —

Cl —

Fe —

6. SPECIAL SOIL SAMPLING SITUATIONS

- **Special soil sampling problems occur in fields that have been leveled for irrigation or have lost all or most of their topsoil due to erosion; are surface (furrow) irrigated; have had band-applied fertilizer; or are not thoroughly tilled.**

a. Land-leveled and eroded areas

- **Areas that have been land-leveled or eroded frequently have little or no original topsoil present and the soil surface may be exposed subsoil material**
-
- **Subsoils —**

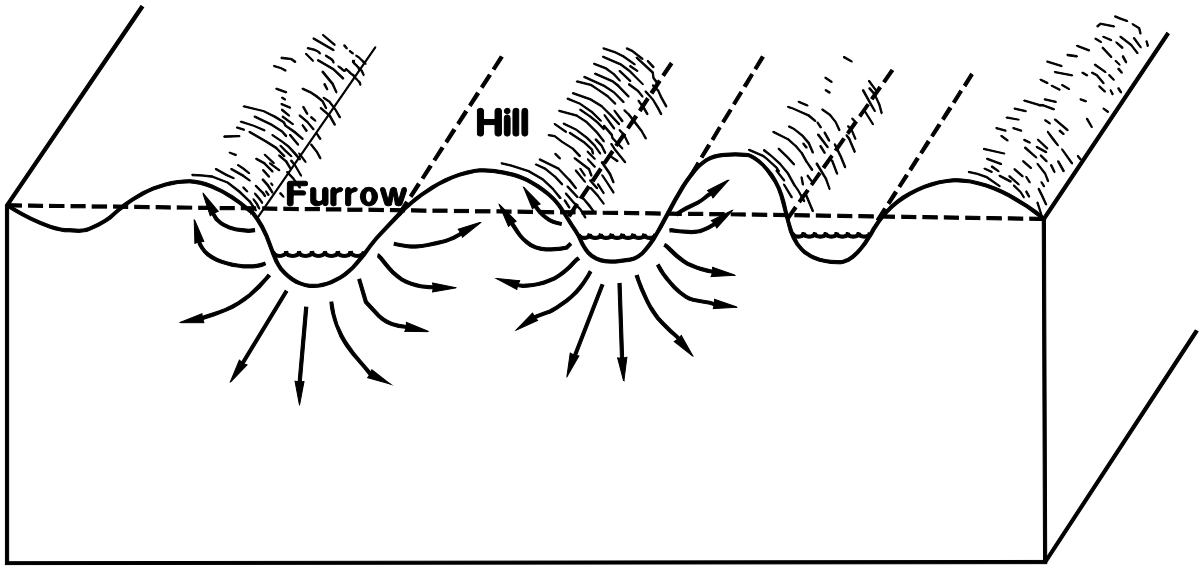
—

—

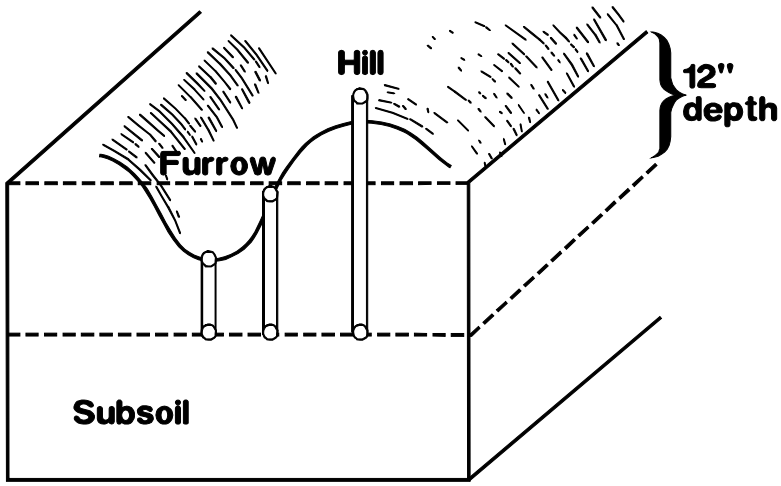
b. Furrow irrigated fields

-

- **A furrowed field:**



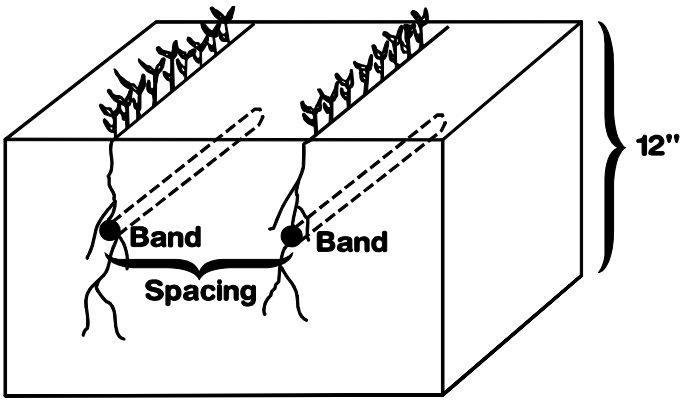
- **Knowledge of furrow direction, spacing, and location along with closely spaced soil sampling perpendicular to the furrow is necessary to obtain a representative soil sample.**



c. Areas where fertilizer has been banded

- **When soil sampling is to be done in fields where fertilizers have been banded and the fields are plowed prior to soil sampling, regular sampling procedures can be followed.**

- **Diagram of banded field:**



-

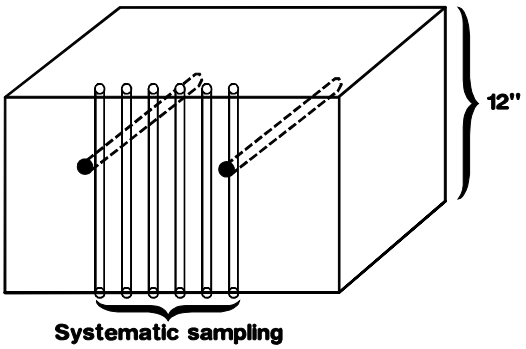
- **Options:**

  -

  -

  -

i. Systematic Sampling



–

– **take 5 to 10 soil samples perpendicular to the band row beginning in the edge of a fertilizer band and ending at the edge of an adjacent band**

–

– **mix and composite samples to obtains a representative sample**
(20 sites x 6 cores/site = 120 cores)

ii. Controlled sampling method

–

– **take 20 to 30 cores scattered throughout**

–

–

iii. Random sampling method

– **use when location of previous season's fertilizer band is not known**

–

–

Comparison of Soil Sampling Procedures (depth 0-12 inches)

Sampling Method	Site 1	Site 2	Site 3
	---------- ppm P ----------		
Systematic	2.9	4.0	2.6
Controlled	1.8	2.4	2.0
Random	2.5	3.4	2.4
$LSD_{.05}$	0.3	0.5	0.3

(Source: Mahler, R. L., 1990. Soil sampling fields that have received banded fertilizer applications. Communications in Soil Science and Plant Anaylsis 21:1793-1802.)

LESSON 3
Specialized Soil Sampling
Soil Test Calibration

d. Reduced or no-till fields

-

- **Need special approaches because the soil has been disturbed so that fertilizer is not mixed into the soil**

-

- **Fertilizer nutrients in the top one-inch of soil will probably not be available to the growing crop**

-

- **Sample for soil pH by 3-inch intervals:**

  -

  -

  -

  -

- **Soil pH can affect:**

  -

  -

- weed germination
- plant diseases

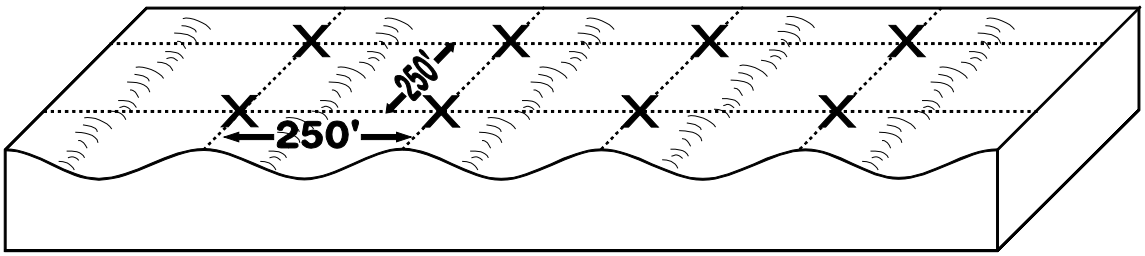
The influence of tillage and fertilizer placement on soil pH

	----------Tillage ----------		
Depth	No-till	Minimum	Conventional
inches	---------- soil pH ----------		
0-3	5.0	5.1	5.3
3-6	5.3	5.0	5.3
6-9	5.4	5.4	5.3
9-12	5.8	5.8	5.8

(Source: Mahler, R. L. and R. W. Harder. 1984. The influence of tillage methods, cropping sequence, and N rates on the acidification of a northern Idaho soil. Soil Science 137:52-60.)

e. Grid Sampling in Non-uniform Fields

-
-
  - variable rates of nutrients across a given field



GRIDS

- 200 to 300 feet grids for irrigated fields

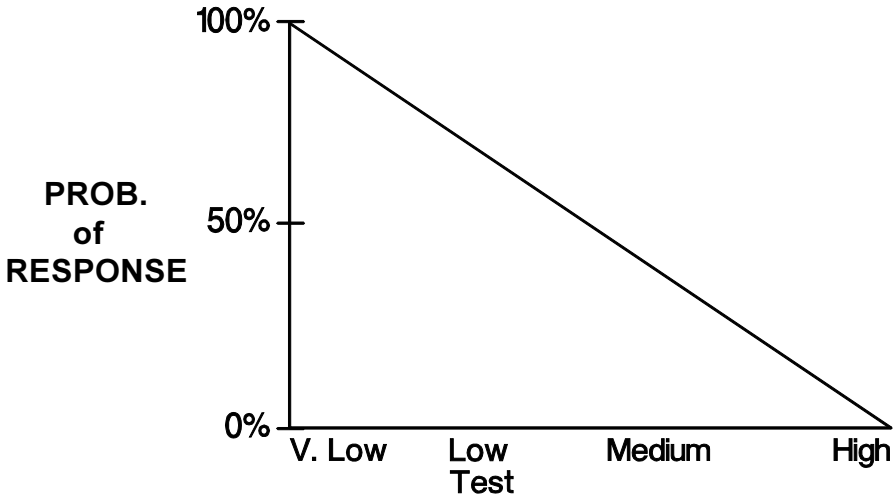
-
-
-

GRIDS

- **400 to 500 feet grids for dryland fields**
-
-

Results from soil testing labs are worthless unless they can be calibrated against crop response.

In general, there is a high probability of getting a response to a nutrient if the soil test is low.



◆

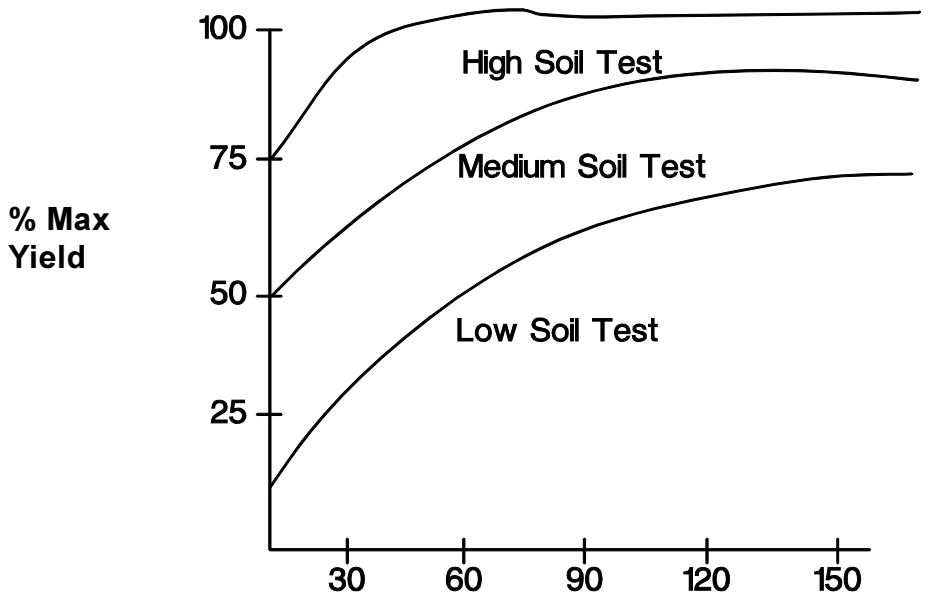
Initial work — greenhouse

◆

- **Then apply the nutrient in question in increments (i.e. 0, 30, 60, 90, 120, 150 lbs/ac)**

-

- **Obtain a graph like:**



CRITICAL LEVELS — are determined using the same methodology; however, it's the value above which no response is expected and below which a response is expected.

Ideally:

-

-

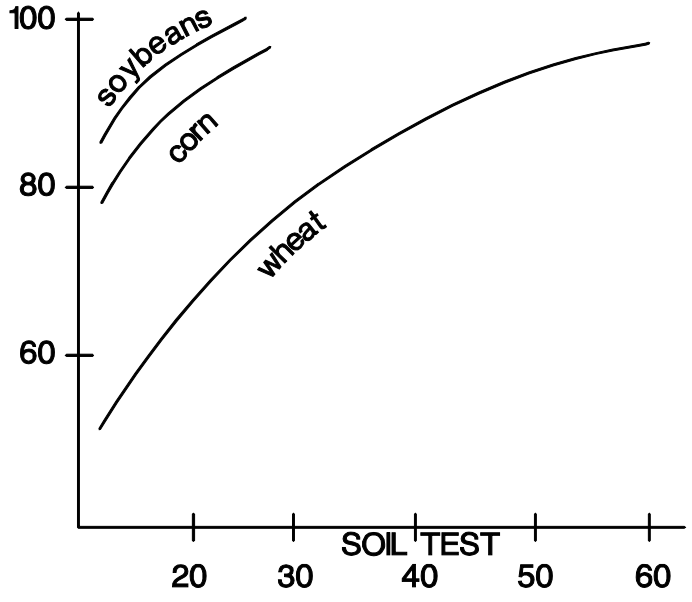
FOR EXAMPLE: Boron

Critical level:

If sample reads 0.4 ppm -- then:

If sample reads 0.6 ppm — then:

Once greenhouse data is obtained then field work can begin by looking at different soils, climates, and crops; then fine tune numbers for different areas around the state.



CONCEPT: THE LAW OF DIMINISHING RETURNS

Fertilizer Added (by increment)

Terms:

Maximum Yield —

Maximum Economic and Environmental Yield —

LESSON 4
Soil Test Correlation
SLAN and BCSR

CONCEPTS IN SOIL TEST INTERPRETATION

- **Concepts in soil test interpretation differ greatly. <u>All</u> are based on <u>valid</u> principles.**

- **Any given principle seems to work well under specific conditions, but insufficient research has been done to make one concept applicable to all conditions. We'll talk about the two most important concepts:**

PHILOSPHIES OF SOIL TEST INTERPRETATION

1. SLAN

2. BCSR

SUFFICIENCY LEVELS OF AVAILABLE NUTRIENTS (SLAN) CONCEPT IN SOIL TEST INTERPRETATION

Implications of Concept:

1. **Levels of available nutrients range in a group of soils from insufficiency to sufficiency for optimum growth of plants**

2. **Amounts of nutrients removed by suitable extractants will be inversely proportional to yield increases from added nutrients**

3.

- **Based on Law of Diminishing Returns**

<u>Principles:</u>

- **Mitscherlich's equation:**

$$dy/dx = (A-y)c$$

- **yield increases (dy) per unit of available nutrient (dx) decrease as the current yield (y) approaches a maximum yield (A), c, being a proportionality constant**

<u>Steps in Using Concept:</u>

1. **Selection or determination of sufficiency lavel based on soil test correlation data**

2.

3.

BASIC CATION SATURATION RATIOS (BCSR) CONCEPT IN SOIL TEST INTERPRETATION

- **Based on Cation Ratios in Soils**

<u>Implications of Concept:</u>

1. **For optimum growth of crops both a best ratio of basic cations and a best total base saturation exist in a soil**

2. **Principles:**

1. **Bonding of cations to exchange sites differ greatly from one type of cation to another, and it differs greatly for the same type of cation at different saturations**

2. **Amount of exchangeable cations are frequently not proportional to amounts soluble, active, or immediately plant available**

3.

4. **Both the capacity (total exchangeable) and intensity (activity) of an absorbed cation influence total availability of a cation to a plant**

5.

<u>Steps in Using Concept:</u>

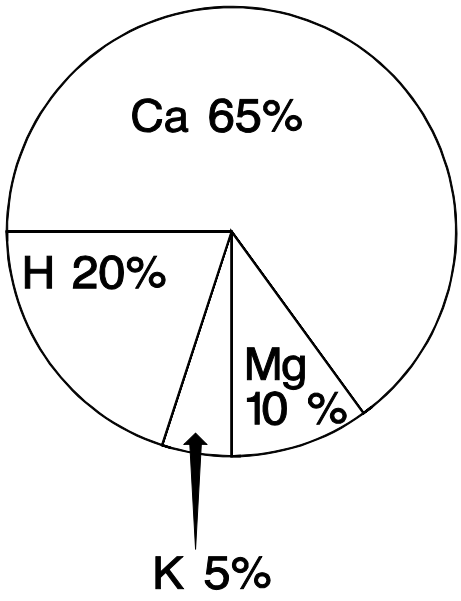
1. **Selection of basic cation ratios**

2.

3. **Computation of amounts of Ca, Mg, and K required for proper ratios**

4.

BASIC CATION RATIO SATURATION CONCEPT



Situation where SLAN is best

Situation where BCSR is best

Situation where a combination of SLAN and BCSR are best

LESSON 5
Specific Nutrients: Liming, Nitrogen

1. Soil Acidity and Liming

a. Status of Soils

-

- **In general, in acid soils Al^{+++} and Mn^{++} cause problems with plant growth; H^{+} is problem under only the most acid conditions; Acid soils are relatively low in bases (Ca^{++}, Mg^{++}, K^{+}, etc.)**

-

-

- **In 1987 24.2 million tons of lime were used in the United States. The lime value exceeded $425,000,000 but was estimated to fill only 30% of the actual need**

- **In the Inland Pacific Northwest soils were initially neutral in soil pH; however, many of these soils have become acid.**

- **Soil acidification is being caused by N fertilizers:**

$$2NH_4^+ + 3O_2 \longrightarrow 2NO_2^- + 4H^+ + 2HOH$$

- **See CIS 629: *Longterm Acidification of Farmland in Northern Idaho*; also see: Communications articles**

Critical soil pH values for maximum crop yields:

Crop	pH
Cotton	5.0 - 5.7
Corn	5.0 - 5.5
Soybean	5.0 - 5.7
Wheat	5.1 - 5.4
Peanuts	None; but Ca level impt.
Alfalfa	5.7 - 6.0
Grass	5.0 - 5.1
Grain sorghum	5.3 - 5.5
Peas/lentils	5.5 - 5.6

See CIS 811: *Relationship of soil pH and crop yields*

Idaho data:
The minimum acceptable soil pH vales acceptable for crops grown in northern Idaho:

Crop	Soil pH
Lentil	5.65a
Spring pea	5.52b
Winter wheat (Stephens)	5.37c
Winter wheat (Hill 81)	5.31c
Spring barley	5.23d
Winter wheat (Daws)	5.19d

b. Correction of Soil Acidity

LIME is a naterial that:

(1)

and
(2)

Some commonly used lime materials include:

$CaCO_3$

$MgCO_3$

$CaMgCO_3$

CaO

MgO

$Mg(OH)_2$

$Ca(OH)_2$

Wood ash

Slags

What constitutes an effective liming material?

(1) Chemical composition

(2) Particle size

See handout on lime material quality

State Regulations:

State laws	Fineness	Minimum	NV
Washington Fertilizer Law	10	X	CCE
	60	X	$CaCO_3$
	100	X	$MgCO_3$
Idaho Fertilizer Law	10	X	CCE
	60	X	
	100	X	
Oregon Rules	10	X	Lime Score
	20	X	
	40	X	

c. Testing Procedures

Lime Requirement Tests:

Lime Requirement Test	Number of States	
SMP	19	(Oregon)
Woodruff	4	(Idaho)
Adams and Evans	4	
Dunn Titration	1	
$BaCl_2$-TEA	1	
Mehlich	1	
Water pH + texture	3	
Water pH/texture/OM	2	
Base saturation	1	(Washington)
Al^{+++} activity	1	
No test	13	

- Idaho – what is best?
- Uses Woodruff (developed in Missouri) easy, simple test

From Blevins: (Soil and Tillage Research 3:135-146)

Yearly N Rate	--- No till ---		--- Conv till ---	
kg/ha	0-5 cm	5-15 cm	0-5 cm	5-15 cm
0	5.75	6.05	6.45	6.45
84	5.20	5.90	6.40	6.35
168	4.82	5.63	5.85	5.83
336	4.45	4.88	5.58	5.43

2. *Nitrogen*

a. Inorganic Nitrogen

Testing Philosophy

1950s – very limited NO_3-N use

1960s – used in semi-arid regions of the Western US

1970s – tests developed for other areas of the western US and Great Plains

1980s – research begins in the Midwest

1990s – research is underway in humid regions of the US

- **NO_3-N tests are currently used in 19 states**

  *

  *

Nitrogen recommendation basis: ***See handout; see WA Bull #609***

Nitrogen recommendation is first based on moisture:

7.2(SM + R -4)

Then base nitrogen rate on yield potential

Today the equation is modified:

Then, the nitrogen recommendation is used to achieve the potential yield:

2.5 - 2.7 lbs N/bushel of wheat

So, the nitrogen fertilizer approach is eastern Washington and northern Idaho has been to have the nitrogen recommendation first based on potential yield based on water supply – which is our greatest yield limiting factor:

7.2(SM + R - 4) - Potential Yield

Example problem:

SM = 10 inches
R = 6 inches
What is potential yield?
How much N is required to produce the potential yield?

This work done in the 1950s is still valid today – *See Northern Idaho Fertilizer Guide for Winter Wheat, Table 1.*

Potential Yield = 100 bu

So N need is still based on Leggett's work from the 1950s.

- **Given the following information, calculate the amount of N mineralized from organic matter during the season:**
  3% OM
  Winter wheat crop (cool season)

Mineralizable Nitrogen: based on calculation

- **Mineralized Nitrogen = % OM x 2AFS x 0.05 x K**
  - **By definition:**
    % OM – from soil test
    2ASF – 4,000,000 lbs
    0.05 – % N in OM
    K – fraction of OM mineralized (1, 2, or 3%)

So a nitrogen recommendation for wheat in northern Idaho and eastern Washington is based on the following:

Total N needed:		
(Yield potential x 2.7)		_____
MINUS Mineralizable N	-	_____
MINUS Soil Test NO_3-N + NH_4-N	-	_____
	N fertilizer =	_____

What about N use efficiency?

- **If potential yield is 100 bu/ac, we use the 2.7 factor to figure N need (100 x 2.7 = 270 lbs N). However, this assumes 50% nitrogen use efficiency (NUE).**

- **At 40% NUE:**

- **At 65% NUE:**

What about newer, more efficienct N fertilizer materials?

Slow release fertilizers may improve N use efficiency substantially but at present cost at least 35% more on a N unit basis than conventional N materials

A comparison between urea and sulfur coated urea (a slow-release fertlizer):

Urea:
Cost: 0.28 per lb N
50% NUE

To produce 100 bu wheat:

SCU Comparison:

If you increase SCU efficiency to 70%:

Inorganic N Soil Test

Simple procedure
KCl extractable NO_3-N
Reliable test

Mineralizable N Calculation

Based on calculation

b. Organic Nitrogen

-

- **Also important in agricultural systems where commercial N fertilizer input is minimal**

- **Excellent, easy test. Currently use CHN analyzer. Loss upon ignition.**

-

LESSON 6
Specific Nutrients: Sulfur, Phosphorus, Potassium

3. Sulfur SO_4^-

References:

Sulfate: Sampling, Testing, and Calibration. Gordon V. Johnson. SSSA Special Publication No. 21.
Relationships between Soil Sulfate-Sulfur and Seed Yields of Winter Rapeseed. 1993. R. L. Mahler, G. A. Murray, and J. B. Swensen. Agron. J. 85:128-133.

Tendency for S deficiencies:

a.

b.

c.

d.

e.

- **The more of the above factors present – the greater the potential S deficiency problems**
- **Northern Idaho / Eastern Washington:**
  - **factor**
  - **factor**
  - **factor**
  - **factor**

- **Western Washington / Western Oregon:**
  - **factor**
  - **factor**
- **Central Washington / Southern Idaho:**
  - **factor**
  - **factor**
  - **factor**
  - **factor**
- **Note that naturally occurring S in irrigation waters will negate all other factors**

Sulfur Soil Testing Philosophy:

- **Sulfate-sulfur soil tests are not widely conducted**
- **Traditionally it was thought that S deficiencies were not widespread in the USA (see handouts and maps)**
-
-
- **Most soil test correlation data is to a depth of only 12”**
  -
  -
  - **problem also likely related to quality impact rather than yield in many cases**
- **The N:S ratio in plants is about 15:1, based on this**
  - **100 bu wheat requires 270 lbs N**

- ▶
- ▶

SULFUR RECOMMENDATIONS:

- **Application rates range from 0 to 25 lbs S/acre in areas known to be deficient in S; rates of 15 to 20 lbs/acre are common**
- **There is quite a bit of current research going on with S in the Midwest, South, and Southeastern USA (coincides with reduced levels of air pollution)**
-
-

SOIL TESTING – SULFUR:

- **Poor soil test extractans for SO_4-S results in poor soil test values**
- **After SO_4-S extraction, S is determined by one of several methods or instruments:**
  - ▶
  - ▶
  - ▶
  - ▶

- **Sulfur is important for crop quality – this is not always reflected in crop yield**

4. Phosphorus

A lot of soil test correlation research has been done with P

SOIL pH	$FePO_4$	$AlPO_4$	$CaPO_4$	Apatite
3				
4				
5				
6				
7				
8				
9				
10				
11				

Phosphorus Soil Testing

Classification of extractants:

a. Dilute concentrations of strong acids

- **very acid (pH 2 to 3)**

b. **Dilute concentrations of strong acids + a complexing ion**

- ▶

c. **Dilute concentrations of weak acids**

- ▶
- ▶
- ▶
- ▶
- ▶

d. **Buffered alkaline solutions**

- ▶

Mechanisms of phosphorus removal by extractants:

a. **Solvent action of acids**

- ▶
- ▶
- ▶

b. **Anion replacement**

- ▶

◆

Common phosphorus soil tests:

Soil Test	Extractants
Bray I	0.025N HCl = 0.03N NH_4F
Bray II	0.1N HCl + 0.03N NH_4F
North Carolina (Double acid)	0.05N HCl = 0.025N H_2SO_4
Troug	0.002N H_2SO_4
Citric Acid	1% citric acid
Enger	0.02N Ca-lactate + 0.02N HCl
Morgan	0.54N HOAc + 0.7N NaOAc
Olsen	0.5M $NaHCO_3$

Phosphorus tests in Washington and Idaho:

Acid soils:

▶

▶

▶

Neutral / alkaline soils:

▶

▶

▶

Ca-P
Apatite
Al-P

Status of phosphorus soil test correlation data:

-

-

P research needs:

1. **Standardization in region for wheat:**

Soil test	Critical P level
NaOAc	4 ppm
$NaHCO_3$	10 ppm

2. **Correlation between P values for different soil tests**

3.

4.

5. Potassium

- **Often same extractants used for phosphorus are used for K**

-

- **Not much of a data base in PNW except for potatoes and alfalfa**

LESSON 7
Specific Nutrients: Micronutrients
Fertilizer Recommendations

6. Micronutrients

a. Extractants:

1.

2. The amount of nutrient should be measured with reasonable accuracy

3.

Examples: DTPA, Mechlich I, etc.
Used for Cu, Fe, Mn, and Zn

b. Boron

- **Correlation work is very difficult**
-
-
- **High demand – legumes, fruits, tuber, and root crops**
-
- **Boron is mobile in soil – sample to effective crop rooting depth?**
-

- **Soil critical levels range from 0.1 to 2.0 ppm (hot water extraction) depending on the crop**

-

- **In Idaho and Washington the established critical level for low boron demanding crops is 0.3 ppm**

c. Copper

- **Little field correlation work has been done in the Pacific Northwest**

-

- **Critical Cu soil test values:**

Extractant	Critical level (ppm)	
	mean	range
DTPA	0.8	0.12-2.5
Mehlich	3.0	0.1-10

d. Iron

- **A disaster as far as soil test correlation is concerned**

-

◆

◆

e. Manganese

- **As with iron, soil collecting and preparation are critical to obtain meaningful values**

◆

- **Critical values for Mn:**

Extractant	Critical level (ppm)	
	mean	range
DTPA (west)	1.4	1-2
Mehlich (east)	7.0	4-8 (pH dep)
0.03M H_3PO_3	10.0	0-20

f. Molybdenum

- **Few attempts have been made to obtain calibration data**

-

- **Molybdenum needed for:**

  legumes **nitrogenase**

  nitrate reductase

g. Zinc

-

-

- **Idaho, Washington critical levels:**

Other critical values for Zn:

Extractant	Critical level (ppm)	
	mean	range
DTPA	0.8	0.25-2.0
Mehlich	1.1	0.5-3.0
0.1M HCl	5.0	2.0-10

Fertilizer Recommendations

- **All fertilizer guides are based on extensive research — both field and greenhouse research**

-

- **All consultants in Idaho use UI data; differences in recommendations ... UI is much more conservative than consultants**

-

- **As new varieties of existing crops and new crops are developed, calibrations need adjustment by doing field research**

-

- **Need to prioritize research needs in Idaho:**
  -
  -
  -
  -

- **At present the most critical needs for soil test calibration work in Idaho are:**
  -
  -
  -

1. Using Fertilizer Guides

- **Fertilizer guides suggest fertilizer rates based on research results for above average yields**
-

- **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%)**
- **There are currently:**
  -
  -

◆

2. Accuracy

Fertilizer guides are accurate if:

a.

b.

c.

Recommendations can be based on:

a.

b.

c.

▶

3. Making Recommendations — Examples

a. See Soil Test Report #1 (Attached)

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

Nitrogen:

FLY-BY-NITE SOIL TESTING LABORATORY
SOIL TEST REPORT

Name: Barry Johnson

Address: Troy, Idaho

Anything unusual about field?

Soil: Severely Eroded

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_			

Cation Content [ ]; Sampling Depth: ___ inches

Cation	meq/100g
Calcium	
Magnesium	
Potassium	
Sodium	
Aluminum	

Check Tests Desired

Standard Test [X]; 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 [X];

Soil Depth (inches)	Nitrate (ppm)	Ammonium (ppm)
0-12	2	0.6
12-24	1.2	0.3
24-36		
36-48		
48-60		

Sulfur	[X]	Result	4 ppm
Boron	[X]	Result	0.6 ppm
Copper	[ ]	Result	___ ppm
Iron	[ ]	Result	___ ppm
Manganese	[ ]	Result	___ ppm
Zinc	[X]	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:

LESSON 8
Fertilizer Recommendations

Continuation of fertlizer recommendation for Barry Johnson in Troy, ID.

Phosphorus:

Potassium:

Sulfur:

Zinc:

Boron:

Remarks:

b. See Soil Test Report #2 (Attached)

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

Nitrogen:

Phosphorus:

Potassium:

Sulfur:

Zinc:

Boron:

Remarks:

FLY-BY-NITE SOIL TESTING LABORATORY
SOIL TEST REPORT

Name: B. Ean

Address: Twin Falls

Anything unusual about field?

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_			

Cation Content [ ]; **Sampling Depth:** ___ **inches**

Cation	meq/100g
Calcium	
Magnesium	
Potassium	
Sodium	
Aluminum	

Check Tests Desired

Standard Test [X]; **Soil Sampling Depth:** 12 **inches**

Soil pH	7.6
Available P (ppm P)	3.4
Available K (ppm K)	130
Organic Matter (%)	1.5

P/K test: NaOAc (NaHCO$_3$)

Nitrogen Test [X];

Soil Depth (inches)	Nitrate (ppm)	Ammonium (ppm)
0-12	1	5.6
12-24	2.5	1.7
24-36		
36-48		
48-60		

Sulfur	[X]	Result	16 ppm
Boron	[X]	Result	0.5 ppm
Copper	[ ]	Result	___ ppm
Iron	[ ]	Result	___ ppm
Manganese	[ ]	Result	___ ppm
Zinc	[X]	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:

c. See Soil Test Report #3 (Attached)

Provide a fertilizer recommendation for irrigated alfalfa for Ray Green. Ray lives in Mountain Home, Idaho (south Idaho). Show all calculations.

Nitrogen:

Phosphorus:

Potassium:

Sulfur:

Zinc:

Boron:

Remarks:

FLY-BY-NITE SOIL TESTING LABORATORY
SOIL TEST REPORT

Name: *Ray Green*

Address: *Mountain Home*

Anything unusual about field?

Field Information (Fill in completely)			
Rotation	Crop	N Fertilizer Applied lbs/N	Yield (measured or anticipated)
Next Crop	*irrigated alfalfa*		
Previous Crop	*clover*		
199_			
199_			

Cation Content [ ]; **Sampling Depth:** ___ **inches**

Cation	meq/100g
Calcium	
Magnesium	
Potassium	
Sodium	
Aluminum	

Check Tests Desired

Standard Test [x]; **Soil Sampling Depth:** *12* **inches**

Soil pH	*7.5*
Available P (ppm P)	*4.2*
Available K (ppm K)	*50*
Organic Matter (%)	*3.4*

P/K test: (NaOAc) $NaHCO_3$

Nitrogen Test [x];

Soil Depth (inches)	Nitrate (ppm)	Ammonium (ppm)
0-12	*1.1*	*1.2*
12-24	*2.5*	*2.6*
24-36		
36-48		
48-60		

Sulfur	[x]	Result	*8* ppm
Boron	[x]	Result	*0.35* ppm
Copper	[ ]	Result	___ ppm
Iron	[ ]	Result	___ ppm
Manganese	[ ]	Result	___ ppm
Zinc	[x]	Result	*0.4* ppm
Total Salts	[ ]	Result	___ ppm
Lime Requirement	[ ]	Result	___ t/acre

Soil Fertility Guide:

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

d. See Soil Test Report #4 (Attached)

Provide a fertilizer recommendation for Jim Stevens for potatoes in Power County, Idaho. Show all calculations.

Nitrogen:

Phosphorus:

Potassium:

Sulfur:

Zinc:

Boron:

Remarks:

FLY-BY-NITE SOIL TESTING LABORATORY
SOIL TEST REPORT

Name: Jim Stevens

Address: Power County

Anything unusual about field?

Field Information (Fill in completely)			
Rotation	Crop	N Fertilizer Applied lbs/N	Yield (measured or anticipated)
Next Crop	Potatoes		400 cwt furrow
Previous Crop	Wheat		40 bu residue
199_			returned
199_			

Cation Content [ ]; Sampling Depth: ___ inches

Cation	meq/100g
Calcium	
Magnesium	
Potassium	
Sodium	
Aluminum	

Check Tests Desired

Standard Test [X]; Soil Sampling Depth: 12 inches

Soil pH	7.0
Available P (ppm P)	5.2
Available K (ppm K)	120
Organic Matter (%)	2.4

P/K test: NaOAc (NaHCO$_3$)

Nitrogen Test [X];

Soil Depth (inches)	Nitrate (ppm)	Ammonium (ppm)
0-12	6.4	4.1
12-24	2.4	5.3
24-36		
36-48		
48-60		

Sulfur	[X]	Result	12 ppm
Boron	[X]	Result	0.7 ppm
Copper	[ ]	Result	___ ppm
Iron	[ ]	Result	___ ppm
Manganese	[ ]	Result	___ ppm
Zinc	[X]	Result	0.4 ppm
Total Salts	[ ]	Result	___ ppm
Lime Requirement	[ ]	Result	___ t/acre

Soil Fertility Guide:

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

LESSON 9
Plant Tissue Diagosis

A. Principles

1. General Picture

a.

b.

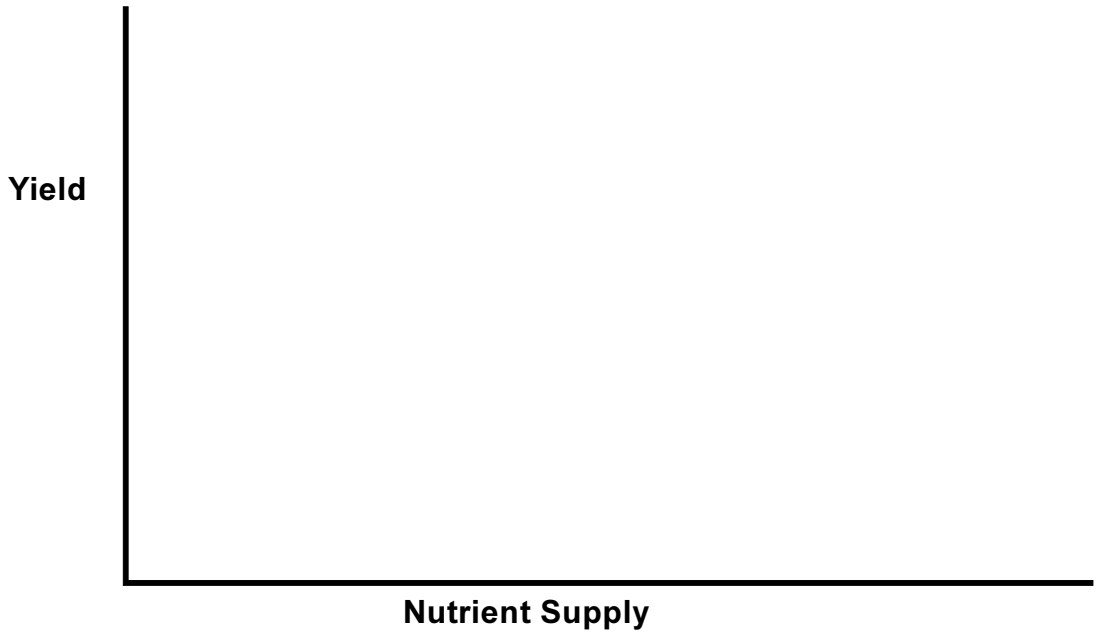
c.

A. Principles

Plant Analysis — is based on the principle that the concentration of a nutrient is an integral value of the factors that have interacted to affect it

1. General Picture

Yield in relation to nutrient supply:



Four distinct zones:

1.

2.

3.

4.

*** Can be divided into two subzones:**

Sub Zone A — Severe deficiency

◆

◆

◆

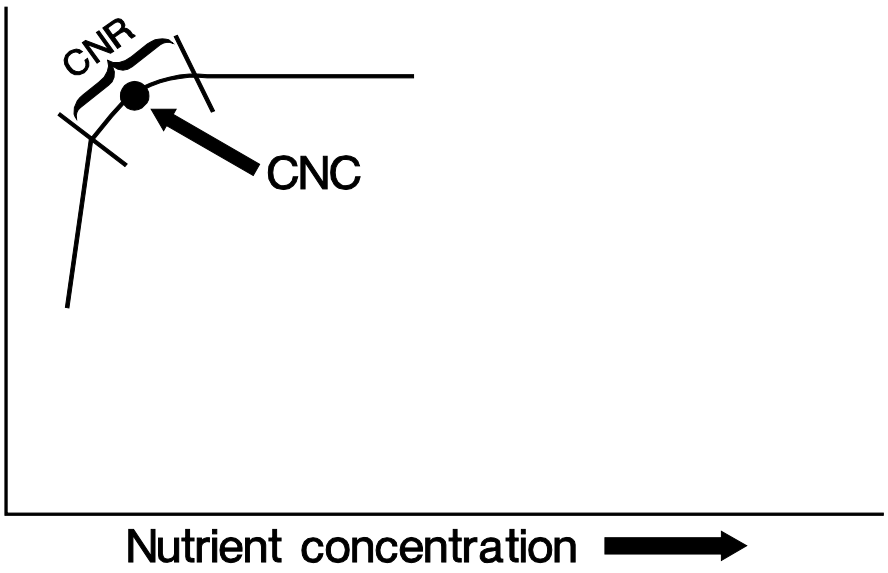
Sub Zone B — Moderate deficiency

- **May not be able to diagnose deficiency by sight**
-
-
- **often called "HIDDEN HUNGER"**

CNR / CNC

CNC — critical nutrient concentration (point)

CNR — critical nutrient range (range)



ADEQUATE —

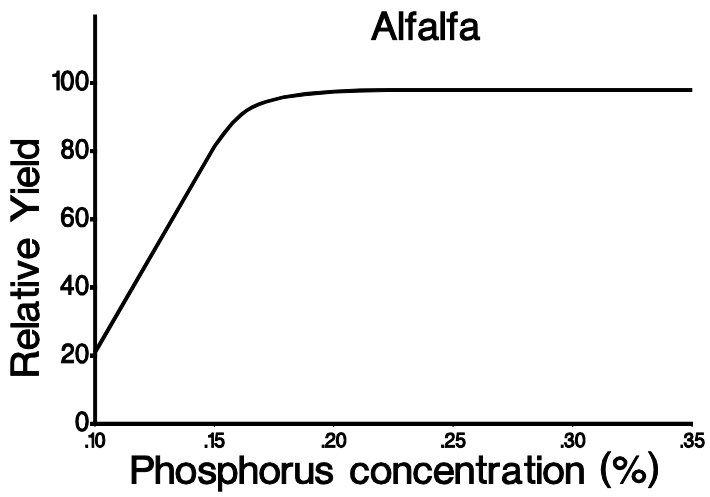
TOXIC —

1.

2.

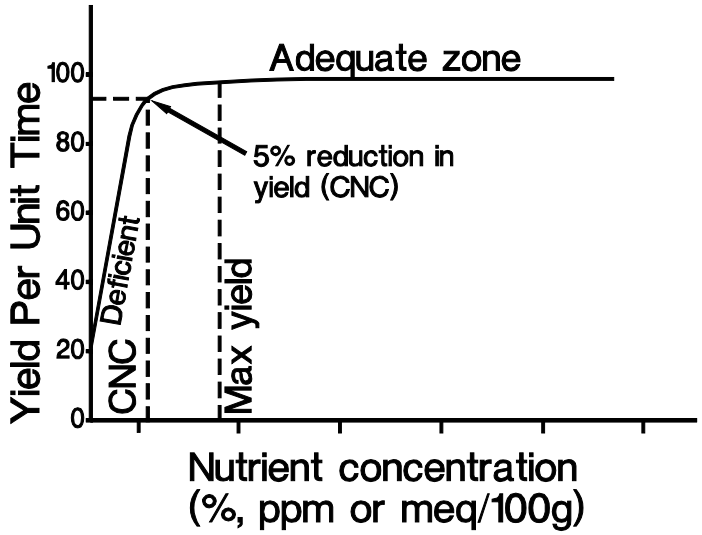
3.

a. Nutrient Concentration Related to Crop Growth



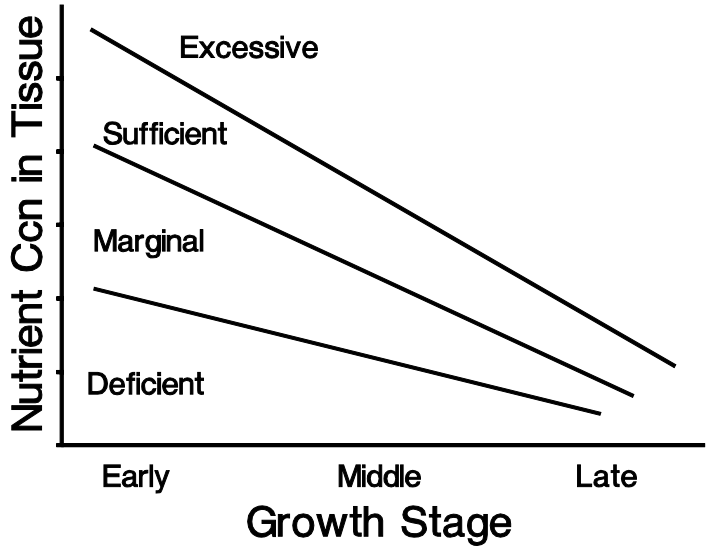
- **Line bends and then plateaus after reaching certain P level**
-
-

A closer look:



b. Nutrient Concentrations and Physiological Maturity of the Crop:

- **Concentrations of some elements change rapidly with time and physiological maturity. Particularly:**
  -
  -
  -
- **Optimum concentrations of these nutrients change with growth stage of the crop**



Idaho Potato Data:

Growth State	Petiole Nitrate-N (ppm)
Plant emergence	>
4 to 8 leaf stage	>
Hooking	
Early tuber set	
Midseason	
Late season	
Harvest	

Nutrient Concentrations and Crop Varieties:

-

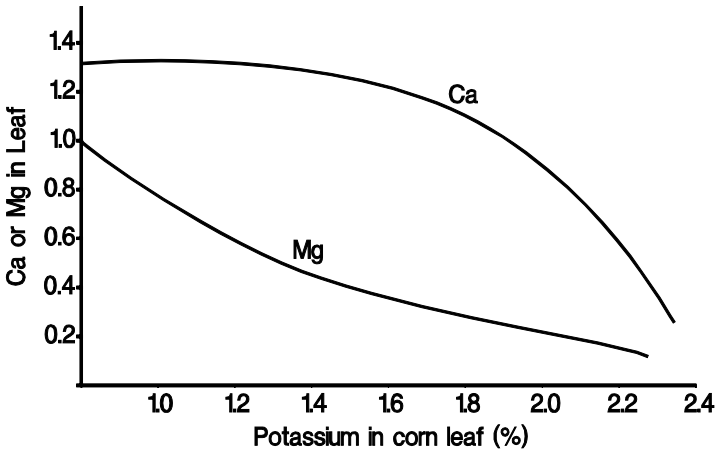
CNC vs CNR:

-

-

- **Inter-relationships with other factors: the uptake of one ion can affect another**

Example: Ca and Mg in potato petioles:

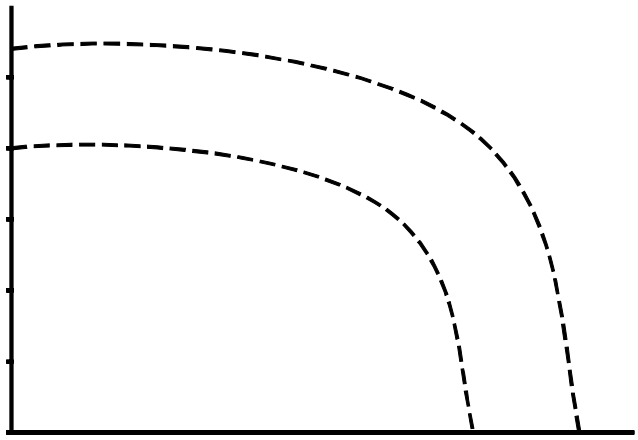


- **In certain crops, one can diagnose the K status of the crop by knowing the Mg content**
-

c. Other factors:

- **Soil moisture**
  -
  - **lack of soil moisture may cause lower plant nutrient concentrations in plant tissue — erroneously recommending nutrient additions**
- **Temperature**
  -
- **Agronomic Factors**
  - **seeding, spacing, liming, etc.**

NO_3-N in petioles (4 or 5):



◆

LESSON 10
Nutrient Deficiency Symptoms
Tissue Sampling

2. Nutrient Deficiency Symptoms

- **Only appear under extremely deficient conditions**
-
-
-
- **Identification of plant nutrient deficiency symptoms can help diagnose field problems**
- **The art/science of identifying nutrient hunger signs is a basic step to profitable crop production**

FIELD KEY:

I. COLOR CHANGES IN LOWER LEAVES

II. COLOR CHANGES IN UPPER LEAVES

I. COLOR CHANGES IN LOWER LEAVES FIRST:

- **Lower leaves turn light green to yellow in color, this will quickly spread to the entire plant . . .**
- **Lower leaves exhibit interveinal chlorosis, eventually spreads to entire plant . . .**

- **Lower leaves exhibit brown discoloration and scorching along outer margins of leaves . . .**

- **Lower leaves remain dark green, plant is stunted, in some cases the plant appears purplish in color . . .**

- **Pronounced bronzing of lower leaves, sometimes with interveinal chlorosis . . .**

II. COLOR CHANGES IN UPPER LEAVES FIRST

A. TERMINAL BUD DIES

B. TERMINAL BUD REMAINS ALIVE

A. TERMINAL BUD DIES

- **Emergence of primary leaves delayed; terminal bud dies . . .**

- **New growth is severely deformed, sometimes yellowish or grayish . . .**

B. TERMINAL BUD REMAINS ALIVE

- **Top leaves turn yellow-green, color change rapidly spreads to rest of the plant . . .**

- **Interveinal chlorosis in new leaves (yellow or white chlorosis) . . .**

- **Leaves yellowish-gray or reddish gray . . .**

- **Poor symptoms, young leaves are pale yellow, wilt, leaf margins exhibit brown color**

3. Tissue Sampling and Analysis

CONCEPT:

There is a good relationship between nutrient concentration in a crop and the growth and yield of the crop

TISSUE ANALYSIS:

KEY: Choice of tissue to collect and analyze

-

- **Some plant parts are much more sensitive to nutrient changes than others**

  Petioles:

  Potatoes —

  Sugar beets —

Upper plant parts:

Alfalfa —

Beans —

Peas/Lentils/Chickpeas —

Lower plant parts:

Wheat —

Oldest leaves of this year's growth:

Sometimes the tissue choice is AGE or NUTRIENT specific:

CORN:

-
-
-

See WREP 43

-
-

Tissue Sampling Problems:

Dryland —

-

- **Difficult to add additional fertilizer to correct problems because of the uncertainty of water moving the nutrient into the plant root zone**
-

Irrigated—

-
- **There has been much correlation work done on different crops**
-

Tissue Sampling and Handling:

-
- **A skilled person knows what to look for; can divide fields into separate units; and take good notes!**
- **In order for plant analysis to be meaningful:**

  1.

  2.

- **In addition, you need to:**

  a. **Take anough samples to represent a field accurately (ie 40 petioles/160 acre field, enough tissue to run an analysis)**

  b.

  c. **If a large area (large enough to treat separately) is obviously different, sample it separately**

  d.

  e.

  f.

  g. **Do not sample the edges of the field — there is a definite edge effect!**

  h. **Partially air dry the collected sample — mail to the laboratory in paper bags (most labs furnish these)**

    -

    - **Use white bags when requesting micronutrients (brown bags have micronutrient contaminants in the glue)**

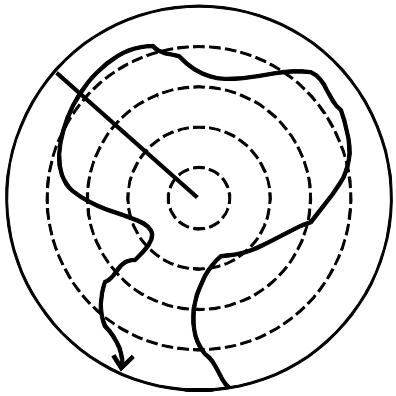
LESSON 11
Tissue Sampling/Diagnosis

Remember:

Stage of maturity influences the CNC/CNR of an element in a plant. For those plants sampled only once a season — always take the sample during the same growth stage — so samples can be compared year to year!

Tissue Sampling Patterns

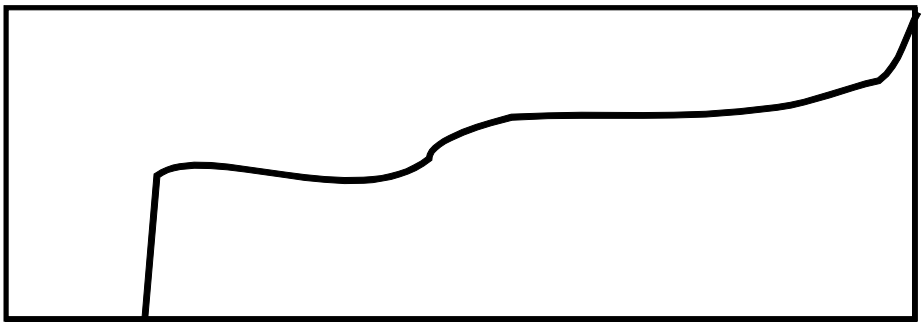
Uniform Field



40 plant samples

Another uniform field:

Sampling pattern for a non-uniform field:



Additional points to remember:

- **Crops sampled at regular intervals during the season should be sampled during the same time of day!**
-
-
- **So nitrate concentrations are higher in the morning than in the afternoon**
  -

Interpretation

- **Much of the work in tissue analysis is based on calibration (ie 3600 is either deficient or sufficient at X growth stage)**
- **HOWEVER; there are other parameters to consider when interpreting a tissue analysis**
  -
  -
  - **Incidence of insects or disease**

-
-
- **Climatic conditions**
-

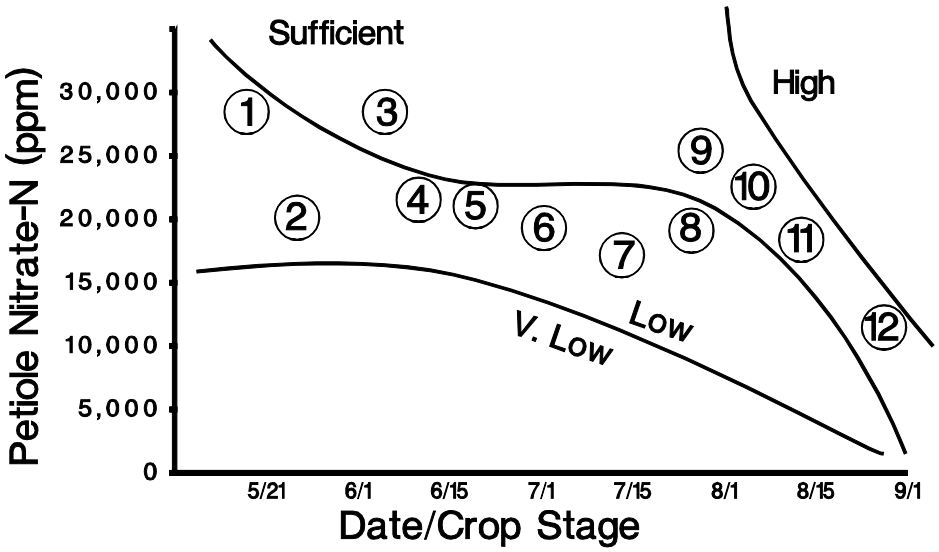
Data handling:

What do we do with data from repeated samplings?

Crop Logging

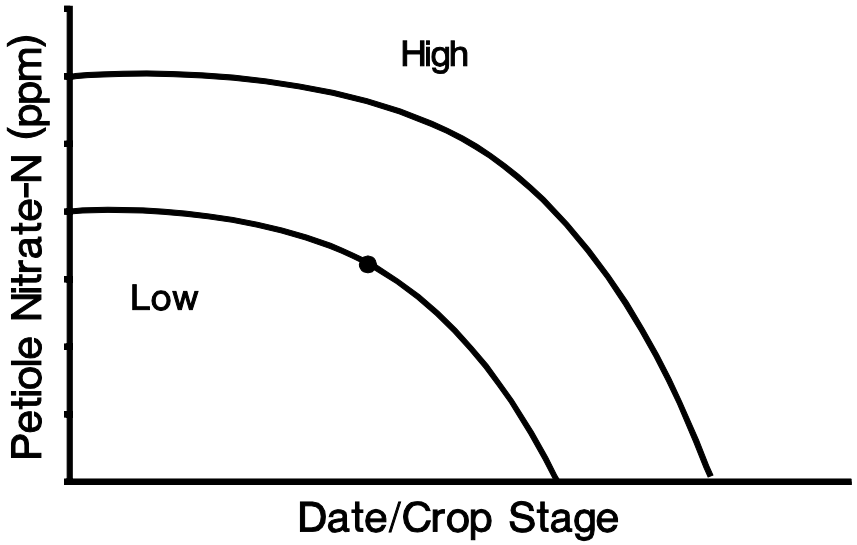
-
-

- **Data is plotted graphically and the trends are considered deciding when and/or if additional fertilizer is required**



Example 1:

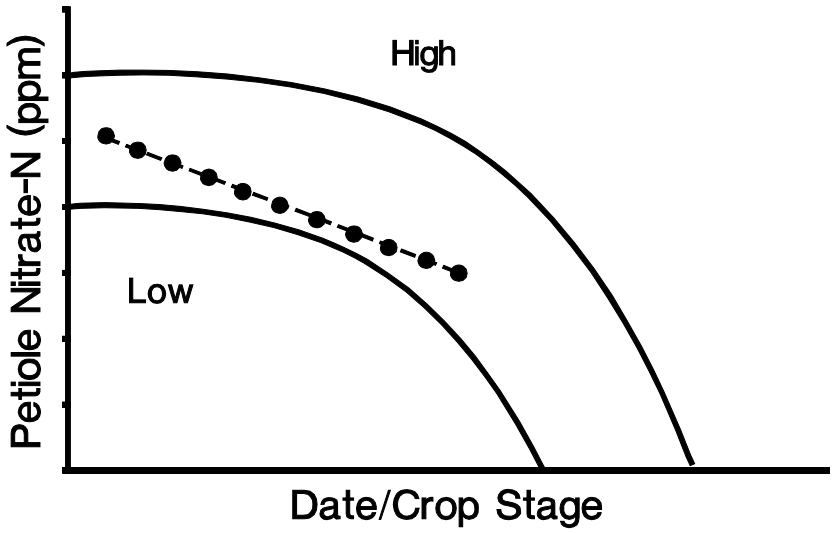
The drawback to only one sampling is in the interpretation — suppose you sample once at midseason:



Diagnosis:

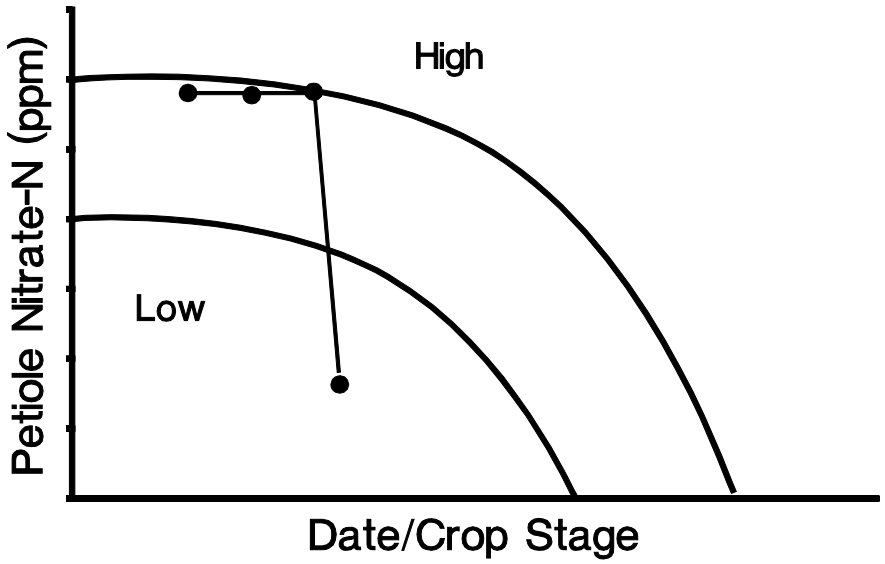
If you had previous samples, you could look at the trends and have an easier dicision to make. If only 1 point is marginal — do you add N? Too much, too little?

Example 2:



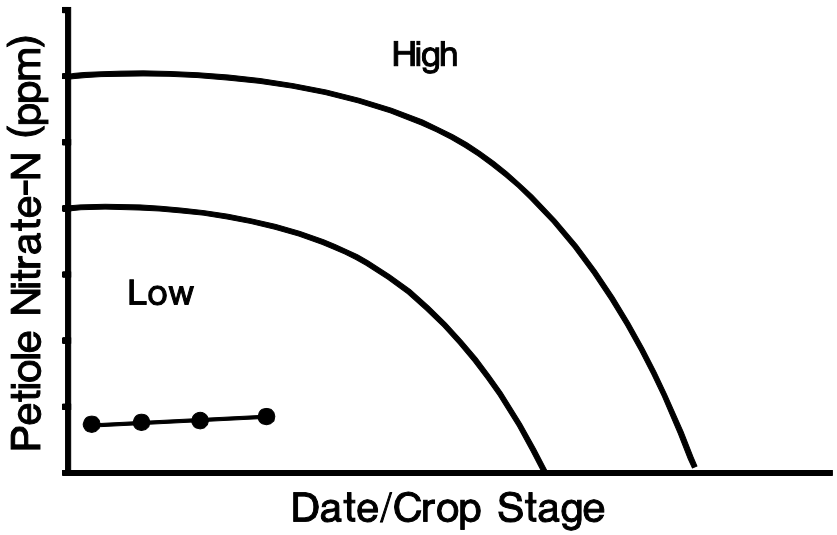
Diagnosis:

Example 3:



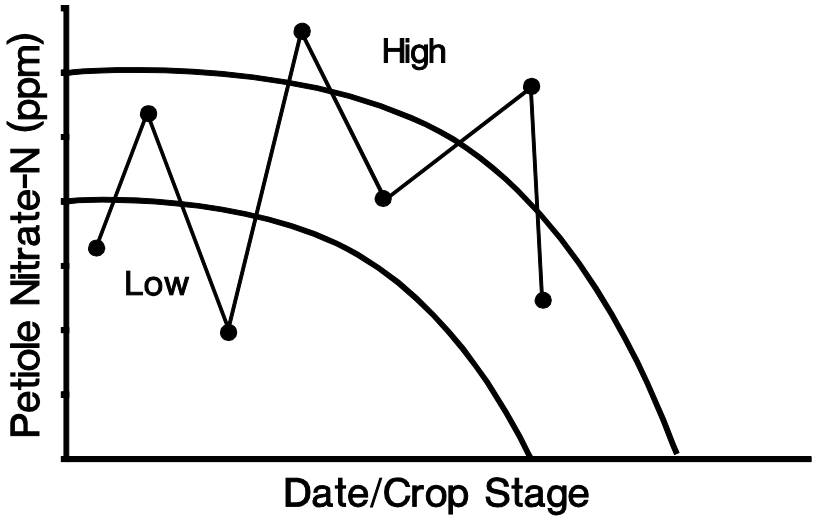
Diagnosis:

Example 4:



Diagnosis:

Example 5:



Diagnosis:

LESSON 12
Tissue Diagnosis: Orchards, Forestry, Interpretation

4. Orchards

- **A nutritional program is dissicult to establish in orchards because:**

1. **Soil diagnosis is very difficult**
   -
   -
   -
2. **Tissue diagnosis also has problems**
   -
   -
   - **Collection of tissue procedures are similar to the information already presented**
   -

-

- **Some currently accepted critical values for N, P, and K in fruit trees grown in the Pacific Northwest:**

Fruit	Nitrogen CNR	Nitrogen Excess	Phosphorus CNR	Potassium CNR
Apples	1.7-2.0	> 3.0	.1%	.8-1.5%
Cherries	2.0-2.5	> 3.5	.1%	.8-1.5%
Peaches	2.5-3.0	> 3.5	.1%	.8-2.5%
Pears	1.7-2.0	--	.1%	.8-1.5%
Plums	2.0-2.5	> 3.5	.1%	.8-1.5%

Fruit trees require moderate nitrogen levels, relatively low phosphorus levels, and moderate potassium levels

Micronutrient requirements:

- **Boron –**
- **Zinc –**
- **Manganese –**
- **Copper –**
- **Iron –**

5. *Forest Fertilization*

Objective of forest fertilization:

1. **Increase plant growth**
2.
3. **Insect control**
4.

5.

6.

7.

8. Range and wildfile browse values

a. Sampling Tissue

- Relatively straight forward for conifers

  -

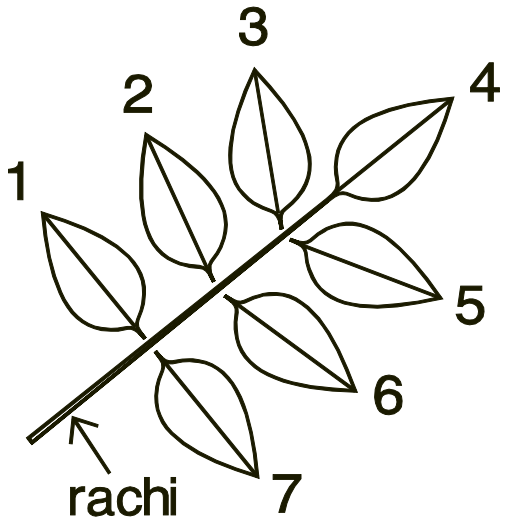
-

Ash leaves and rachi:

Plant portion	Nitrogen content (%)
Rachi	0.76
leaf 1	1.1
leaf 2	2.3
leaf 3	2.4
leaf 4	3.4
leaf 5	2.4
leaf 6	2.2
leaf 7	1.4

Conclusion: pick a leaf or rachi; do not composite because the composite could mask problems. Choose either leaf 4 or rachi.

Ash example:



Which species? Which storey?

b. Sampling Position

- **This is another problem. Questions:**

  1.

  2.

  3.

c. Sampling time

- **Problems**
  -
  -

d. Sample analysis

-

e. Some Critical Values

Nutrient	CNR's (species dependent)	
Nitrogen	1.3 - 1.5%	
Phosphorus	0.05 - 0.13%	
Potassium	.3 - .7%	
Sulfur	.1 - .3%	
Calcium	.1 - .4%	
Magnesium	.05 - .15%	
Manganese	no good values	25-2300 ppm
Iron		50 ppm
Copper		4-6 ppm
Zinc		8-12 ppm
Boron		5-8 ppm
Molybdenum		0.03-0.06 ppm

B. Interpretations

1. Using CNR/CNC Systems

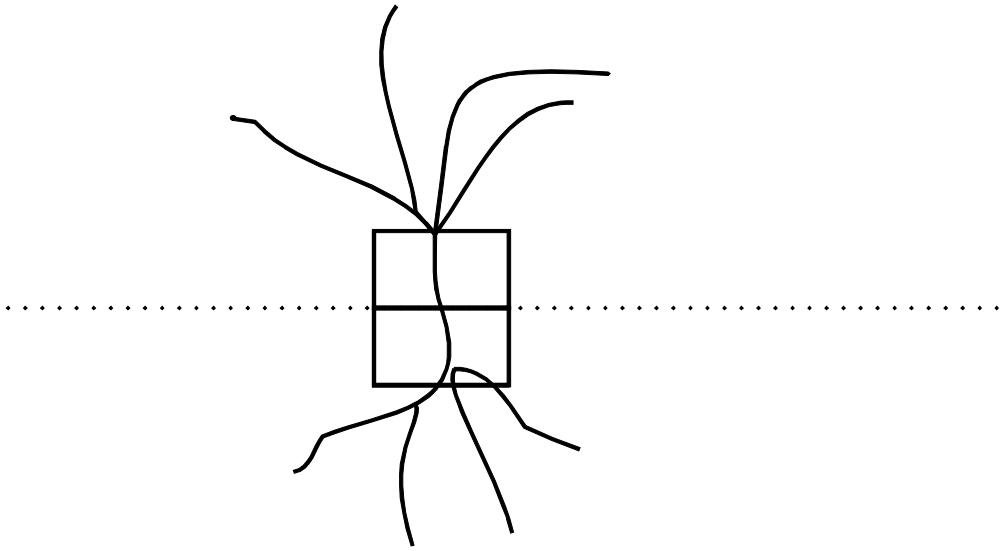
a. Irrigated Winter Wheat

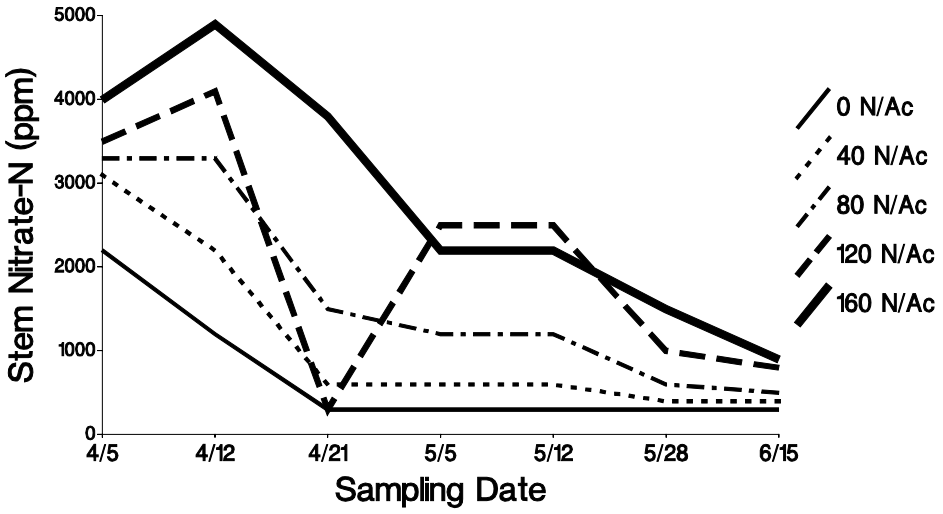
- **Use tissue as an indicator of the nitrogen status of winter wheat cultivars**

Sampling:

- **Sampling begins when the wheat seedlings reach the 3 or 4 leaf stage**
-
-

- **At least 25 plants should be removed at random from each field**
-
-
- **Later at jointing, the first 2 inches of the stem portion above the ground are used**





- **There is a good relationship between NO_3-N and nitrogen fertilizer rate at given sampling dates**

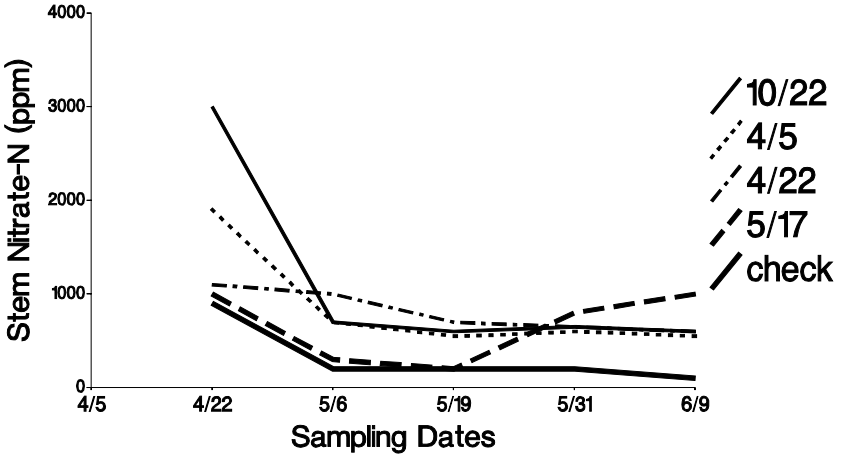
N Treatment (lb/a)	Yield (bu/a)	Protein (%)
0	57	8.0
40	59	8.0
80	70	8.9
120	93	9.5
160	102	9.9

Results:

- **For maximum yields NO_3-N concentrations in leaf tissue should exceed 3,500 ppm at the 3 to 4 leaf stage, and 1,000 ppm at jointing**

-

All rates: 80 lbs N/ac:



Applications Date		Yield (bu/a)	Protein (%)
10/22		70	8.9
4/5		84	8.6
4/22		88	9.1
5/17		82	9.8
Check	≥	57	8.0

Results showed that the early srping applications were more effective in increasing YIELD and TISSUE NO_3-N

- **Applications made later in the spring, after jointing, increased the NO_3-N content in wheat tissue but were less effective in increasing yield**

- **When interpretations and recommendations are made based on NO_3-N levels, remember that factors other than sampling date may influence NO_3-N levels**

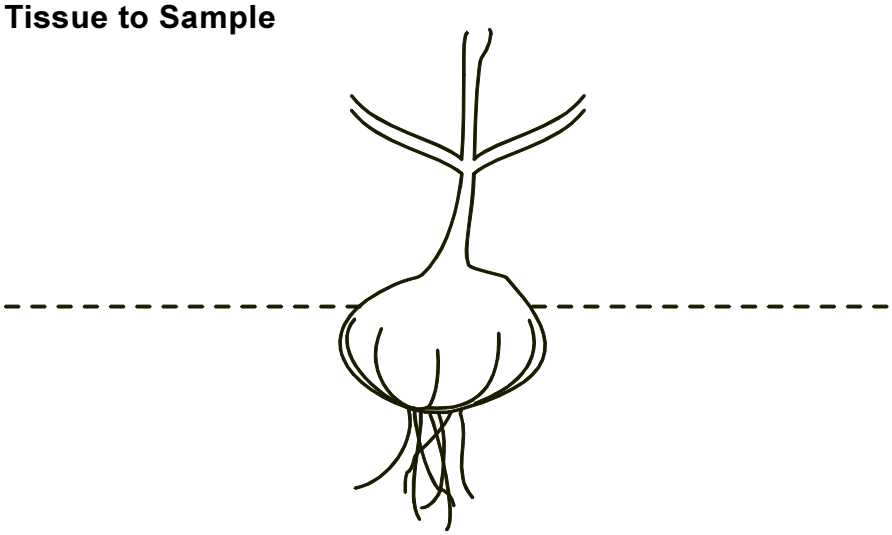
  -
  -
  -
  -

LESSON 13
Interpretation: Onions, Peppermint
Integration with Soil Sampling

b. Onions

- **Adequate nitrogen is necessary for maximum onion production, yet excess N can reduce:**
  -
  -
  -

Tissue to Sample



1. Most recently matured leaf

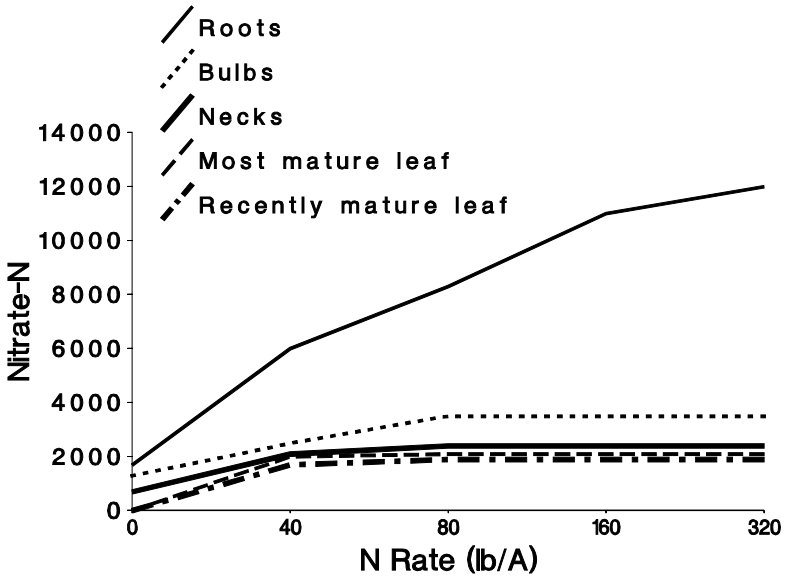
2.

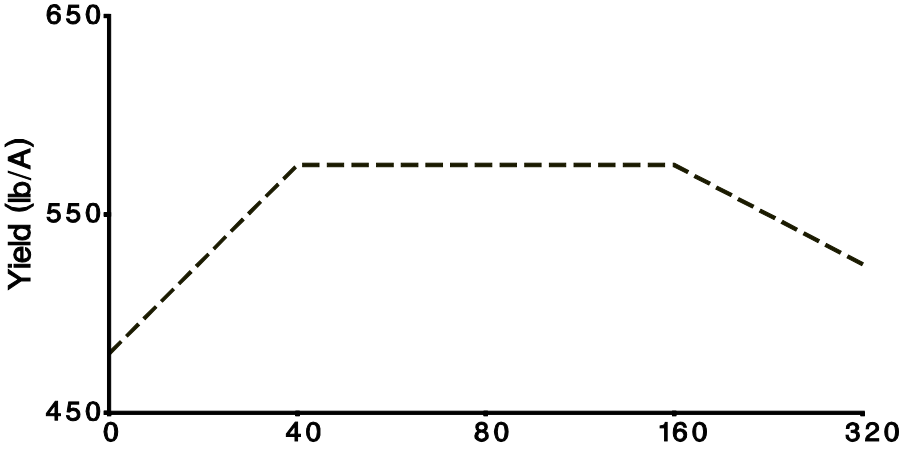
3.

4.

5.

Tissue Sensitivity:





◆

◆

Major problem with onions is that sensitivity is poor

Root NO_3-N levels

- **6,600 ppm NO_3-N in roots when bulbs are ¼ - ½" in diameter**

Maximum onion yield are achieved when:

- **bulbs —**
- **necks —**
- **most mature leaf —**
- **recent mature leaf —**
- **roots —**

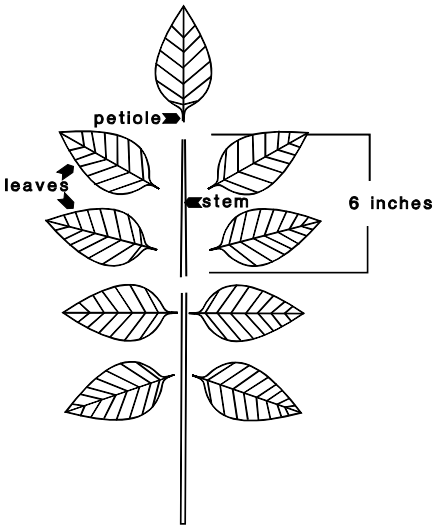
c. Peppermint

- **Nitrogen is the nutrient most often responsible for reducing peppermint oil yields in Idaho**
-
-

Sampling:

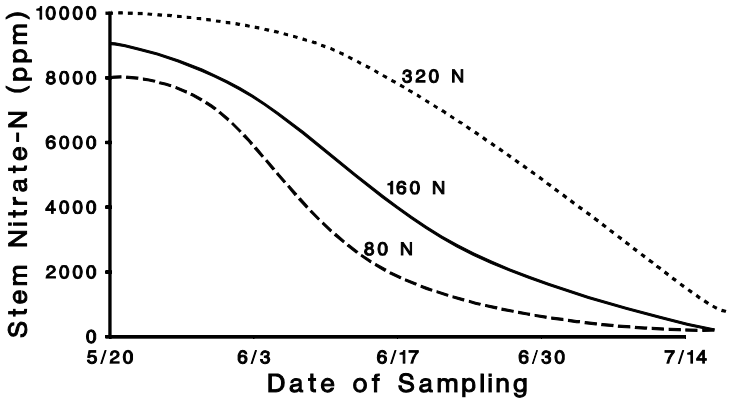
- **Sampling should begin when the plant reaches a height of 8 to 10 inches and continue periodically until harvest**

- **Part of the plant sampled:**



- **The sample should consist of the top 6 inches of the stem with leaves, petioles, and blossoms removed**

-

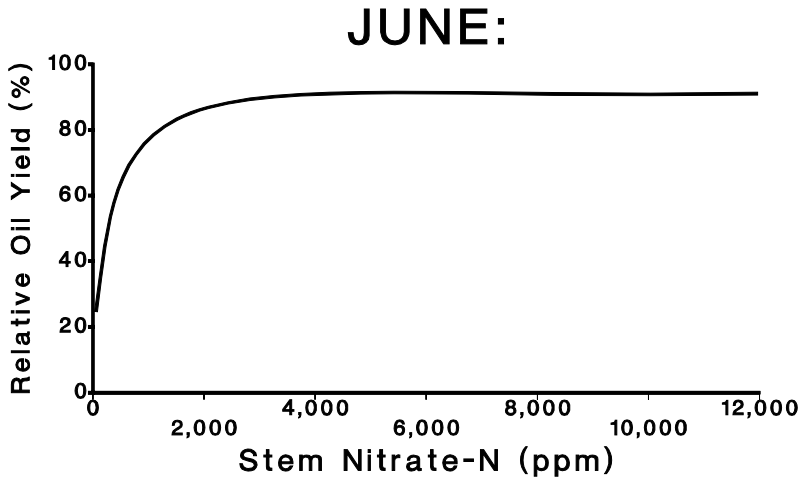


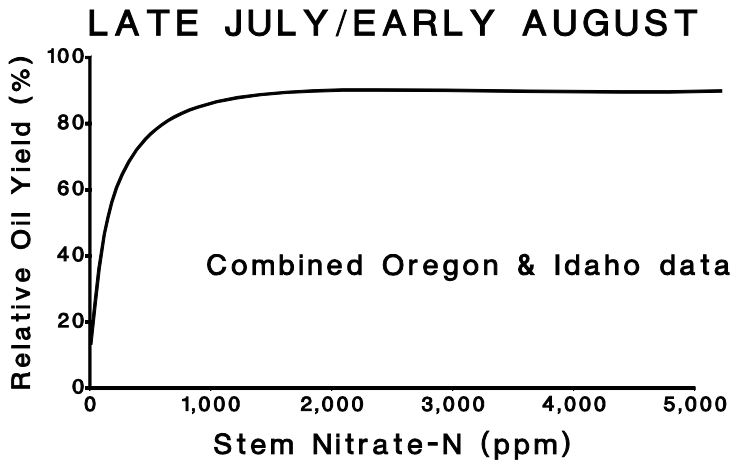
Research:

- **Critical levels were established using field experiments**

-

- Levels of stem NO_3-N decreased with time, the rate of decline dependent on nitrogen fertilization rate
- Relative oil yield (% of maximum yield) was related to peppermint stem NO_3-N levels occurring during the season

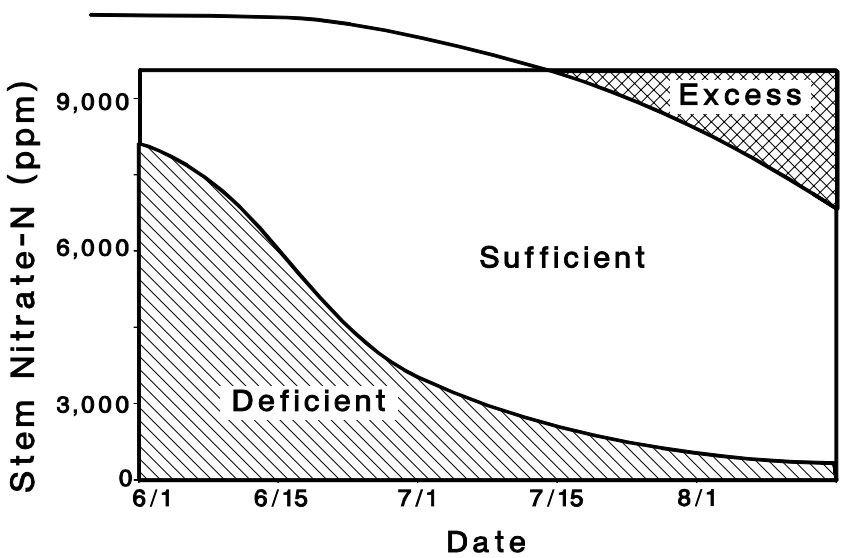




- **Relative oil yield did not increase when stem NO_3-N levels exceeded 4,000 ppm in late June and 2,000 ppm in late July to early August**

-

- **Stem NO_3-N concentrations above 8,000 ppm in early June, 4,000 ppm in early July, and 1,000 ppm in early August are necessary for maximum oil production**



Summary of the three presented examples:

Parameter	Wheat	Onions	Peppermint
NO_3-N or TKN	NO_3-N	NO_3-N	NO_3-N
Plant part	Stem	Roots	Stem
Stage of growth	Many	Few	Many
Critical values	1,000-3,500	6,600	1,000-8,000

2. Integration with Soil Sampling

Earlier example: POTATOES

a. Cropping Systems

- **Most important for situations where soil sampling by itself does not provide entirely satisfactory results:**

(i) Reduced tillage systems

-

-

-

▶

(ii) Perennial Crops

– sod crop	**– alfalfa**
– pastures	**– mint**

- **situations where fertilizer is topdressed and non-mobile elements (P, K) are concentrated in the surface inches**

▶

▶

(iii) Irrigated Cropping Systems

▶

Bernerally:

-
-
-

LESSON 14
Integration with Soil Sampling
DRIS

(iv) Fertilizer Banded Fields

-
-
- **potential for integration is good only in higher precipitation areas**

(v) Cropping Systems where Fall-seeded Crops receive Spring Applications of Fertilizers

aa. Winter Wheat:

-
-

bb. Winter Rapeseed

- **planted in the fall (before September 1)**
-
-
- **high nitrogen demand, but too much in fall reduces winterhardiness**

Strategy:

1. Soil test 3 weeks before planting

2.

3.

4. Spring N rate on basis of:

(1)

(2)

Comments: good strategy but there are some gaps ...

1.

2.

3.

b. Environmental Considerations

In the near future:

1.

2. Fertilizers will only be applied to soils when a demonstrated need has been shown

3. Soil sampling will be used not only for fertilizer recommendations but to quantify the levels of nutrients at different depths in the soil, and proximity to the water table

4.

- **major work in this area**

3. DRIS

The Diagnostic and Recommendation Integrated System

-
-
-

A. Nutrient Concentration and Aging

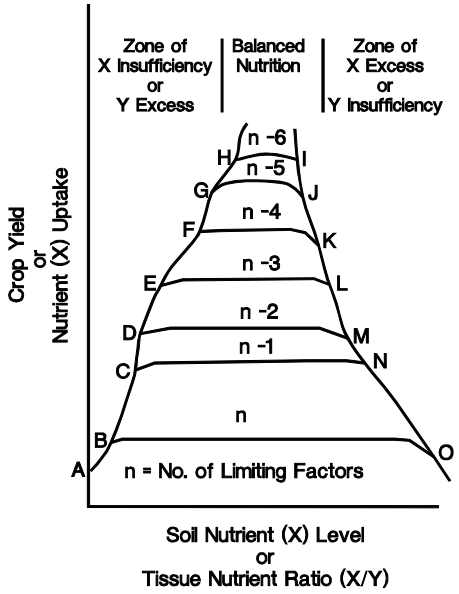
-
-
- **Calcium and magnesium tend to increase in tissue with aging**
-
-
- **Some have reasoned that since N, P, and K all decrease at relatively the same rate during the season that ratio's will remain constant ... N/P/K ratio constant throughout the growing season**
  -
  -

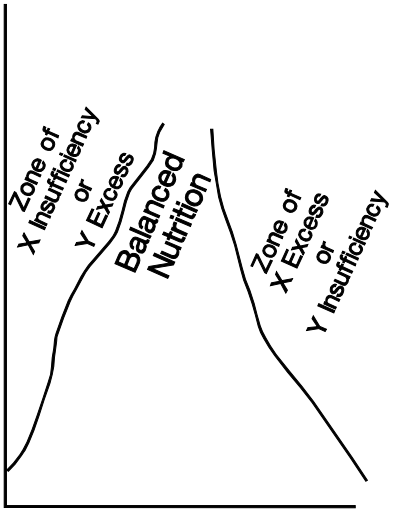
B. DRIS Norms

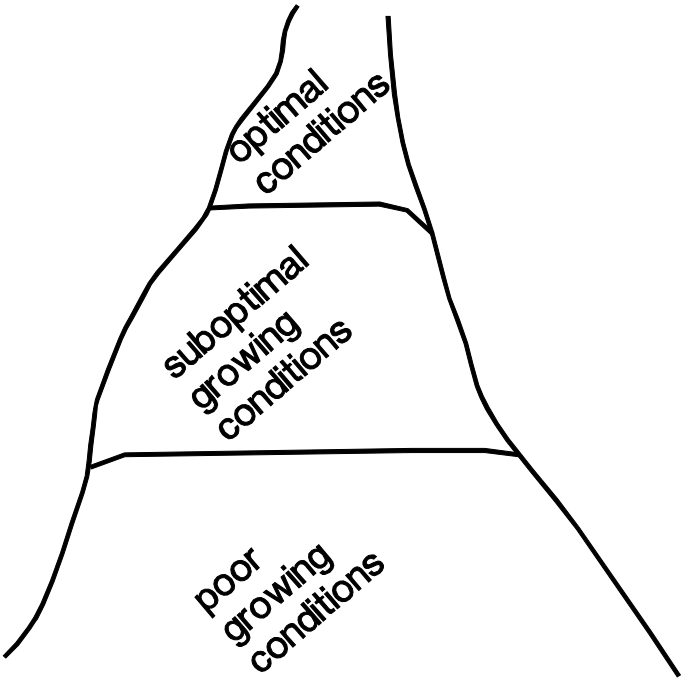
1st step:

◆

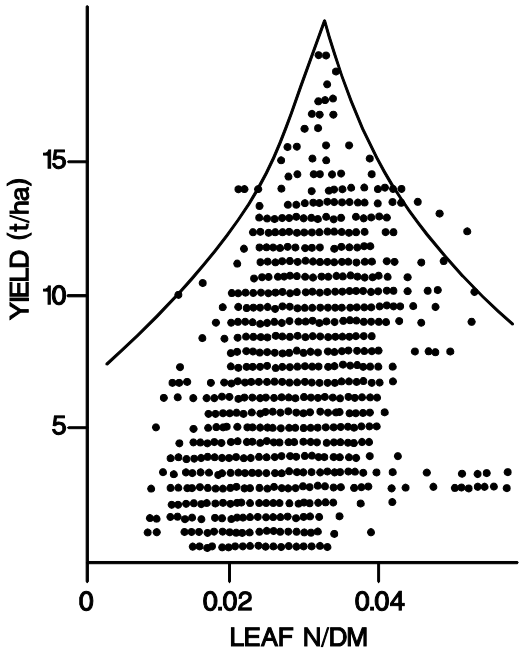
◆ **DRIS utilizes a survey approach for norm determination that is based on a crop response model:**




Zone of
X Insufficiency
or
Y Excess
Balanced
Nutrition
Zone of
X Excess
or
Y Insufficiency

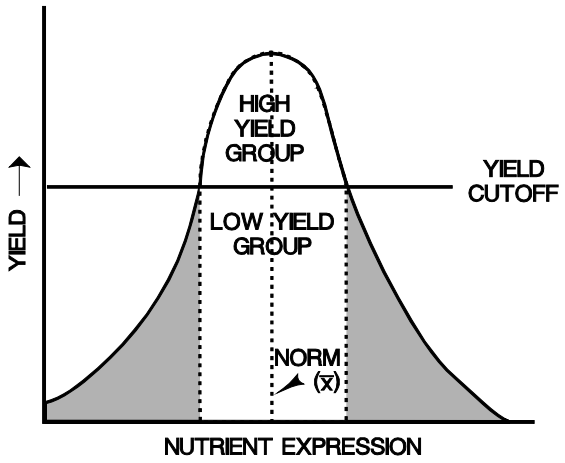

optimal
conditions
suboptimal
growing
conditions
poor
growing
conditions

Because tissue data is not normally distributed:



◆

◆



◆ **The High/Low yield cutoff point is not critical as long as high yield is normally distributed**

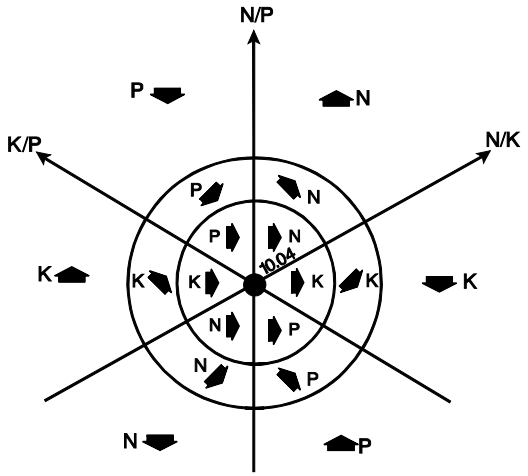
- **When comparing nutrient ratios of any two nutrients there are three possible forms of expression:**
  -
  -
  -
- **Use only 1 expression**
-
- **This is done by comparing the variance of the low-yielding group to that of the high-yielding group. The form of expression (N/P, P/N, or N x P) selected for use within DRIS calculations is that with the largest variance ratio**
-
- **The forms of expression found that best discriminate between high and low-yielding subpopulations have been selected on the basis of the variance ratio and are N/P, N/K, and K/P**

LESSON 15
DRIS

C. Making a Diagnosis:

Use of a DRIS Chart

- **In the simplest case the norms of three selected nutrients can be related to one another in a so-called DRIS chart**
- **The point of intersection of the three axes corresponds to the mean value for the high-yielding population for each form of expression:**
  -
  -
  -
- **A DRIS chart:**



- **This is the composition desired in order to increase the chances of obtaining a high yield**
-

-

- **A tissue analysis composition falling in the inner circle would be considered balanced and is denoted by horizontal arrows**

-

- **The zone of imbalance is divided into 2 subzones:**

1. **The first zone of imbalance is a zone of slight to moderate nutrient imbalance**

   -

   -

2. **The second zone is beyond the outer circle; this is a zone of marked imbalance and is denoted by vertical arrows**

Example:

	Nitrogen		Phosphorus	Potassium
	3.30%		0.20%	1.2%
N/P =	3.3/.2	=	16.5	
N/K =	3.3/1.2	=	2.75	
K/P =	1.2 / .2	=	6.00	

- **Because the excess of one nutrient corresponds to a shortage of another in terms of balance only insufficiencies are recorded by convention for purpose of diagnosis**

So:

N/P: lies beyond outer zone giving

N/K: lies beyond outer zone giving

K/P: inside circle

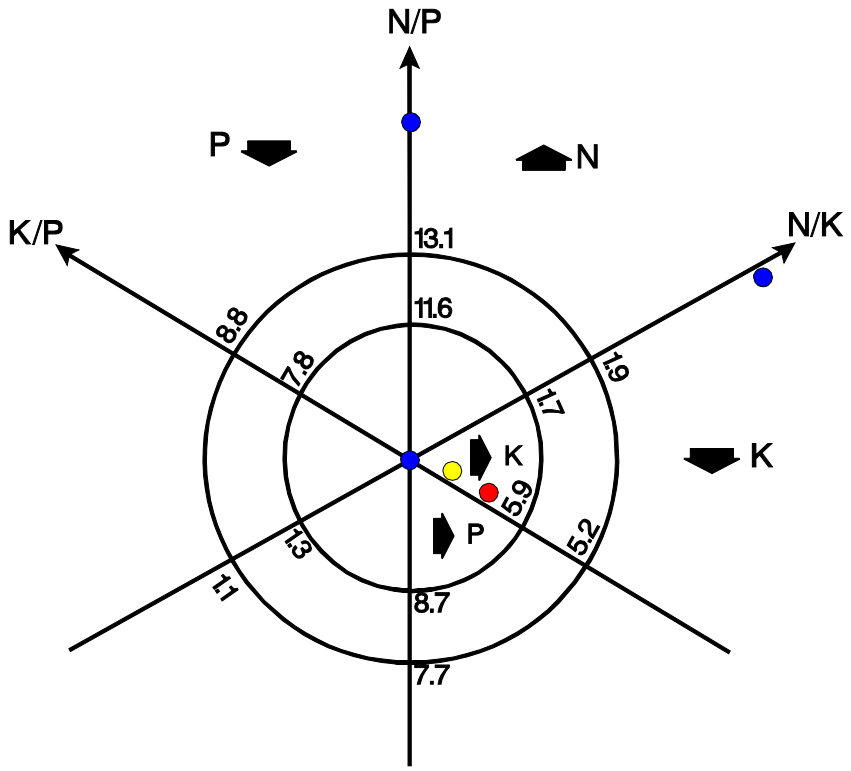
- **Once the three common functions are assigned the remaining element gets a horizontal arrow:**

- **Order or requirement:**

- **K and P are more limiting than N**

Going back to the DRIS chart:

N/P = 16.5
N/K = 2.75
K/P = 6.0



D. Calculating DRIS Indicies

- **Diagrams are okay for three nutrients but mathematical expressions should be used for more nutrients**

-

- **Initially, standard values or norms must be obtained in a manner previously described. The norms are than used to generate indicies by the following equations:**

For nutrients A through N:

$$\text{A Index} = \frac{\left[\int(A/B) + \int(A/C) + \int(A/D) \ldots + \int(A/N)\right]}{z}$$

$$\text{B Index} = \frac{\left[\int(A/B) + \int(B/C) + \int(B/D) \ldots + \int(B/N)\right]}{z}$$

$$\text{N Index} = \frac{\left[\int(A/N) + \int(B/N) + \int(C/N) \ldots + \int(M/N)\right]}{z}$$

where, when A/B $\geq$ a/b,

$$\int(A/B) = \left(\frac{A/B}{a/b} - 1\right) \frac{1000}{CV}$$

or, when A/B < a/b,

$$\int(A/B) = \left(1 - \frac{a/b}{A/B}\right) \frac{1000}{CV}$$

A/B is the value of ratio of elements in tissue

a/b is the norm for that ratio

CV; z is the number of functions comprising the nutrient index

-

For example:

$$\int\left(A/B\right) = \left(\frac{A/B}{a/b} - 1\right)\frac{1000}{CV}$$

E. Nutrient Index Interpretation

- **Because the value of each ratio function is added to one index subtotal and subtracted from another all indices are balanced to 0**

-

  -

Example: using only N, P, and K:

  -

  -

  -

Corn Leaves:

Form	Low Yielding Pop. Mean	CV	Var S_A	High Yielding Pop. Mean	CV	Var S_B	Variance Ratio S_A/S_B
N (% DM)	2.86	20	.326	3.16	18	.303	1.075
P	.30	20	.0036	.32	22	.0050	.720
K	2.32	27	.392	2.12	23	.238	1.647
N/P	9.88	18	3.158	10.04	14	1.996	1.582
P/N	.10	18	.00032	.10	16	.00026	1.231
NP	.85	33	.0792	.98	32	.0961	.824
N/K	1.39	28	.150	1.49	21	.101	1.485
K/N	.81	24	.0380	.72	22	.0259	1.467
NK	6.59	34	5.040	6.45	34	4.910	1.026
K/P	6.94	29	4.000	6.74	22	2.222	1.800
P/K	.13	26	.0011	.15	24	.0013	.0846
PK	.71	37	.0675	.68	36	.0611	1.105

Sample ratios:

N/P =

N/K =

K/P =

Therefore:

$$\int\left(N/P\right) = \left(\frac{N/P}{n/p} - 1\right)\frac{1000}{CV}$$

because N/P > n/p.
Inserting proper values:

[(16.5/10.04) - 1][1000/14] = 45.96

for N/K:

$$\int\left(N/K\right) = \left(\frac{N/K}{n/k} - 1\right)\frac{1000}{CV} = \left(\frac{2.75}{1.49} - 1\right)\frac{1000}{CV} = 40.27$$

For K/P because k/p > K/P:

$$\int\left(K/P\right) = \left(1 - \frac{k/p}{K/P}\right)\frac{1000}{CV} = \left(1 - \frac{6.74}{6.00}\right)\frac{1000}{CV} = -5.6$$

N Index = $[\int(N/P) + \int(N/K)] / 2 =$
$(45.96 + 40.27) / 2 = 43$

P Index = $[\int(N/P) + \int(K/P)] / 2 =$
$(-45.96 + 5.61) / 2 = -20$

K Index = $[\int(N/K) + \int(K/P)] / 2 =$
$(-40.27 - 5.61) / 2 = -23$

Based on the Index values: