the Southern Region small fruit consortium

Small Fruit Crops Fertility Programs, January 7, 2016, Savannah, GA

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SMALL FRUIT CROPS FERTILITY PROGRAMS

SRSFC SPONSORED COUNTY AGENT TRAINING

January 7, 2016

Savannah International Trade and Convention Center

Savannah, Georgia

in cooperation with

2016 Southeast Regional Fruit and Vegetable Conference

SRSFC In-Service Training, January 7, 2016
Small Fruit Crops Fertility Program

Savannah International Trade and Convention Center Room 201

Time	Speaker	Topic
8:00 – 08:15	Mitchem	Welcome & Housekeeping
8:15 – 09:45	David Butler	Soils & soil fertility Lime & nutrient movement in the soil Functions of the various essential elements in plant growth & fruiting Carbon Products Differences among private & university labs in testing methods and reporting
9:45 – 10:15	**BREAK**	
10:15 – 12:00	Bernadine Strik	Blueberry, raspberry & blackberry: - Soil sampling & requirements - Site preparation (pH adjustment, organic matter, mulching) - Assessment of plant nutrient status - Interpretation of tissue analysis results - Fertilizer rates … starting points - Adjustment of nutrient management programs based on plant uptake of nutrients & losses - Sources of nutrients/fertilizers
12:00 – 12:45	**LUNCH**	
12:45 – 01:30	Dave Lockwood	Liming & fertilization: - what to use (soil testing & tissue analysis) - when to use it - how to apply it (incorporation, broadcast, banding, fertigation, foliar application) Is it SNAKE OIL or the REAL DEAL? Thoughts on new products.
1:30 – 2:15	Allen Straw	Strawberry fertilization – from site preparation through harvest
2:15 – 2:45	**BREAK**	
2:45 – 3:45	Butler, Strik, Lockwood & Straw	Interpreting soil & tissue tests Formulating recommendations
3:45 – 4:45	Butler, Strik, Lockwood & Straw	Group exercise: writing soil fertility recommendations (pre & postplant) and crop fertility recommendations based on tissue analysis results Review & Discussion
4:45 – 5:00	Mitchem & Monaco	Wrap up

SRSFC INSERVICE TRAINING

SOIL FERTILITY & TESTING OVERVIEW

David Butler, Ph.D.

Assistant Professor

Organic, Sustainable & Alternative Crop Production

Plant Sciences Department, The University of Tennessee

Jan 7, 2016

Learning Objectives

- Review basic properties of soils
- Describe nutrient cycles of plant macronutrients
- Describe functions of plant macronutrients in plant growth
- Briefly describe plant micronutrient functions and soil dynamics
- Describe basic soil testing procedures used in the southeastern US
- Discuss potential use of liquid C products in crop production

Overview: Plant nutrition & soil fertility

- Basic soils review
- Primary macronutrients
  - Nitrogen
  - Phosphorus
  - Potassium
- Secondary macronutrients
  - Sulfur
  - Calcium & Magnesium
- Micronutrients
- Soil testing overview
- Carbon products

(Photo from: D. Butler)

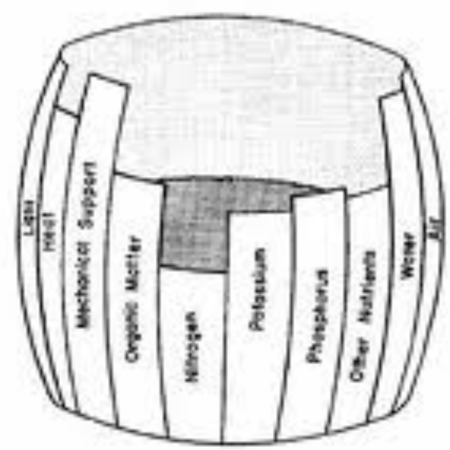
Plant nutrients

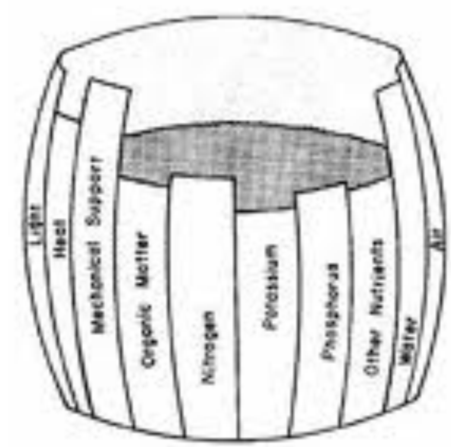
- *"A chemical element essential for plant growth and reproduction"*
- Derived from air or water
  - C, H, O
- Macronutrients (> 0.1% of tissue)
  - N, P, K, Ca, Mg, S
- Micronutrients (< 0.01% of tissue)
  - Fe, Mn, Cu, B, Zn, Mo, Cl, Ni
- Soil fertility is the capacity of the soil to provide nutrients for plant growth

(Barker and Pilbeam, 2007)

Nutrients and soil fertility

- Sprengel-Liebig law of the minimum
- Growth controlled by limiting resource
- Not necessarily nutrients (temperature, water, genetics, etc.)

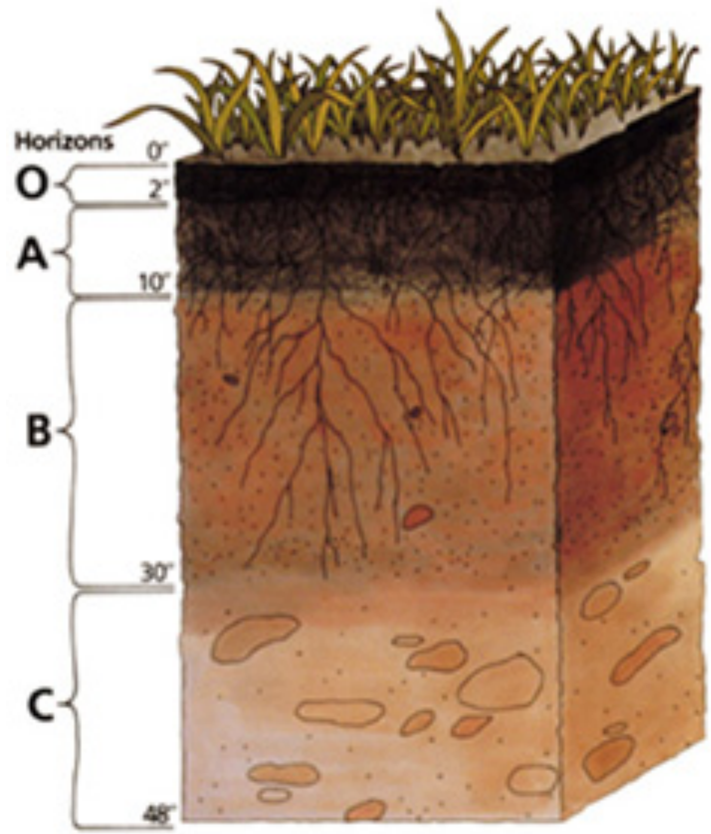




(Image from waternut.org)

What is soil?

- Unconsolidated mineral or organic matter on the Earth's surface influenced by genetic and environmental factors of:
  - climate
  - macro- and microorganisms
  - topography
  - parent material
  - time

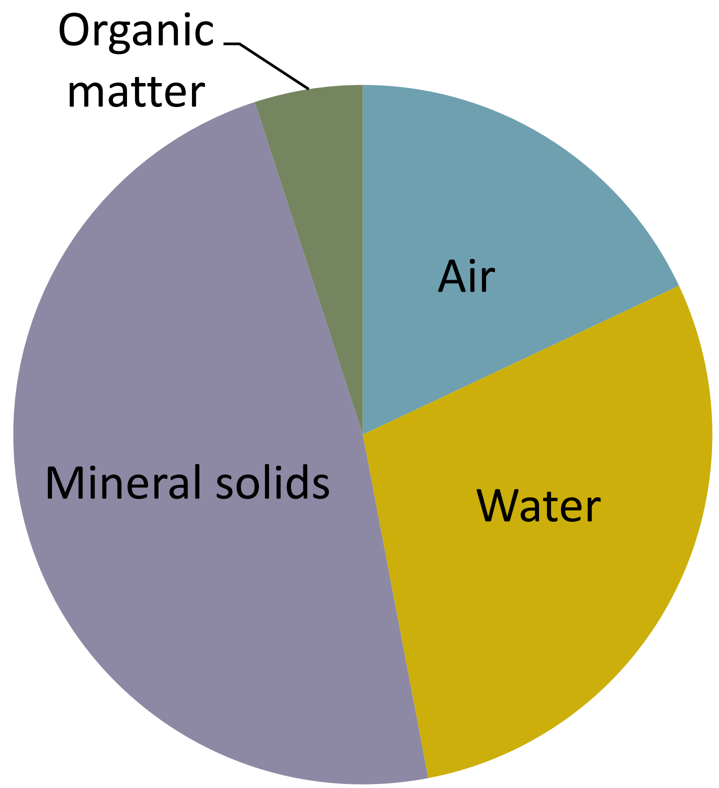


(Soil Science Society of America; image: usda.gov)

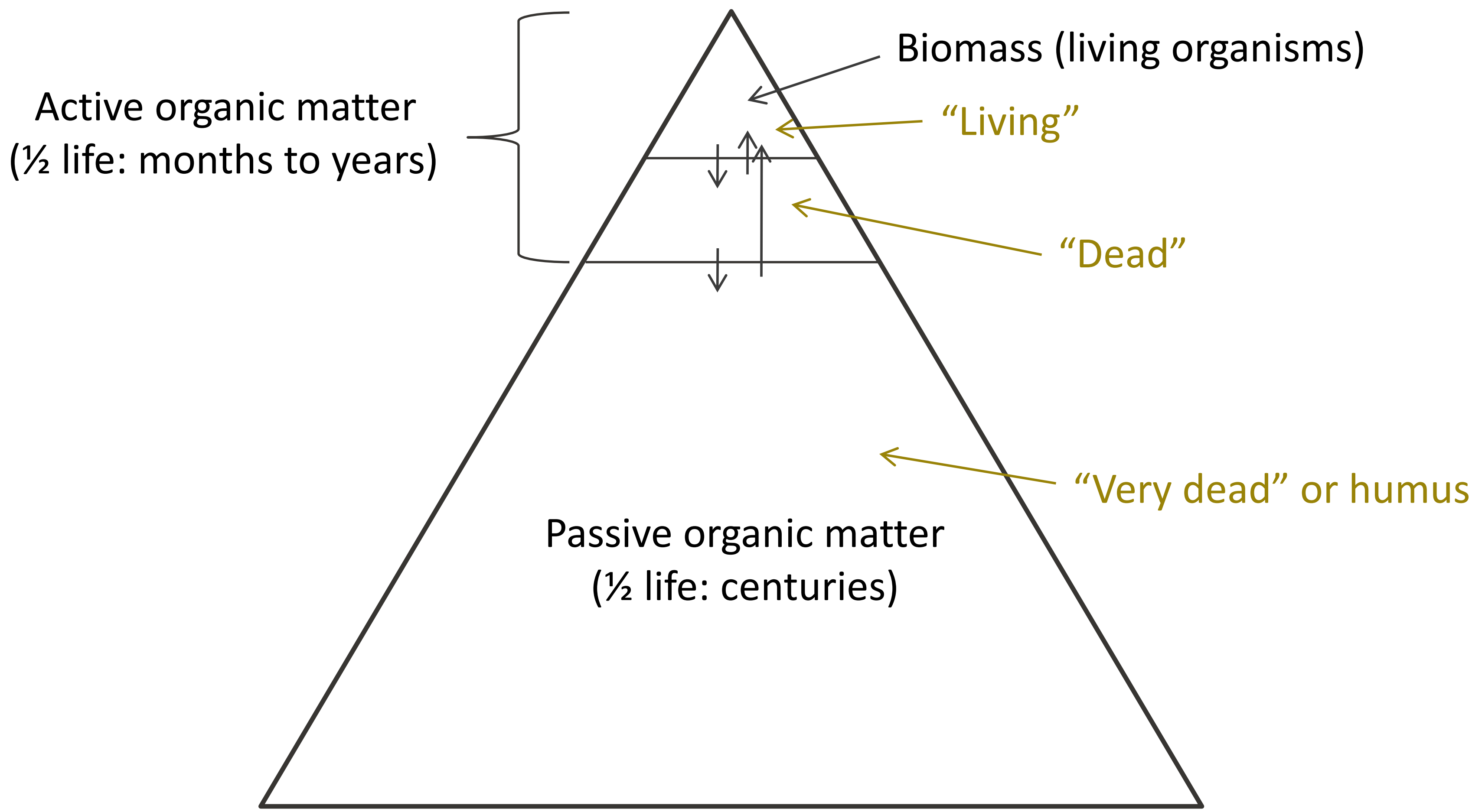
What is soil?

- Mineral solids
  - Sand, silt, clay
  - Mainly consist of O, Si, Al, Fe*, Mg*, Ca*, Na, K*
- Water/soil solution
- Air
- **Organic matter**
  - C (~ 58%), O, H
  - N*, S*, P*, all other nutrients*

* indicates plant nutrient



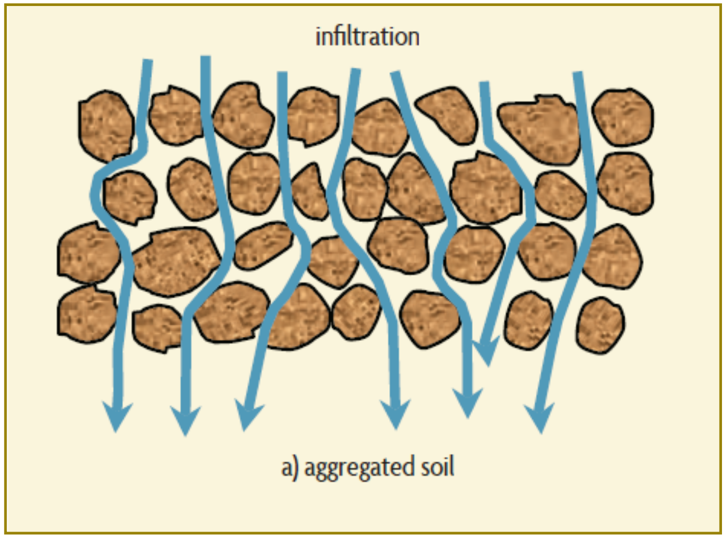
Soil organic matter



(Magdoff and van Es, 2009; figure adapted from Magdoff and Weil, 2005)

Active or labile organic matter

- Materials of recent origin
- High nutrient/energy value
- Non-aggregate protected
- Most important to:
  - Soil aggregation
  - Nutrient mineralization
    - Efficient cycling of N,P, & S
  - Micronutrient chelation
  - Plant growth-regulating substances
- <u>Most sensitive to management changes</u>



(Magdoff and van Es, 2009; figure adapted from Magdoff and Weil, 2005)

Passive or recalcitrant organic matter

- Physically protected or stable due to biochemical properties or mineral association
  - Humic substances, aliphatic molecules, lignins, etc.
- Responsible for much of CEC
  - Greater % in coarse-textured soils
- Nutrients in organic-mineral complexes
- Key role in water holding capacity, bulk density, etc.
- <u>Changes slowly with management</u>

(Magdoff and Weil, 2005)

Soil pH

- Measure of soil acidity or alkalinity (concentration of H^+ ions)
- Measured on a log scale (1 to 14)
- Most crops prefer slightly acidic pH (6 to 6.5)
- Nutrient availability is greatest at slightly acidic to near neutral pH
- Increase soil pH: lime ($CaCO_3$ or $CaMg(CO_3)_2$)
- Decrease soil pH: elemental sulfur (S)

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(Photo from: D. Butler)

Nitrogen (N)

- Earth's atmosphere is 78% N by volume
  - Must be converted (fixed) to NH_3 or NH_4 before it can be utilized
  - Most natural systems are N-limited
- In plants: DNA, RNA, proteins; ~1 to 6% of plant biomass (~ 25 to 200+ lbs/acre uptake)
- Adequate N = high photosynthesis, vigorous growth and dark green leaves
- Excess N = excessive vegetative growth, reduced quality attributes, increased disease/insect susceptibility
- Deficient N = reduced growth, slowed maturity, reduced quality attributes

(Barker, 2010; Tisdale et al., 1993; Barker and Pilbeam, 2007)

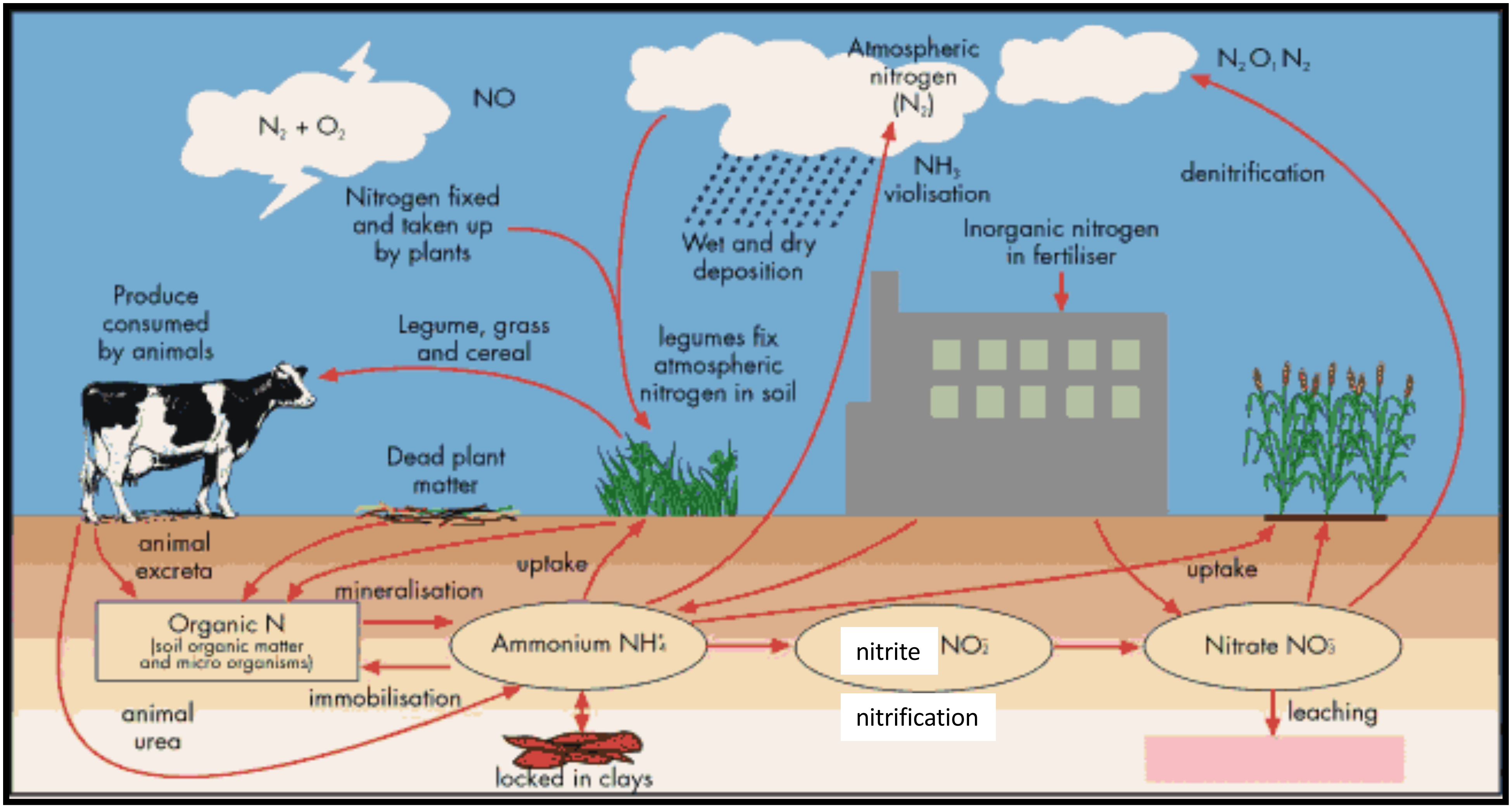
Nitrogen deficiency

(okstate.edu; ucanr.edu)

Nitrogen

- Nitrogen transformations
  - Fixation
  - Mineralization
  - Nitrification
  - Denitrification and volatilization

Nitrogen cycle



(Graphic from: msu.edu)

Mineralization

- Organic N → NH_4^+
- Soil organic matter, plant residues, manures, etc.
- Optimum conditions
  - 95 deg F
  - pH 7
  - 50% water filled pore space
- Positive charge allows it to be held tightly by negative soil charges
- Mineralized N can be *immobilized* (into organic N forms) by soil microbes

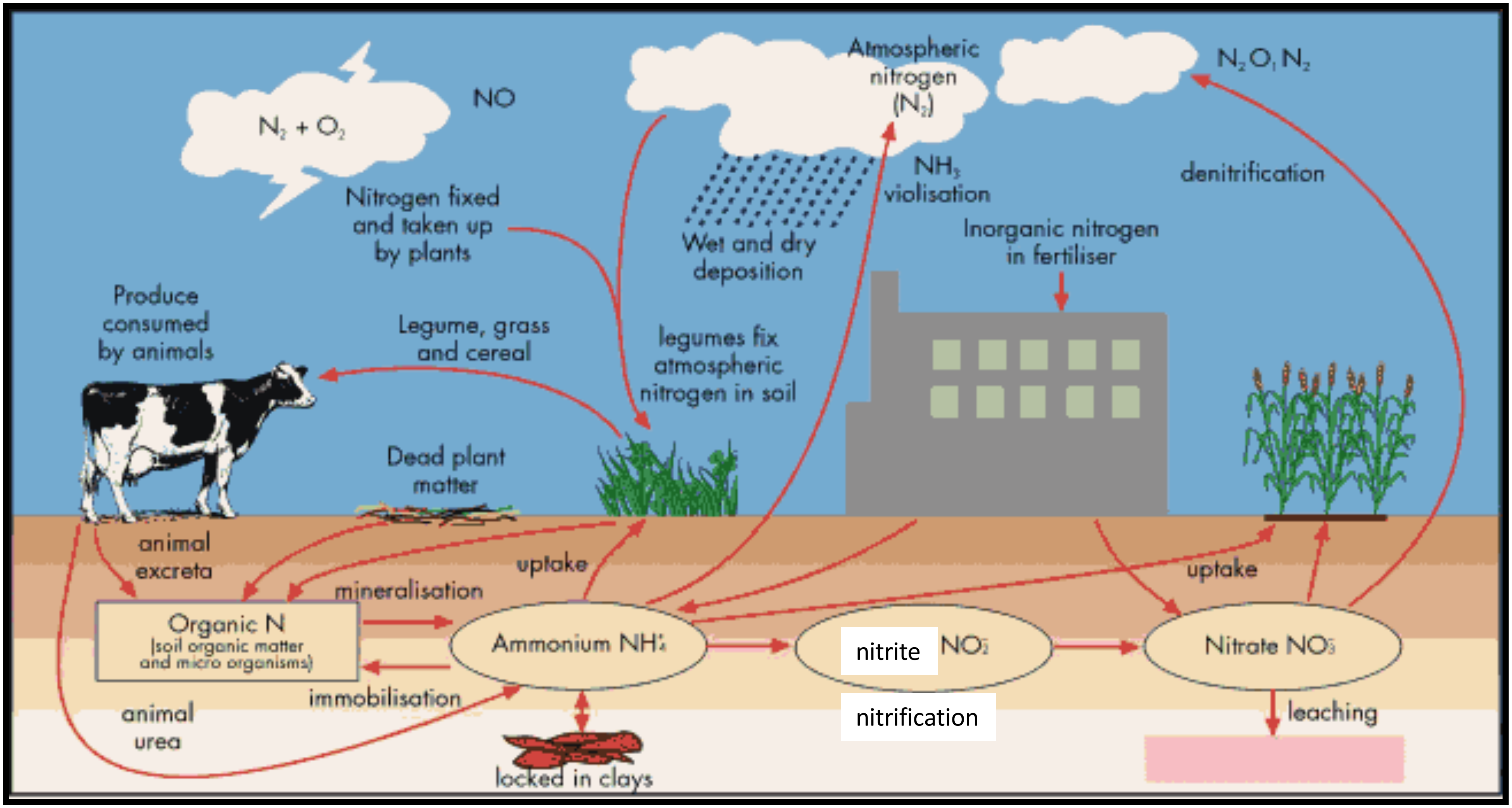
(Cabrera, 1998)

Mineralization

- What is the mineralization rate of SOM?
- General assumption:
  - ~ 20 lbs N acre^{-1} for every 1% SOM mineralized annually
  - So, for a soil with 2% organic matter (0 to 6" sample), we would expect a release of ~40 lbs N per acre^{-1} yr^{-1}
- Temperature, precipitation, aeration, management…

(Grubinger, 1999)

Nitrogen cycle



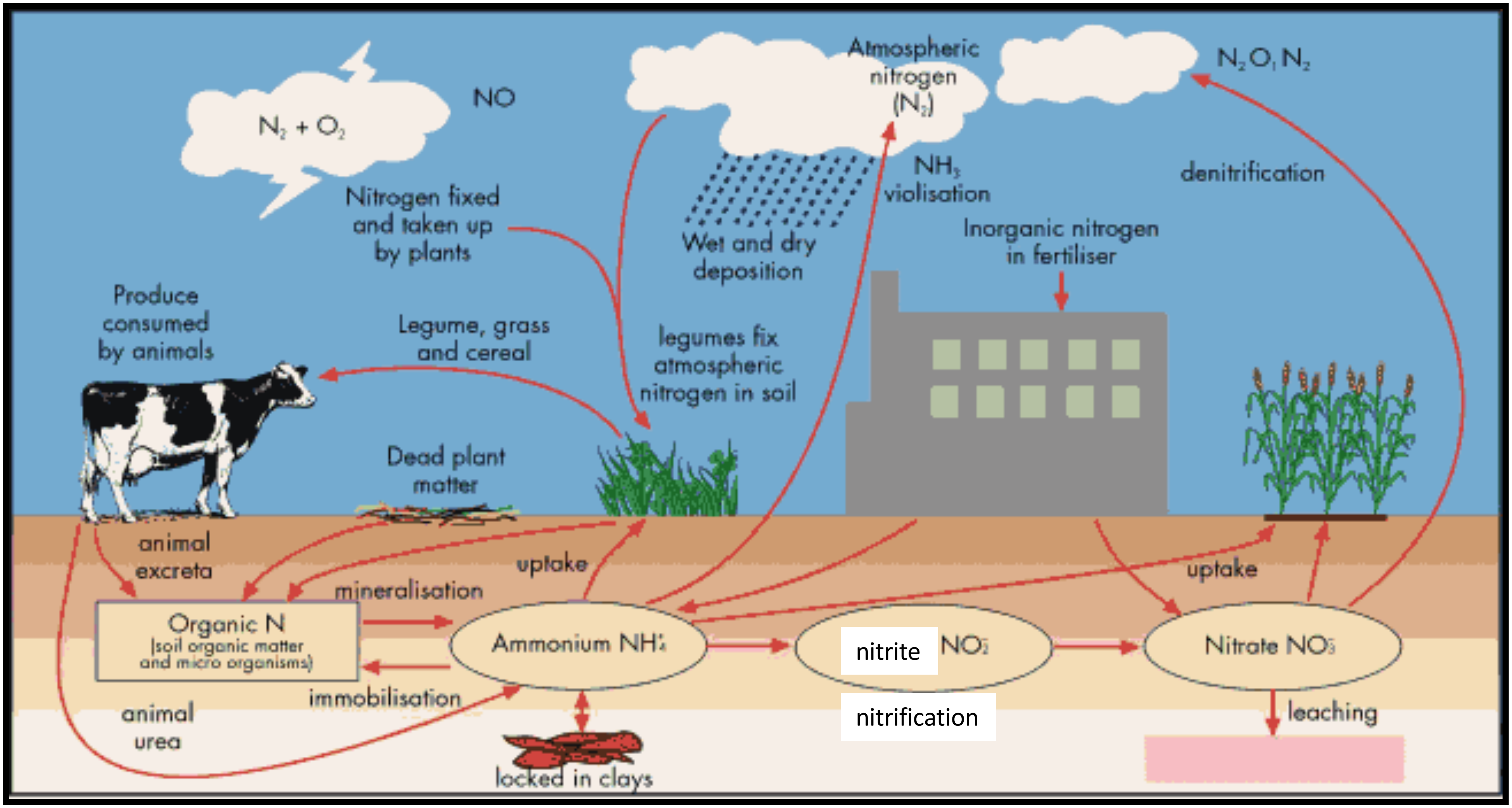
(Graphic from: msu.edu)

Nitrification

- NH_4 converted to NO_3 by nitrifying soil bacteria
- Optimum nitrification at 86 deg F, pH 7, and ~50% WFPS (needs oxygen!)
- Acidifying effect in the soil
- NO_3 is negatively charged (like soil minerals) and leaches easily

(Cabrera, 1998)

Nitrogen cycle



(Graphic from: msu.edu)

Denitrification and volatilization

- Denitrification
  - NO_3 converted to gaseous forms of N
  - Occurs in soils when oxygen is depleted by either saturation or high biological activity
- Volatilization
  - NH_4 converted to gaseous NH_3
  - Occurs primarily when high concentrations of NH_4 are present under high pH (7.5+)
  - e.g., urea-based fertilizers or poultry litter applied to the soil surface

(Cabrera, 1998)

Phosphorus (P)

- Plant concentration 0.1 to 0.4% (crop uptake ~ 10 to 40 lbs/acre)
- Energy storage and transfer (ADP/ATP), DNA, RNA
- Lipids, carbohydrates, proteins, enzymes, other plant metabolites
- Increases strength of cell walls
- Increases lateral root development
- Essential to flowering
- Large quantities in seed and fruit

(Barker, 2010; Tisdale et al., 1993; Barker and Pilbeam, 2007)

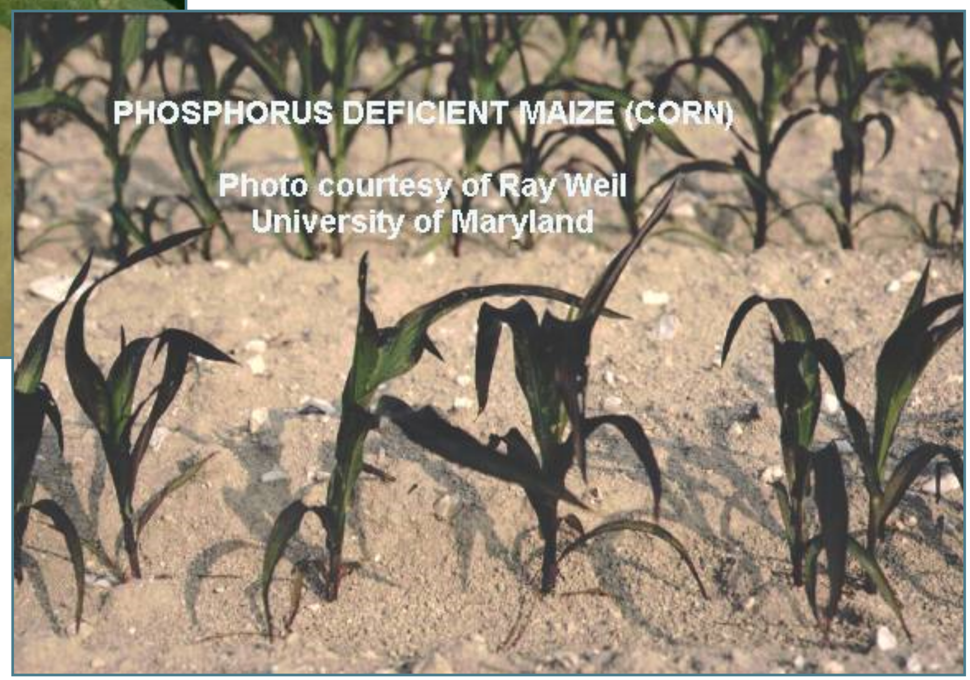
Phosphorus

- Many agricultural soils have ample P due to history of manure and fertilizer application
- Commonly limits plant growth due to low solubility in soils, esp. subtropical/tropical soils (soil minerals, soil pH)
  - Deficient P = slowed maturity, reduced quality attributes, reduced disease resistance, reduced cold-tolerance
  - Excess P = limited direct effect on plants due to buffering by soils, can induce Zn or Cu deficiency, environmental issues

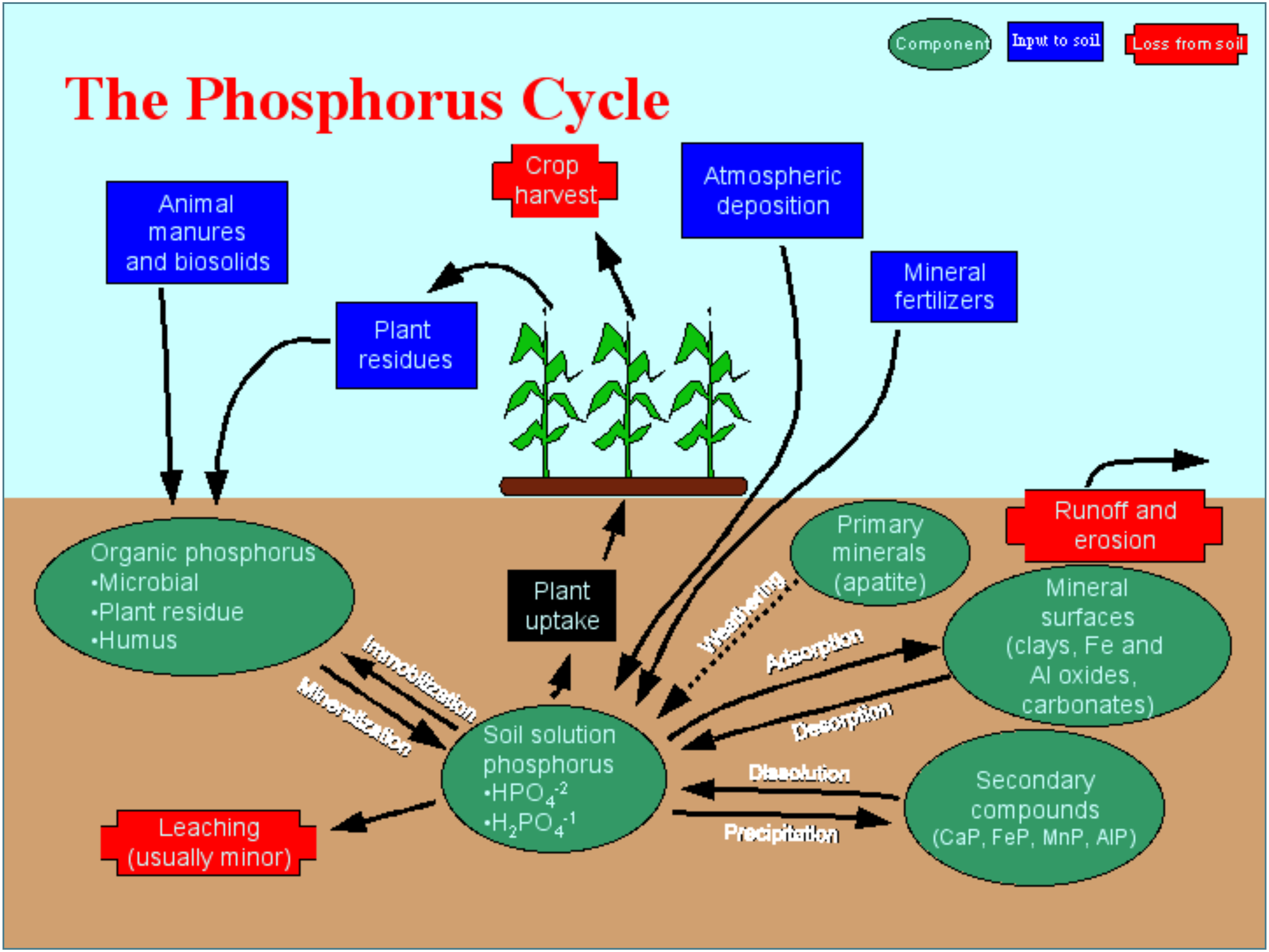
(Barker, 2010; Tisdale et al., 1993)

Phosphorus deficiency

- Foliar symptoms less obvious than N or K deficiency
- Purpling of older leaves in many species (but can also happen for N)



(Photo from: R. Weil, UMd)



(Image from: msucares.com)

Potassium (K)

- Second to N in plant accumulation (~ 1 to 4%)
- Mobile element in plants (uptake and storage as K^+)
- Important to synthesis of chlorophyll, complex carbohydrates, and proteins; activation of enzymes; energy relations
- Promotes water movement into cells (turgor pressure)
- Required for development of fruits and seeds, roots and tubers

(Barker, 2010)

Potassium

- Deficient K = reduced growth, potentially large yield reductions, reduced quality attributes, reduced stem strength, reduced disease and insect resistance
- Excess K = limited effect due to strict regulation by plant, indirect effects in soil on Ca and Mg uptake are of greater concern

(Barker and Pilbeam, 2007)

Potassium

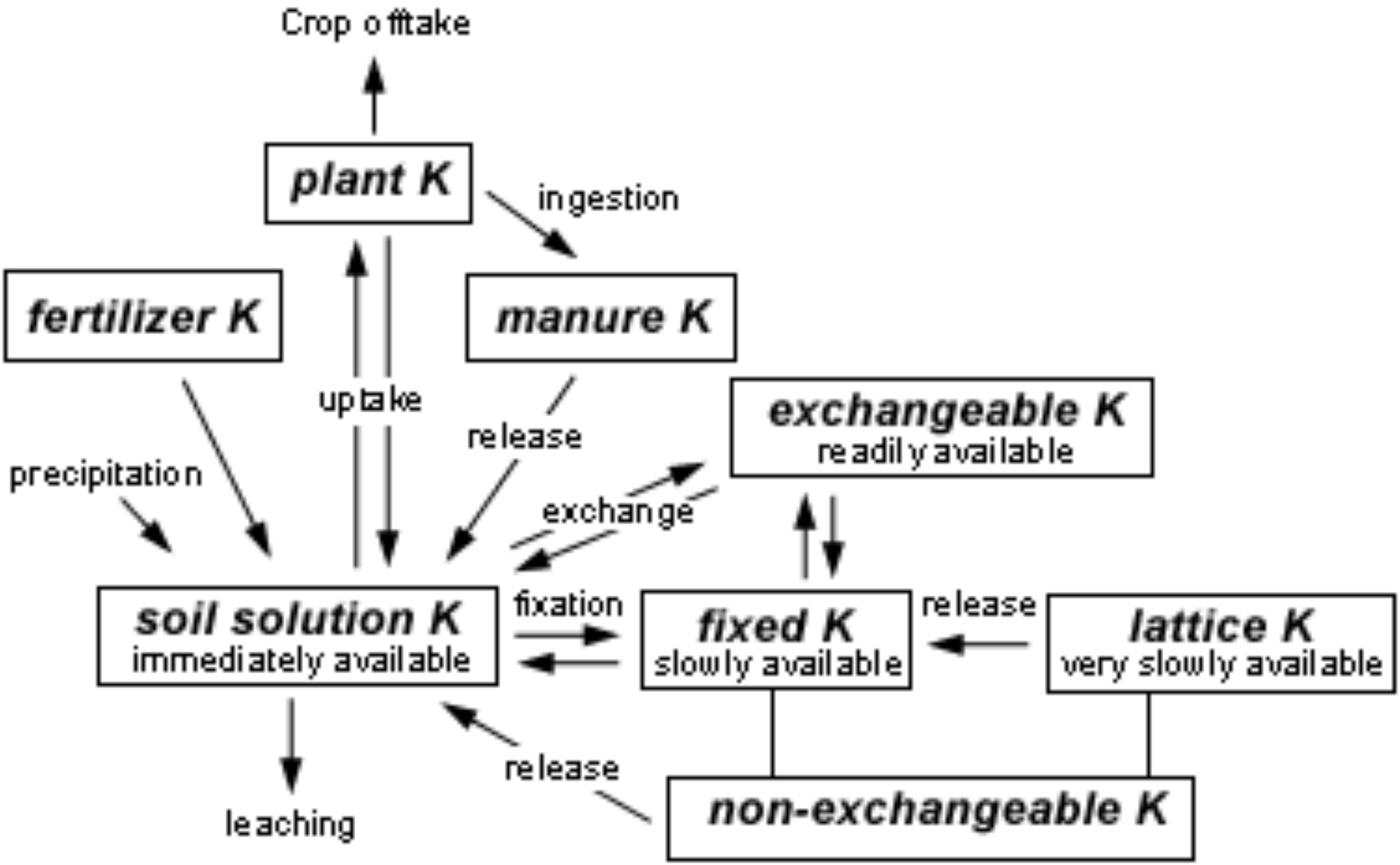
- High levels of K in soils (up to 50,000 lb $acre^{-1}$ in clay loam; uptake compares at ~ 25 to 100+ lbs/acre)
- However, most of this is fixed in primary minerals (90 to 98%; feldspar, mica)
- Nonexchangeable (1 to 10%)
- Exchangeable (1%)
- Soil solution (<<<1%)

(Barker, 2010)

Potassium (K) deficiency

- Leaf margin necrosis in older leaves common in grasses
- At left, strawberry leaf symptoms at a range of leaf ages

(Photos from: umd.edu)



(Image from: ipipotash.org)

Overview: Plant nutrition & soil fertility

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(Photo from: D. Butler)

Sulfur

- Plant accumulation of 0.1 to 0.4%, uptake as SO_4^{2-}
- Essential to protein synthesis
- Likely plays a role in conferring resistance to fungal pathogens and insect pests
- Moderately mobile in plants, deficiency symptoms on young leaves (required for chlorophyll synthesis)
- Sandy, low organic matter soils most likely to be sulfur deficient

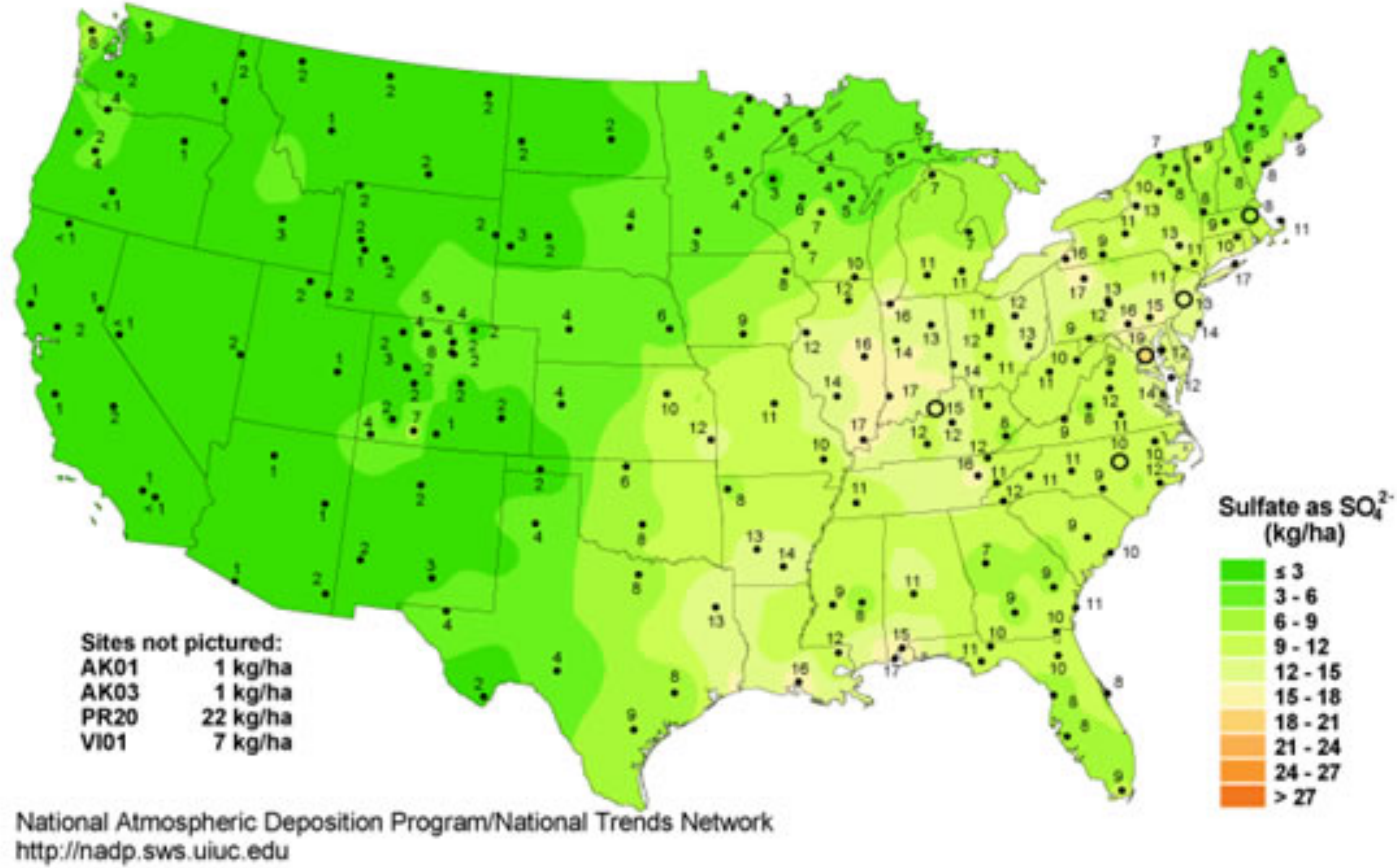
(Barker, 2010, Bloem et al., 2005, Francis et al., 2009)

Sulfur

- ~ 800 lbs ac^{-1} in soils
  - Most of sulfur in soil is in soil organic matter
  - ~ 15 lbs ac^{-1} yr^{-1} in precipitation (depending on location)
  - Plant requirement ~ 15 to 30 lbs ac^{-1}, although some higher
  - Deep-rooted crops effective at uptake of SO_4^{2-} adsorbed in subsoils
  - Response to S amendment most likely in low organic matter soils (<1% SOM)

(Barker, 2010; Francis et al., 2009)

Sulfate ion wet deposition, 2009

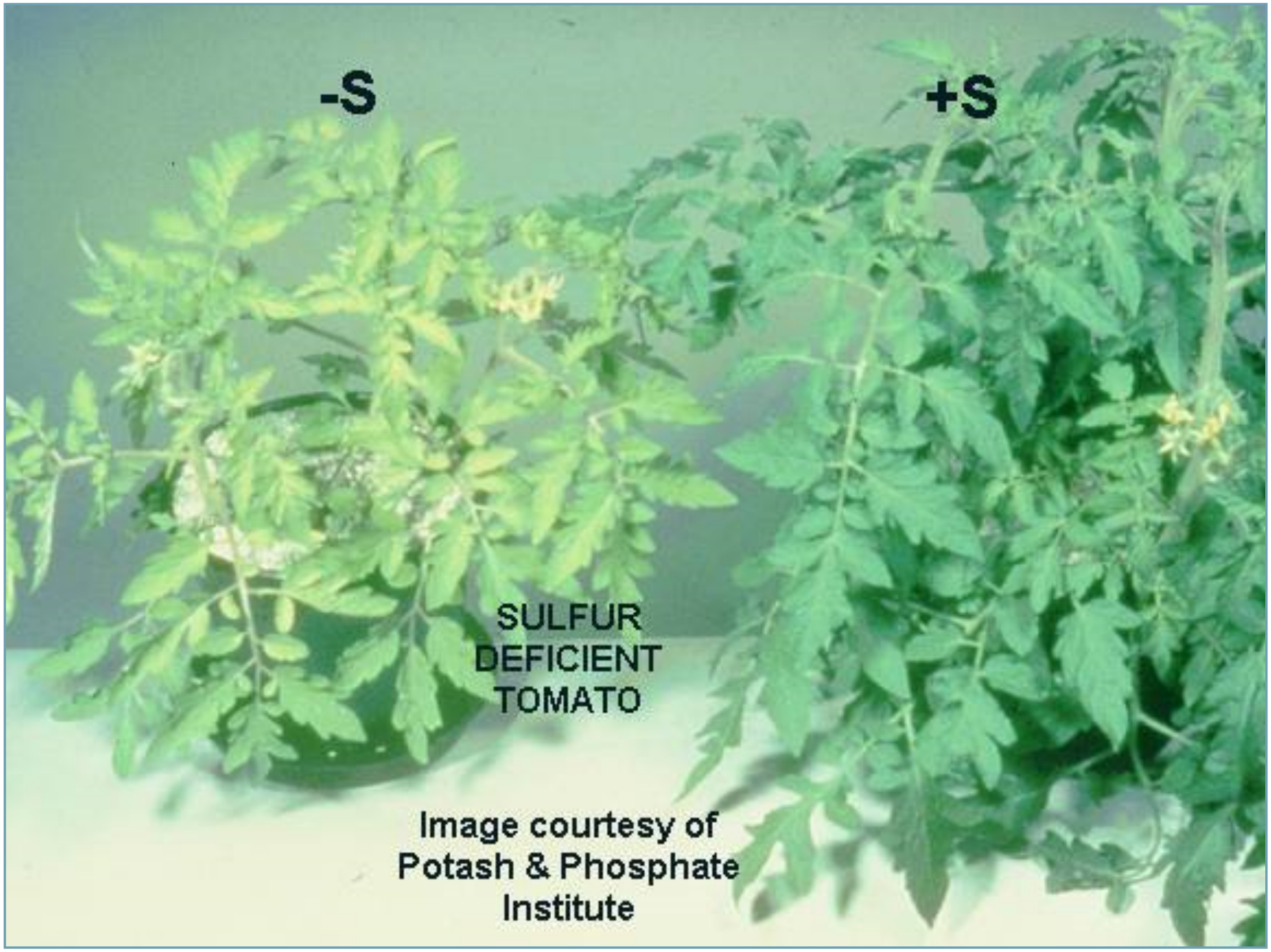


(fws.gov)

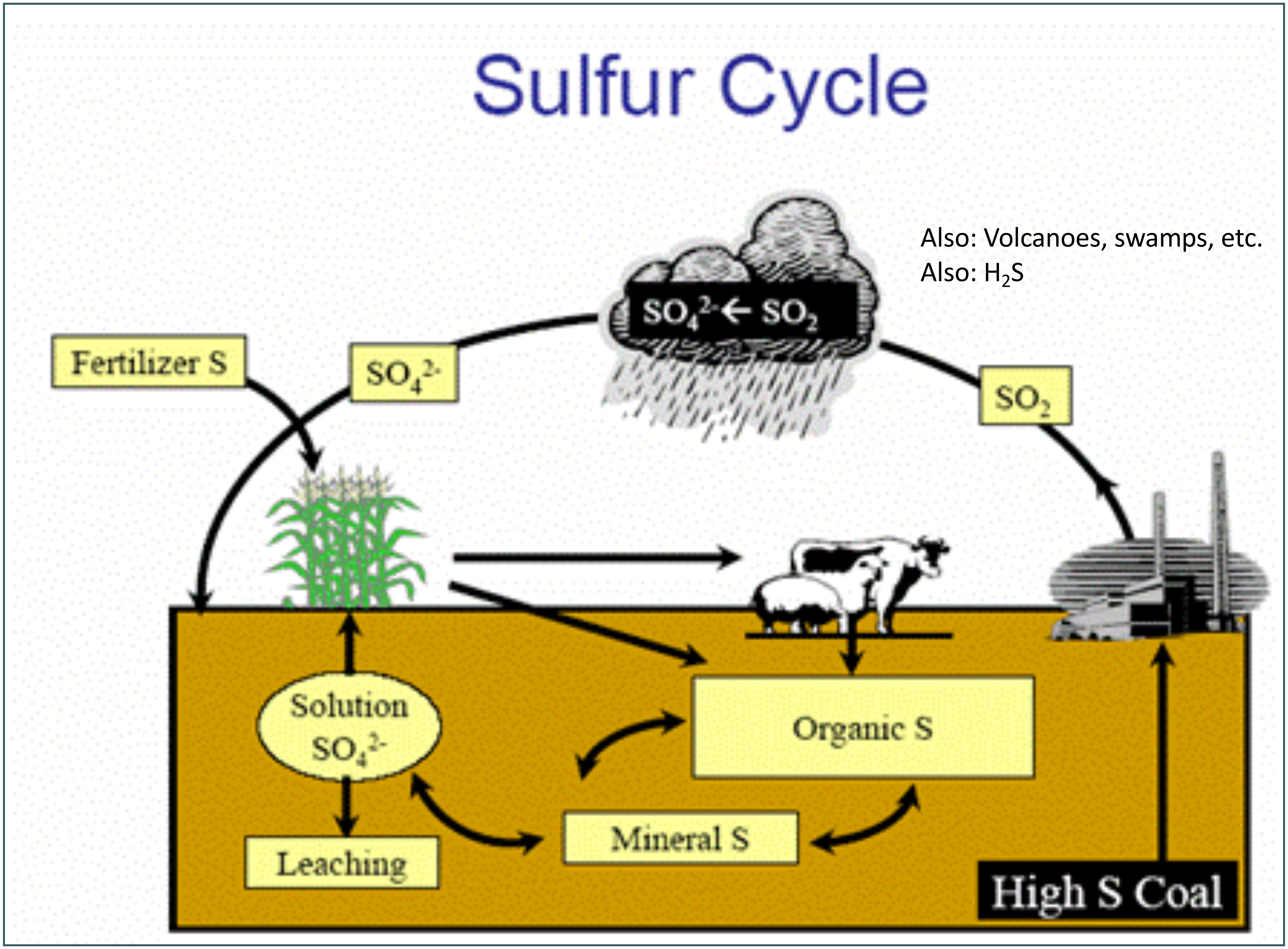
Sulfur deficiency

(Photos from: ncsu.edu)

Sulfur (S) deficiency



(Photos from: umd.edu)



Also: Volcanoes, swamps, etc.
Also: H_2S

(Image from: gov.on.ca)

Calcium

- Uptake as Ca^{2+}, 0.2 to 1% plant concentration
- Much of calcium in pectin between cell walls
- Also has roles in cell division and regulation of membrane permeability
- Regulates cation uptake
- Not mobile in phloem, so deficiency symptoms begin at growing points
- Disorders in storage tissues (e.g., blossom end rot of tomato, bitter pit of apple)

(Barker, 2010)

Calcium

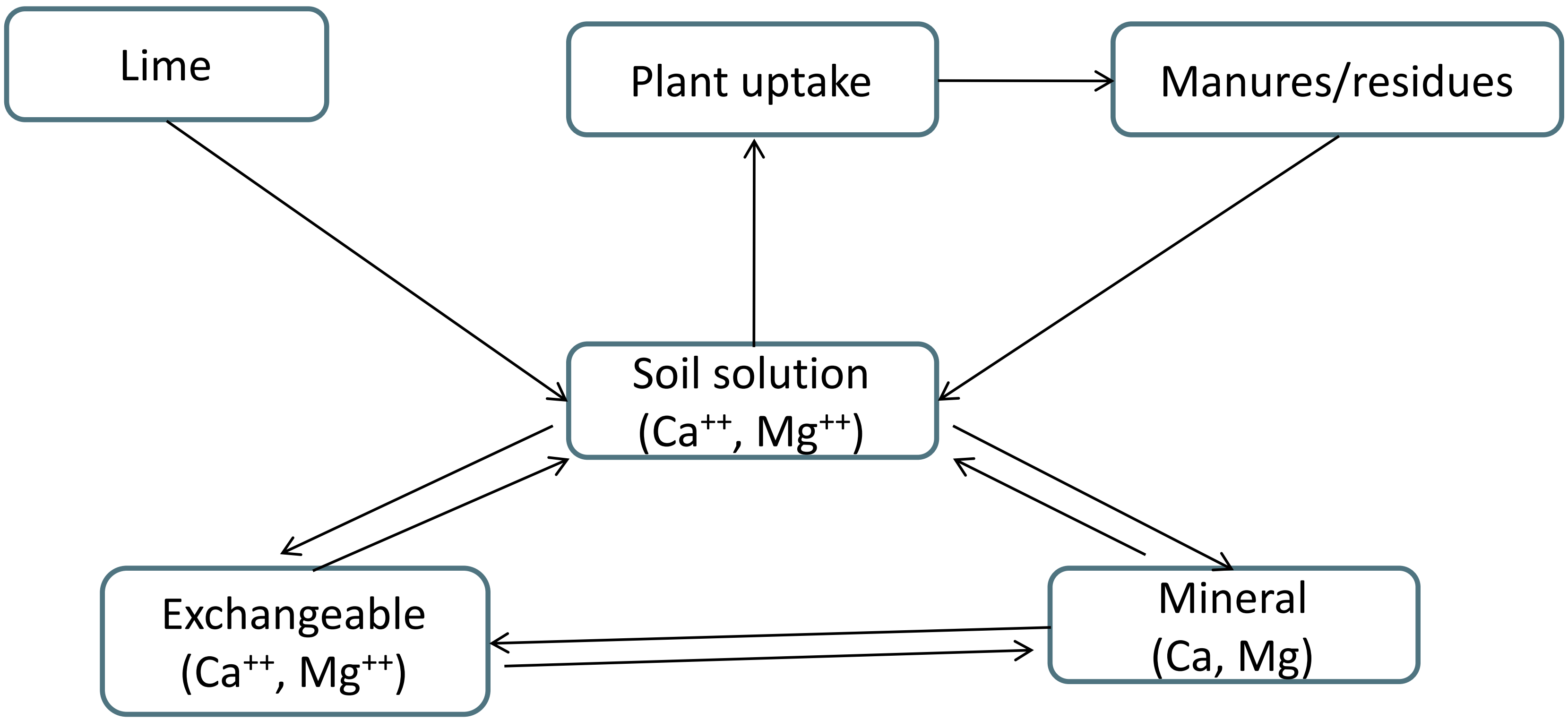
- Deficiency most common in acid, sandy, highly-leached soils or in dry soils
- High K^+ and NH_4^+ can suppress plant sorption
- Total calcium in humid region soils ~ 1,000 to 8,000 lbs ac^{-1} without liming
- Crop uptake 10 to 50 lb ac^{-1} yr^{-1}

(Barker, 2010; Francis et al., 2009)

Calcium (Ca) deficiency

(Photos from: umd.edu; ucanr.edu)

Calcium and magnesium



(adapted from: Tisdale et al., 1993)

Magnesium

- Uptake as Mg^{2+}, 0.1 to 0.5% concentration
  - Plant uptake 15 to 30 lbs ac^{-1} yr^{-1}
  - ~ 6,000 lbs ac^{-1} in primary minerals
- Required for chlorophyll synthesis
- Metabolism of ATP, enzyme activation
- Deficiency common in acid, leached, sandy soils
- High Ca^{++} and NH_4^+ can suppress plant sorption
- Mobile element in plants
  - Yellowing of older leaves, initially between veins

(Barker, 2010)

Magnesium (Mg) deficiency

(Photos from: umd.edu)

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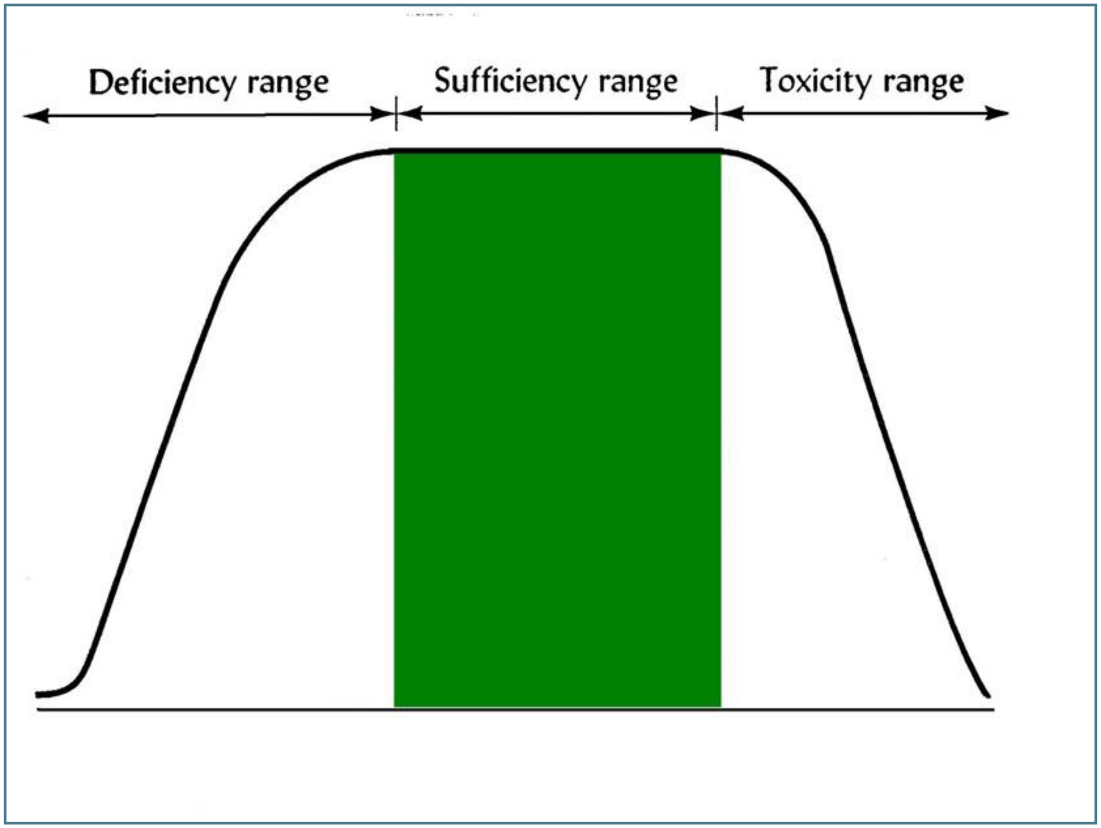
(Photo from: D. Butler)

Micronutrients

- Macronutrients = wide range
- Micronutrients = narrow range
  - More likely to cause toxicity, yield loss with overapplication



(Adapted from: J. Gruver, WIU)

Micronutrients

- Most are metals (exception of Boron)
- Most are limited in availability with increasing soil pH (exception of Molybdenum)
- Building (within reason) soil organic matter *generally* has a positive impact on micronutrient availability

(Barker, 2010; Francis et al., 2009)

Boron

- Important to pollination and seed/fruit development
- Non-mobile in plants
- Stem die-back, splitting, cracking, corking, hollowing, dry rotting can all result from B deficiency

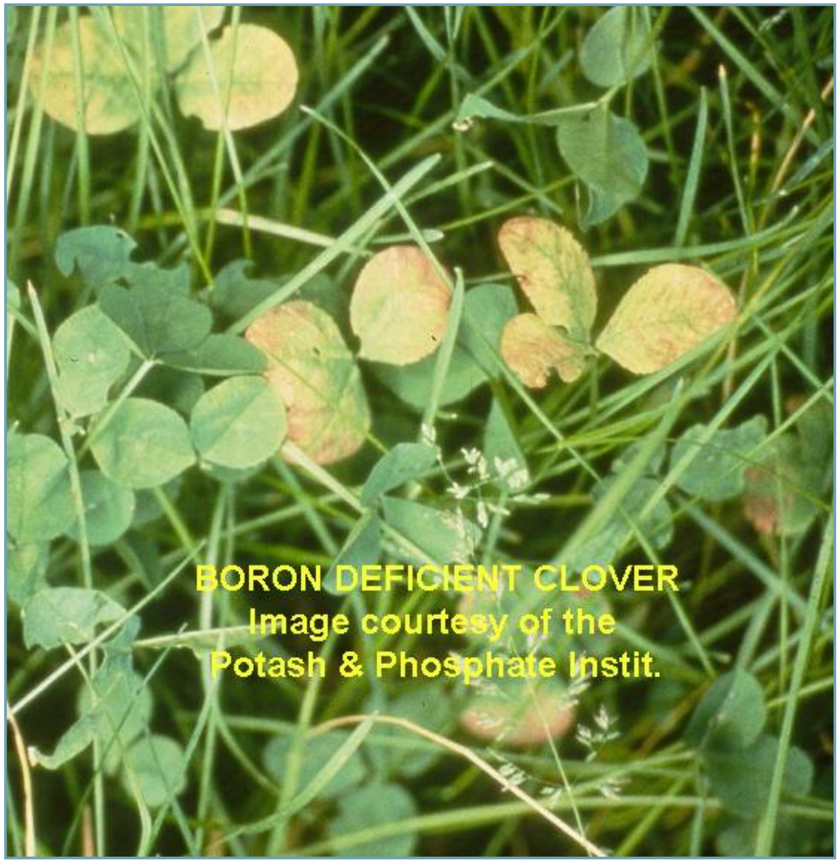
(Barker, 2010; Francis et al., 2009)

Boron

- Leaching in humid regions often causes deficiency
- ~ 10 to 220 lbs ac^{-1} in soils
- Crops remove 1 to 2 lbs B ac^{-1} yr^{-1} (plant concentration ~ 30 ppm)
- Very narrow sufficiency range
- High demand crops include legumes, tomato family, and brassica crops

(Barker, 2010; Francis et al., 2009)

Boron (B) deficiency



(Photos from: umd.edu)

Boron (B) deficiency

(ncsu.edu)

Boron (B) deficiency

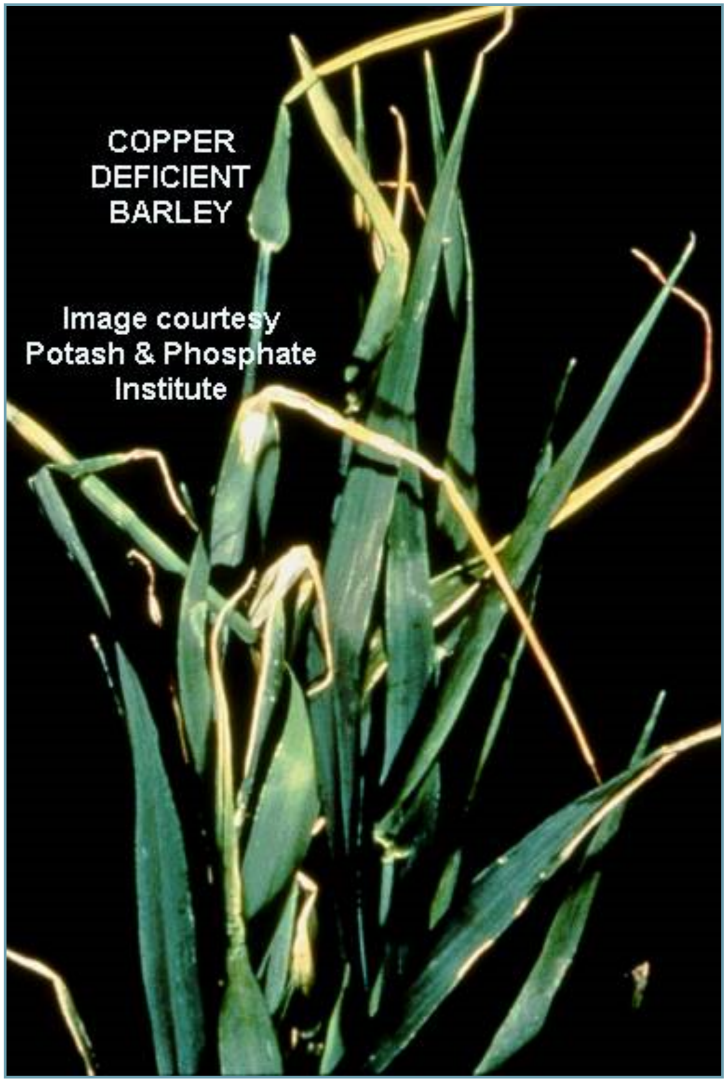
(ncsu.edu)


B toxicity
(ucdavis.edu)

B toxicity

(ncsu.edu)

Copper (Cu) deficiency



- ~ 10 to 300 lb ac^{-1} in soils
- Tightly sorbed to organic matter
- Deficiencies most common in peats, Histosols or acid, leached, sandy soils
- Plant concentration ~ 5 ppm

(Photos from: umd.edu; Barker, 2010)

Manganese

- ~40 to 12,000 lbs ac^{-1} in soils
- Plant uptake is a few pounds $acre^{-1}$ (~50 ppm)
- Most is precipitated as MnO_2
- Can become toxic below pH 5
- Deficiencies most likely in Histosols; acid, leached, sandy soils or high pH soils
- Interveinal chlorosis on younger leaves

(Barker, 2010; Francis et al., 2009)

Manganese (Mn) deficiency

Magnesium left, manganese right.
With magnesium deficiency the margins curl downward,
discolouration is more continuous with magnesium deficiency.

(Photos from: omafra.gov.on.ca/)

Mn deficiency

(Photos from: ucanr.edu; high fruit load, high pH (7.6))

Molybdenum

- ~ 4 to 20 lbs ac^{-1} in soils
- Crop uptake < 1 ounce ac^{-1} yr^{-1} (~0.1 ppm)
- Can become deficient below pH 5.3
- Legumes, citrus, and brassicas most susceptible to deficiency
- Whiptail of cauliflower

(Barker, 2010; Francis et al., 2009)

Other micronutrients

- Iron (Fe)
  - At right, blueberry…why?
  - ~ 100 ppm in crops
- Zn
  - ~ 150 lbs Zn ac^{-1} in soils
  - Plant uptake a few lbs ac^{-1} yr^{-1} (~20 ppm)
  - While generally rare, tree fruits and nuts deficiencies more common
- Ni
  - ~ 1 ppm
- Cl
  - Most soils have adequate Cl
  - ~100 ppm

(photo from uky.edu; Barker, 2010; Francis et al., 2009)

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(Photo from: D. Butler)

Soil testing & interpretation

- Choice of lab
  - Methods
  - Result interpretation
  - Recommendations
- Methods
  - Soil pH
    - "Water"
    - Lime requirement
    - Sulfur requirement
  - No routine soil analysis for N
    - Why?
    - How are recommendations developed?

Soil testing: Methods

- Mehlich 1 and 3 extractants
  - M1: AL, FL, GA, SC, TN, VA
  - M3: AR, KY, NC
  - Mehlich 1
    - Weak, double acid extractant
    - Primarily used in the Southeast on acid soils low in CEC and organic matter
    - P, K, Ca, Mg, Zn, Mn, Fe, Cu, Na, B

(SERA-17)

Soil testing: Methods

- Mehlich 3
  - Improved predictions with high pH and high CEC soils (i.e., broader range of soil types than Mehlich 1)
  - Solution is more acidic, contains F (extraction of P associated with Fe and Al), better extracts exchangeable cations and uses a chelate (EDTA) to extract micronutrients
  - While improved, not widely adopted (recalibration would be a substantial effort, less user-friendly in lab settings, Mehlich 1 works well for most SE soils)
- Other extraction methods

(SERA-17)

Soil testing: Interpretation

- Lab procedure and field calibration
  - In brief, small amount of soil shaken with extract for short time period, filtered and concentration of nutrients in liquid measured
  - Research has correlated ranges of extracted soil nutrient concentrations to likelihood of crop response to fertilization for a range of soil types
- Values often reported as lbs/acre or ppm (ppm x 2 = lb/acre)
  - **<u>Very, very misleading</u>**
  - Values are of limited to no value without field calibration
  - Use as an index, not a raw value

(Savoy, 2005)

Soil testing: Interpretation, e.g., TN

- P and K results typically reported as:
  - Low (L): Crop likely to respond to application of nutrient. If not applied, deficiency may occur and crop will typically yield 75% or less of potential
  - Medium (M): Crop may or may not respond to nutrient application. Symptoms of deficiency unlikely and production can be expected at 75% or greater of potential.
  - High (H): The soil will produce at or near 100% potential without nutrient application
  - Very High (VH): Nutrient supply in soil is well in excess of the amount needed, no further application recommended.

(e.g., TN; Savoy, 2005)

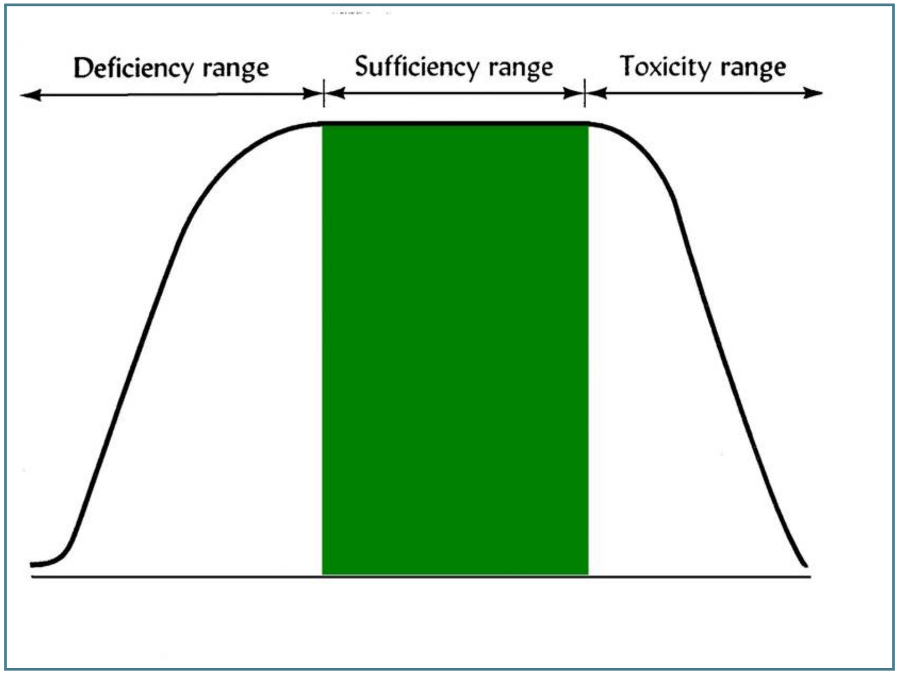
Soil testing: Interpretation

- Secondary nutrients and some micronutrients often reported as:
  - Sufficient or deficient (or low/adequate)
  - Recommendations may or may not be based (or only loosely based) on soil nutrient test (i.e., region, crop or soil pH may be more predictive of need)

(Savoy, 2005)

Soil testing: Recommendations

- Maintenance vs. sufficiency vs. build-up
  - Mineral weathering
  - Organic matter dynamics
  - Atmospheric deposition
  - Economics
  - Sustainability
- Plant tissue testing



(Adapted from: J. Gruver, WIU)

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(Photo from: D. Butler)

Liquid carbon products

- Numerous commercial liquid C products on market
  - Largely derived from leonardite/lignite (brown coal) or peat
  - Contain humic substances (HS) /humic acid
  - Promoted for plant growth promoting properties
- Do extracted humic substances benefit plant growth?
  - Enhance micronutrient availability (through chelation; esp. Fe, Zn, Mn and Cu)
  - However, specific *field* conditions where amendment is economically-justifiable are probably limited

(Chen et al., 2004)

Liquid carbon products

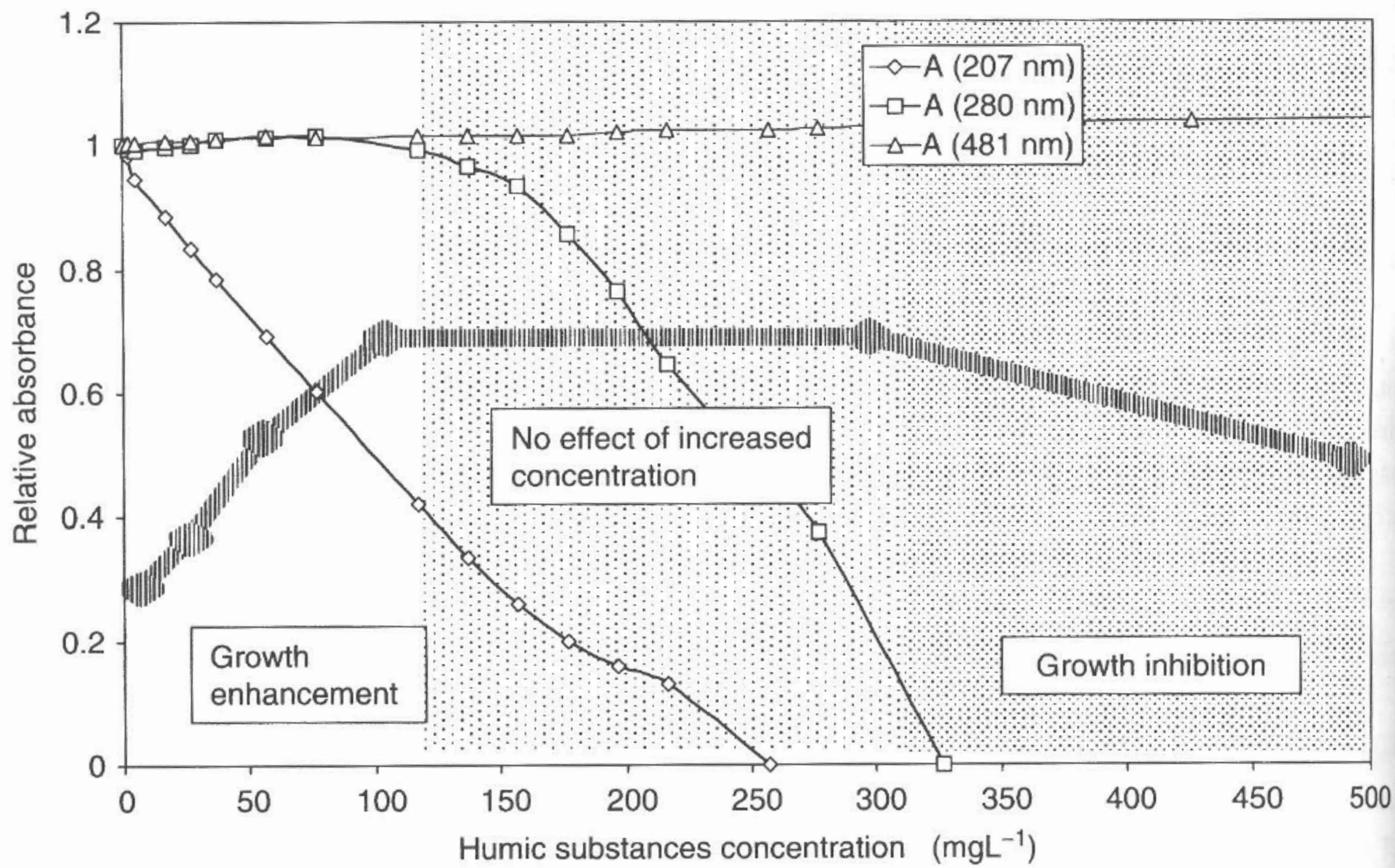


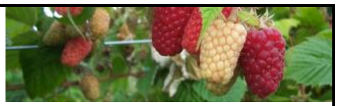
FIGURE 4.5 Differential spectrophotometric tritration of Fe EDDHA by humic substances (HS). The etc line represents the trend of shoots yield obtained by Rauthan, B.S., and M. Schnitzer. 1981. *Plant S* 63:491–495 for cucumber plants grown in nutrient solution (NS) at different fulvic acid (FA) concentrati (Modified from Catalano, L. et al. 2002. In *Proceedings of the International Humic Substances Soc Twentieth Anniversary Conference.* Northeastern University, Boston, MA, pp. 268–271.)

(Chen et al., 2004)

Liquid carbon products

- Extrapolated published data suggests field application of ~ 60 lbs HS/acre are needed
  - Unlikely effective in fertile, humid region soils (already high HS concentrations)
  - In sandy soils in humid regions, response is still unlikely due to limited micronutrient deficiencies
  - In arid/semi-arid regions under fertigation, HS application may be beneficial (at rates given above)
  - Lower rates (by a factor of ~ 150) can be effective (and far more economical) for foliar micronutrient sprays
  - Composts/manures

(Chen et al., 2004)



Site Preparation & Nutrition of Blueberry, Raspberry & Blackberry

Dr. Bernadine C. Strik
Extension Berry Crops Professor
Department of Horticulture
Presented January 7, 2016

Outline

- Introduction
- Items covered specific to blueberry, raspberry & blackberry:
  - Soil sampling & requirements
  - Site preparation (pH adjustment; organic matter, mulching)
  - Assessment of plant nutrient status
  - Interpretation of tissue analysis results
  - Fertilizer rates…starting points
  - Adjustment of nutrient management programs based on plant uptake of nutrients & losses
  - Sources of nutrients/fertilizers

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Introduction

- Fertilize to promote sustainable growth and production

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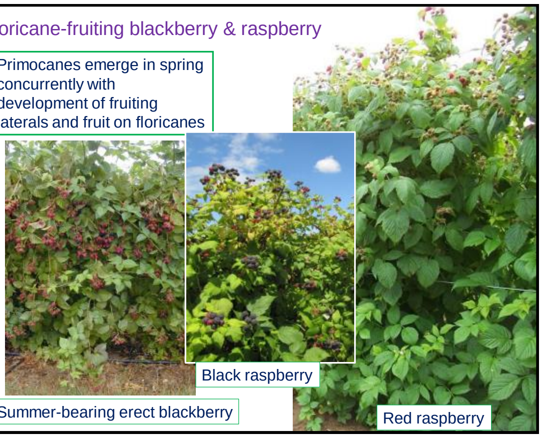
Nutrients needed to balance growth with fruiting

Floricane-fruiting blackberry & raspberry

Primocanes emerge in spring concurrently with development of fruiting laterals and fruit on floricanes



Black raspberry

Summer-bearing erect blackberry

Red raspberry

Primocane-fruiting raspberry and blackberry

Introduction

- Fertilize to promote sustainable growth and production
- Fertilizer will not correct for other production problems
- Supply the plant with ample nutrition in advance of demand
- Use soil and tissue sampling to assess nutrient needs
- Keep records & observe plant growth, yield, weather, and any pest issues
- If fertilizer needed: 1) How much nutrient? 2) When to apply? 3) Best nutrient source? 4) Best method?

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Soil and tissue testing are important tools, but …….

Adding more fertilizer will not compensate for other limiting factors

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Reference Publications

https://catalog.extension.oregonstate.edu/

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Pre-Plant Soil Testing

- Adjust soil nutrients, pH, and organic matter prior to planting if required
- Obtain representative soil sample of field – take down to tillage depth
- Test well in advance of planting
- Add fertilizer and other amendments based on test results

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Critical levels for soil nutrient content

Note: test methods vary by lab which may affect results. Values in table are from Oregon

	Blueberry	Raspberry & Blackberry
pH (2:1; in water)	4.5 to 5.5	5.6 to 6.8
Nutrient	Deficient at less than (ppm)	
Phosphorus (P; Bray)	25 to 40	20 to 40
Phosphorus (Olsen)	10 to 20	10 to 20
Potassium (K)	100 to 150	150 to 350
Calcium (Ca)	1000	1000
Magnesium (Mg)	60	120
Manganese (Mn)	20 to 60	20 to 60
Boron (B)	0.5 to 1.0	0.5 to 1.0

Soil EC: < 2 dS/m

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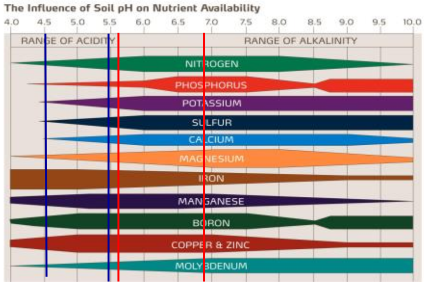
Soil pH affects nutrient availability

Figure 1
The Influence of Soil pH on Nutrient Availability



Optimum pH for raspberry & blackberry
Optimum pH for blueberry

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Modify soil pH before planting

https://catalog.extension.oregonstate.edu/

- If soil pH is too high then add elemental sulfur (S) [e.g. to achieve target pH of 5.5 or 5.6 (upper end of adapted range) in blueberry]
- In some situations, can only create acceptable pH by irrigating with acidified water
- Check rates of S carefully!
- If pH is too low, add lime
- Apply lime or S in autumn, six months to one year before planting.
- Apply other fertilizers and incorporate, if required, based on test results

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Nutrient content of some fresh animal manures. From, PNW 646 Oregon State University

Type of Manure	N	P_2O_5	K_2O	Moisture	Weight
		lb/cubic yard[b,c]		%	lb/cubic yard[b]
Chicken with litter	23	29	30	30	900
Dairy manure, separated solids	4	1	2	80	1400
Horse	6	4	11	70	1400
Sheep	13	6	25	75	1400
Rabbit	11	7	10	75	1400
Beef	8	6	12	75	1400

[a]Data derived from Gale et al. (2006) and Cogger (2004).
[b]These values are on an as-is basis, meaning wet material with moisture content typical for manure stored under cover. Note that nutrient and moisture values can vary widely, depending on handling, bedding, and age of the manure.
[c]Divide these values by 40 to estimate the nutrients in a 5-gallon bucket of fresh manure.

- Aged/composted manures contain less N than fresh
- Often less than 25% of the N in manures is available the first year
- More than 50% of N may be lost if applied to soil surface or during manure storage. Incorporate immediately
- Manure can be a source of pests and weed seeds

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Ideal organic materials for berry crops:

- Should not injure plants with salts when applied liberally
- Should be of proper pH for the target crop (5.5 or below for blueberry; 5.6 or above for others)
- Have a "manageable" C:N or N content
- Should be free of weed seeds, insect, disease


High pH symptoms


Symptoms of salt injury

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Organic materials

Compost type	pH	EC	Comments
Dairy	7.6	6.1	C:N <12; excess N (2+%)
Horse	7.8	7.8	C:N <12; excess N (2+%)
Yard debris	7.0	4.0	C:N 12-25; 1-2% N
Leaf debris	7.4	2.2	
Peat	4.8	0.7	
Sawdust; wood chips	4.5-5.2	0.4	C:N 200+; deficient N

Adapted from D. Sullivan, OSU; pH and EC by saturated media extract (SME)

All materials with an EC above 1.5 are too “salty” for use as a pre-plant amendment and in high amounts after planting

Incorporation of organic materials prior to planting

Douglas fir sawdust

Yard debris compost

- Incorporation of organic matter (OM) increases soil porosity (drainage) and soil OM
- Test any new materials prior to use to ensure that the pH or salt content (EC) of the material are not too high
- Do NOT incorporate yard compost, composted manures, horse bedding, fresh manures “as is” prior to planting in blueberry and test in caneberries

Pre-plant incorporation & mulch type - blueberry

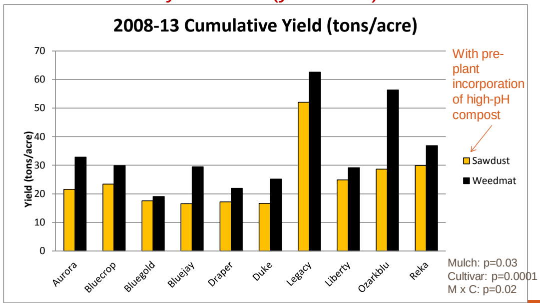
Mulch treatment	Soil pH at planting (Autumn, 2006)	Soil pH (Autumn 2011)	Soil pH (Autumn 2012)
Weed mat (no pre-plant amendment)	4.9	5.35	5.10
Yard debris compost 1 inch deep topped with 2 inches of sawdust (pre-plant amendment & as mulch)	4.9	6.85	(after 300 lb S/a) 5.85


Sawdust+compost incorporated before planting & as mulch


No incorporation of organic matter before planting
weed mat mulch

Strik and Vance, in progress

Effect of soil management on cumulative yield of 10 blueberry cultivars (years 2-7)



Strik and Vance, in progress

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'Duke', high soil pH symptoms caused by using high pH compost prior to planting

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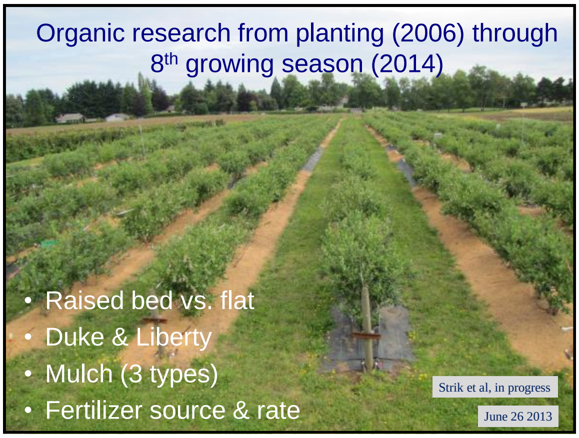
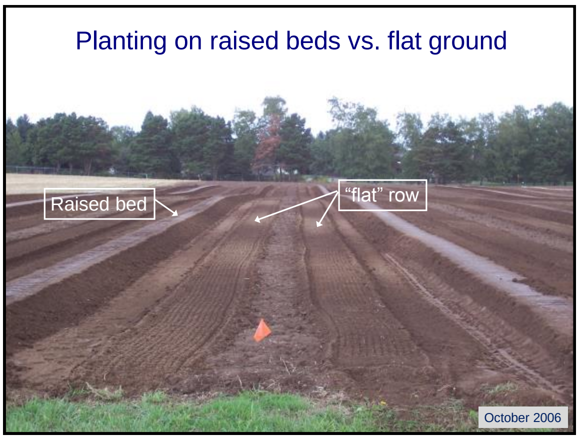
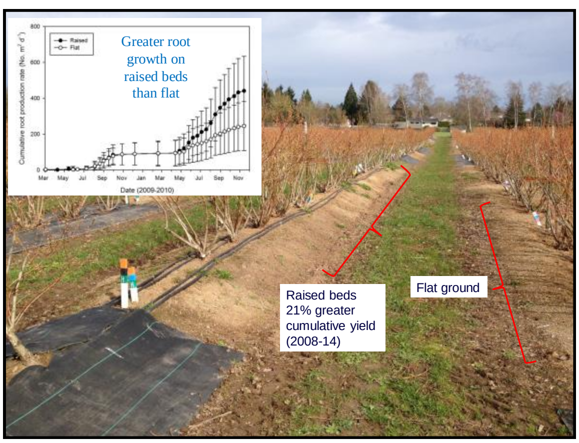
Acidify high-pH composts before using as amendment in blueberry (or use a more appropriate organic material)

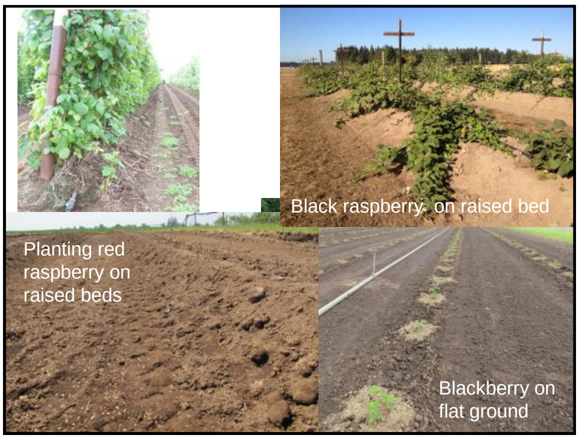
- Acidification prior to amending in soil improved growth (Costello et al. 2011)
- Acidified pine sawdust used for production on alkaline soils in Switzerland (Suter et al., 2010)

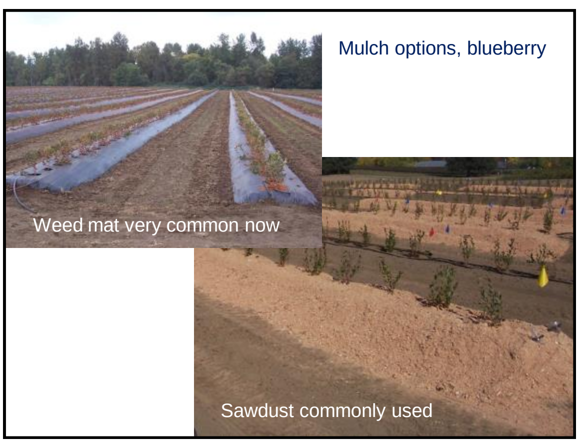

Organic research from planting (2006) through 8th growing season (2014)
• Raised bed vs. flat
• Duke & Liberty
• Mulch (3 types)
• Fertilizer source & rate
Strik et al, in progress
June 26 2013


Planting on raised beds vs. flat ground
Raised bed
"flat" row
October 2006


Greater root growth on raised beds than flat
Raised beds 21% greater cumulative yield (2008-14)
Flat ground

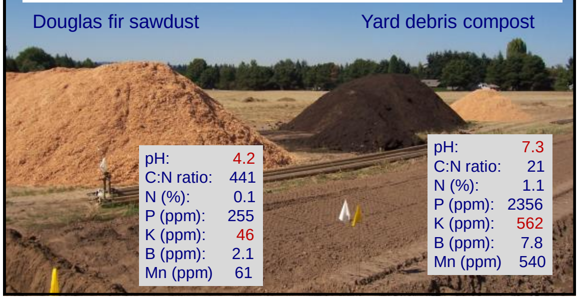

Planting on raised beds (Oct.)

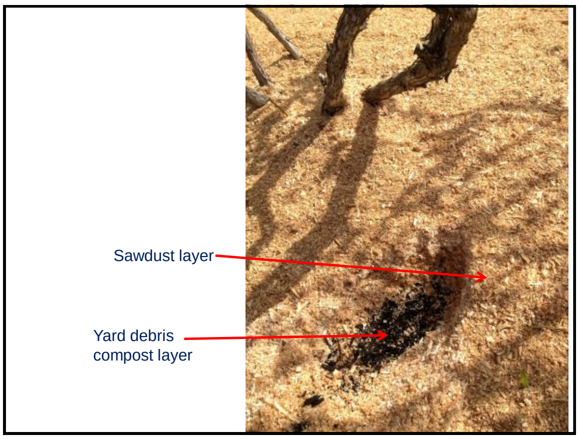

Black raspberry on raised bed
Planting red raspberry on raised beds
Blackberry on flat ground


Mulch options, blueberry
Weed mat very common now
Sawdust commonly used

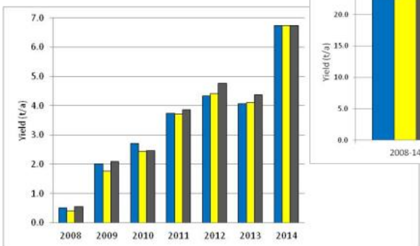
Surface, in-row mulch options tested

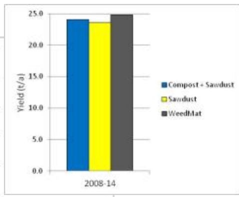
1) Sawdust mulch (3" deep)
2) Compost (~ 1" deep) topped with sawdust (2" deep) mulch
3) Weed mat (porous, polyethylene ground cover)





Yield – Mulch effect





Strik et al., in progress

Yield averaged over cultivar, raised/flat & fertilizer

- Larger differences when plants were young
- Cumulative yield slightly higher with weed mat (was significant)

Nutrient content of sawdust and municipal yard debris compost when used as a mulch (Strik et al., in progress)

Mulch		Nutrients applied based on actual fertilizer content (as analyzed in a lab)										
		Macronutrients (lb/acre)						Micronutrients (oz/acre)				
		N	P	K	Ca	Mg	Na	B	Fe	Mn	Cu	Zn
sawdust	2-3" deep	62	5	20	27	5	-	32	-	16	-	0
compost	1.5" deep	545	86	305	546	127	-	32	-	385	-	96

- Adding organic materials to the mulching program technically adds high levels of many nutrients
- This does not mean that all of these nutrients are available to the plants
- High levels of some nutrients may limit availability of others (e.g. K and Mg)

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Impact of mulch treatment on soil pH, OM, and K content

pH (in water)	2008	2009	2010	2011	2012	2013	2014
Compost+sawdust	5.47 a	5.09 b	5.41 a	5.29 a	5.11 b	5.14 b	5.47 a
Sawdust	5.28 b	5.09 b	5.31 ab	5.17 b	4.91 c	4.94 c	5.14 b
Weed mat	4.78 c	5.36 a	5.21 b	5.20 ab	5.27 a	5.22 a	5.49 a

Organic Matter (%)	2008	2009	2010	2011	2012	2013	2014
Compost+sawdust	4.65 a	3.19 a	4.06 a	3.75 a	3.73 a	4.22 a	4.20 a
Sawdust	3.59 b	2.81 b	3.56 b	3.18 b	3.17 b	3.35 b	3.34 b
Weed mat	3.62 b	2.68 c	3.42 c	3.02 c	2.92 c	2.89 c	3.08 c

Potassium (mg/kg)	2008	2009	2010	2011	2012	2013	2014
Compost+sawdust	401 a	327 a	255 a	371 a	421 a	332 a	346 a
Sawdust	238 b	235 b	183 b	234 b	261 b	201 c	192 c
Weed mat	243 b	221 b	175 b	224 b	268 b	226 b	233 b

Adding compost to mulch compared to sawdust alone:

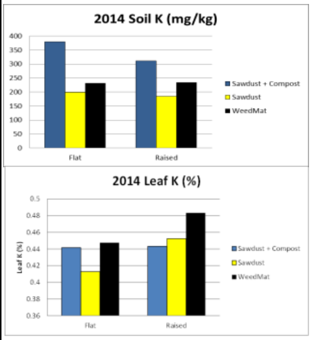
- ↑ Soil pH
- ↑ Soil organic matter
- ↑ Soil potassium

↑ Organic mulches replenished (2008, 2011, 2013)

Organic matter declined over time under weed mat

Strik et al., in progress

Leaf tissue K and Soil K – effect of mulch type



- Soil K highest with compost + sawdust mulch
- Leaf %K highest with weed mat

Strik et al., in progress

Soil sampling in established plantings

- every few years unless correcting problem
- Collect samples at same time of year; avoid spring, after fertilization
- Collect in the row; with drip irrigation sample within few inches of emitter
- Collect samples down to 1 - 1.5 ft
- Remove any mulch that is present
- Compile sub-samples from a representative area in the block

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Plant tissue analysis

- Provides information on the nutrient content of the plant
- Goal is to detect nutrient problems before visual symptoms or yield reductions appear
- Tool to diagnose visual symptoms and evaluate fertilizer programs
- Does not work well for anticipating current season fertilizer needs (except for micronutrients)
- Need to know: 1) What tissue to sample; 2) When to sample; 3) Interpreting results

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What tissue to sample
Raspberry & Blackberry

- Sample cultivars separately
- Collect 50 of the most recent fully-expanded primocane leaves
- Collect leaves ~ 1 ft from tip of primocane in floricane-fruiting types
- Published sufficiency levels (“standards”) are only for primocane leaves

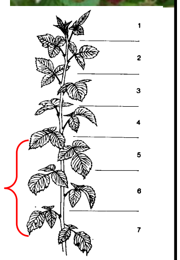

Fig. 1. Schematic drawing of red raspberry cane, showing 7 positions sampled.

(Hughes et al., 1979)

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What tissue to sample
Blueberry

- Sample cultivars separately
- Collect 50 of the most recent fully-expanded leaves
- Pick shoots below fruiting area, not whips
- Do not wash (soak) leaves

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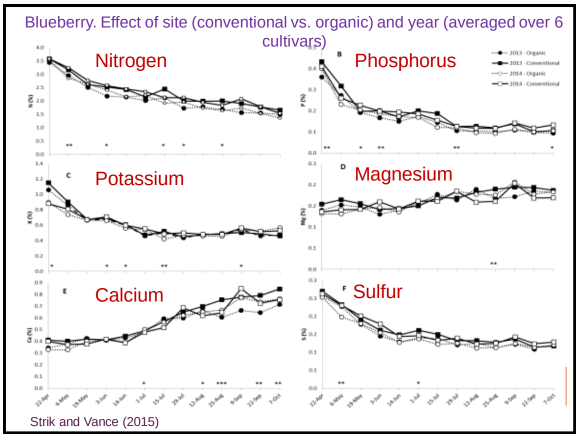
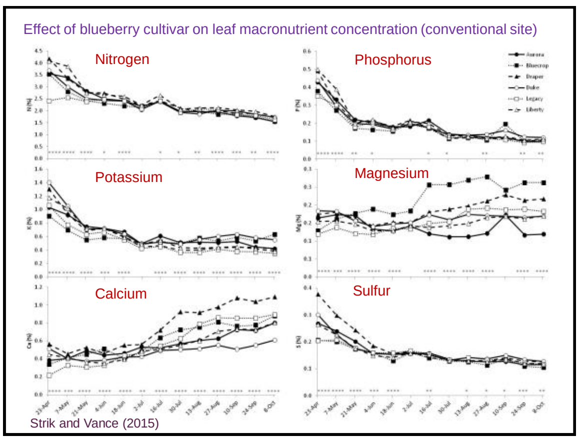
Sampling to diagnose causes of leaf symptoms can be done at any time during the season

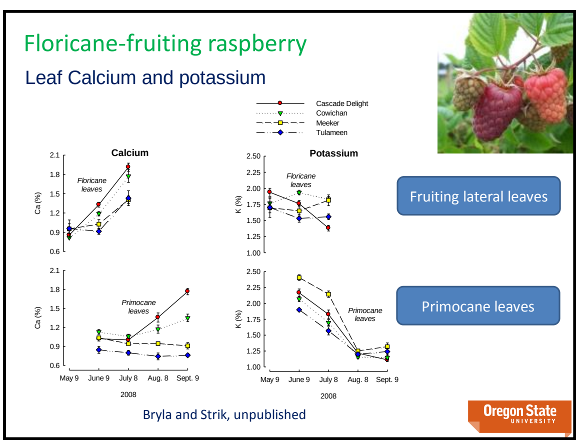
Sample leaves from problem plants & "normal" looking plants and compare results at any time of year

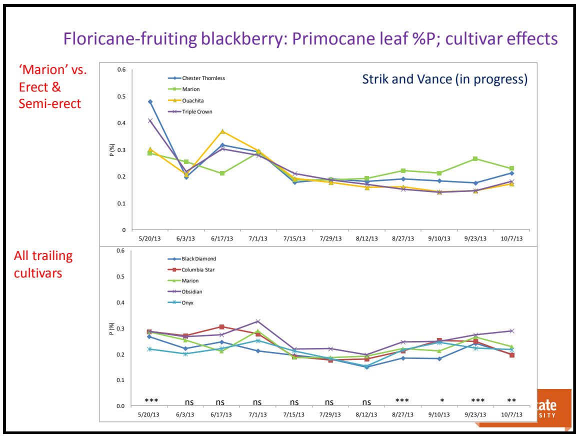
When to sample

- Tissue nutrient concentrations change over the growing season


Blueberry. Effect of site (conventional vs. organic) and year (averaged over 6 cultivars)
Nitrogen
Phosphorus
Potassium
Magnesium
Calcium
Sulfur
2013 - Organic
2013 - Conventional
2014 - Organic
2014 - Conventional
Strik and Vance (2015)


Effect of blueberry cultivar on leaf macronutrient concentration (conventional site)
Nitrogen
Phosphorus
Potassium
Magnesium
Calcium
Sulfur
Strik and Vance (2015)


Floricane-fruiting raspberry
Leaf Calcium and potassium
Cascade Delight
Cowichan
Meeker
Tulameen
Calcium
Potassium
Floricane leaves
Primocane leaves
Ca (%)
K (%)
May 9
June 9
July 8
Aug. 8
Sept. 9
2008
Fruiting lateral leaves
Primocane leaves
Bryla and Strik, unpublished
Oregon State University


Floricane-fruiting blackberry: Primocane leaf %P; cultivar effects
'Marion' vs. Erect & Semi-erect
All trailing cultivars
Strik and Vance (in progress)
Chester Thornless
Marion
Ouachita
Triple Crown
Black Diamond
Columbia Star
Marion
Obsidian
Onyx
P (%)
5/20/13
6/3/13
6/17/13
7/1/13
7/15/13
7/29/13
8/12/13
8/27/13
9/10/13
9/23/13
10/7/13
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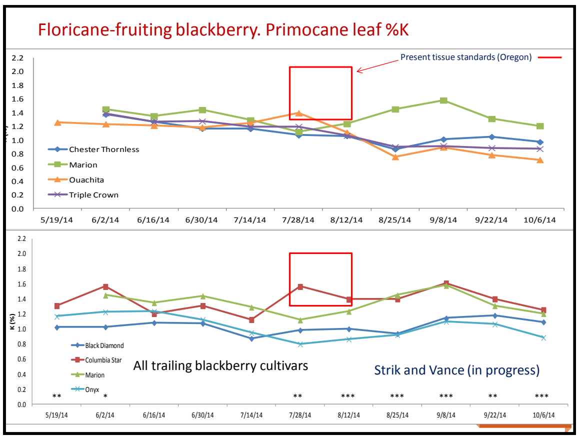
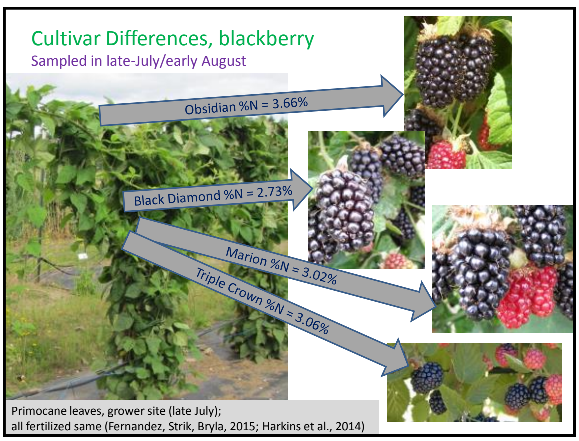
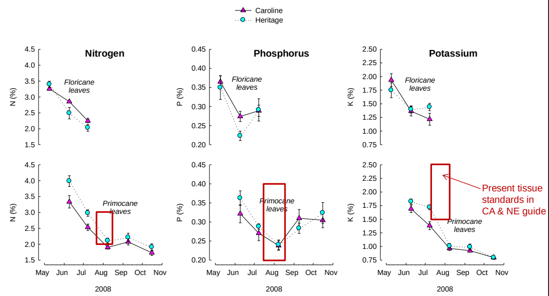

Floricane-fruiting blackberry. Primocane leaf %K
Present tissue standards (Oregon)
Chester Thornless
Marion
Ouachita
Triple Crown
5/19/14
6/2/14
6/16/14
6/30/14
7/14/14
7/28/14
8/12/14
8/25/14
9/8/14
9/22/14
10/6/14
Black Diamond
Columbia Star
Marion
Onyx
K (%)
All trailing blackberry cultivars
Strik and Vance (in progress)
** * ** *** *** *** ** ***


Cultivar Differences, blackberry
Sampled in late-July/early August
Obsidian %N = 3.66%
Black Diamond %N = 2.73%
Marion %N = 3.02%
Triple Crown %N = 3.06%
Primocane leaves, grower site (late July);
all fertilized same (Fernandez, Strik, Bryla, 2015; Harkins et al., 2014)

Primocane-fruiting raspberry

Nitrogen, phosphorus, potassium



OR standards: 2.3-3%

OR standards: 0.19-0.45%

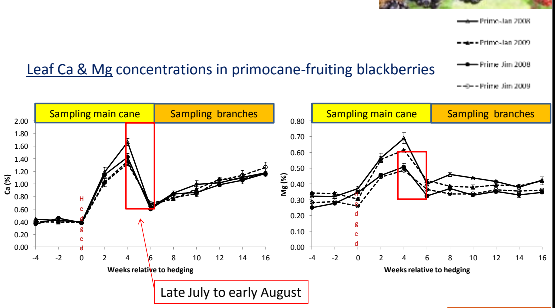
OR standards: 1.3-2.0%

Bryla and Strik, unpublished

Primocane-fruiting blackberry

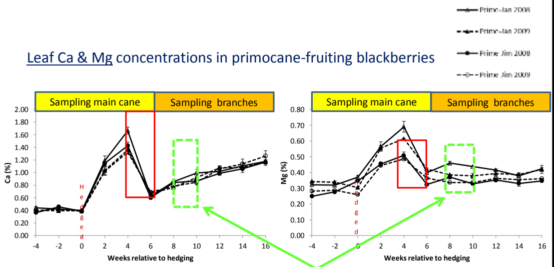
Primocane-fruiting blackberry

Leaf Ca & Mg concentrations in primocane-fruiting blackberries



Adapted from: Strik (2015)

Primocane-fruiting blackberry



Adapted from: Strik (2015)

Sample primocane-fruiting blackberry in the late-green fruit stage (8 to 10 weeks after hedging or tipping main cane)

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Interpreting Sample Analysis Results

- Tissue nutrient concentrations are expressed as a percentage (or ppm) of dry weight (concentration)
- Values can only be compared to published sufficiency levels if the leaf samples were taken at the correct time

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Current primocane leaf nutrient sufficiency levels

Raspberry & Blackberry

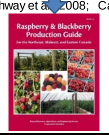
Nutrient	OSU	N.E. North America	California
	Caneberry Nutrient Mangement Guide	Raspberry & Blackberry Production Guide	Caneberry Production Manual
Nitrogen (%N)	2.3 to 3.0	2.0 to 3.0	2.0 to 3.0
Phosphorus (%P)	0.19 to 0.45	0.25 to 0.40	0.25 to 0.40
Potassium (%K)	1.3 to 2.0	1.5 to 2.5	1.5 to 2.5
Calcium (%Ca)	0.6 to 2.0	0.6 to 2.0	0.6 to 2.5
Magnesium (%Mg)	[illegible]	[illegible]	[illegible]
Sulfur (%S)	[illegible]	[illegible]	[illegible]
Manganese (ppm Mn)	[illegible]	[illegible]	[illegible]
Boron (ppm B)	30 [illegible] 70	30 [illegible] 70	30 [illegible] 50
Iron (ppm Fe)	60 [illegible] 250	60 [illegible] 250	50 [illegible] 200
Zinc (ppm Zn)	15 [illegible] 50	20 [illegible] 50	20 [illegible] 50
Copper (ppm Cu)	6 [illegible] 20	6 [illegible] 20	7 [illegible] 50

OSU - Hart et al., 2006; NE North America - Bushway et al. 2008; California - Bolda et al. 2012

"late-July to early August"

"after fruit harvest"

"May to August"



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Leaf nutrient sufficiency levels - Blueberry

Late July-early Aug

Nutrient	Northern Highbush Current standards	Southern Highbush Current standards	Rabbiteye Current standards
Nitrogen (%N)	1.76 to 2	1.8 to 2.1	1.2 to 1.7
Phosphorus (%P)	0.11 to 0.4	0.12 to 0.40	0.08 to 0.17
Potassium (%K)	0.41 to 0.7	0.35 to 0.65	0.28 to 0.60
Calcium (%Ca)	0.41 to 0.8	0.4 to 0.8	0.24 to 0.7
Magnesium (%Mg)	0.13 to 0.25	0.12 to 0.25	0.14 to 0.2
Sulfur (%S)	0.11 to 0.16	0.12 to 0.25	na
Manganese (ppm Mn)	31 to 350	50 to 350	25 to 100
Boron (ppm B)	30 to 80	30 to 70	12 to 35
Iron (ppm Fe)	60 to 200	60 to 200	25 to 70
Zinc (ppm Zn)	8 to 30	8 to 30	10 to 25
Copper (ppm Cu)	5 to 15	5 to 20	2 to 10
Aluminum (Al)	na	na	na

From: Hart et al. 2006 Blueberry Nutrient Management Guide, Oregon State University

From: Krewer and NeSmith Blueberry Fertilization in Soil Fruit Pub. 01-1, Univ. GA

- Sample ALL cultivars in late-July to early August despite fruiting season
- Tissue levels outside range may indicate nutrient problem or cultural problem

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Outline

- Introduction
- Items covered specific to blueberry, raspberry & blackberry:
  - Soil sampling & requirements
  - Site preparation (pH adjustment; organic matter, mulching)
  - Assessment of plant nutrient status
  - Interpretation of tissue analysis results
  - Fertilizer rates…starting points
  - Adjustment of nutrient management programs based on plant uptake of nutrients & losses
  - Sources of nutrients/fertilizers

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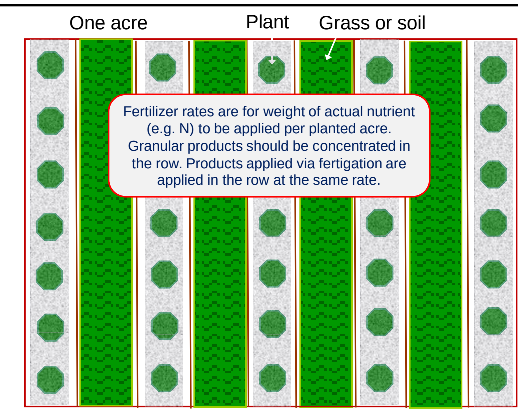
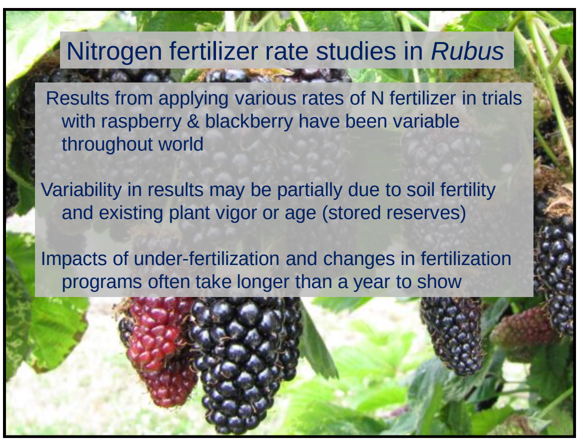


Total fertilizer required/acre is applied in row (as broadcast band or fertigated)



Nitrogen fertilizer rate studies in *Rubus*

Results from applying various rates of N fertilizer in trials with raspberry & blackberry have been variable throughout world

Variability in results may be partially due to soil fertility and existing plant vigor or age (stored reserves)

Impacts of under-fertilization and changes in fertilization programs often take longer than a year to show

Research on N fertilization rates

- Low N rates reduce cane numbers, vigor, berry size, and yield
- High rates of N can increase internode length (reducing yield per cane) and fruiting lateral length (harvest & disease issues)
- High N rates may reduce fruit firmness and shelf life
- High N rates may increase fruit and cane disease
- Late or high rates of N may increase risk of winter cold injury

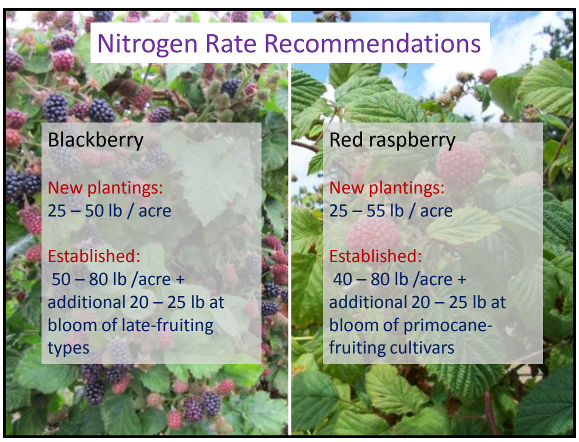



Possible Negative Effects of Above-ideal Nitrogen Fertilization

N and K fertilizer effects, 'Thornless Evergreen' (Nelson & Martin, 1986)

N and K (lb/a)	Yield (tons/a)	Berry wt. (g)	Brix (%)	Firmness (N)
0	2.5a	3.2a	13.4a	3.98a
60	3.6b	3.5b	12.4b	4.06b
120	3.1c	3.3a	12.9c	3.82a

- Yield and berry weight increased with increasing N rate (0, 35, 110 lb N/a) in 'Hull Thornless' in Kentucky (Archbold et al., 1989)
- N rate had little effect on fruit pH, titratable acidity, soluble solids, and firmness in 'Thornless Evergreen' blackberry (Nelson and Martin, 1986)
- increased %N & pH, but no effect on soluble solids, TA and sugar-acid ratio in 'Arapaho' (Alleyne and Clark, 1997)
- High N rates, decreased Brix in red raspberry (Papp et al., 1984)



Nitrogen Rate Recommendations

Blackberry

New plantings:
25 – 50 lb / acre

Established:
50 – 80 lb /acre + additional 20 – 25 lb at bloom of late-fruiting types

Red raspberry

New plantings:
25 – 55 lb / acre

Established:
40 – 80 lb /acre + additional 20 – 25 lb at bloom of primocane-fruiting cultivars

Nitrogen Rate, Blueberries – Starting Point

Adjust rates based on mulching, tissue analysis & plant growth

		Recommended N rate (lb/a)	
		Granular fertilizer	
Year	Fertigation	Oregon*	British Columbia†
1	90	25-40**	19
2	90	40-50**	27
3	60	50-60	45
4	70	55-65	50
5	75	65-75	62
6	85	80-100	71
7	95	90-120	89
8+	100-150	100-140	102

- ** Fertilizer is applied by hand per bush in year 1 and 2 for granular and using a fertilizer spreader when canopies touch in year 3+; based on 2.5-3 ft in-row spacing and 10 ft between rows
- Once canopies touch, in-row spacing is not relevant
- Oregon: un-mulched plantings. If sawdust mulch is used add 25 lb N/acre to rate ONLY if fertilizer N applied on top of mulch (Hart et al., 2006)
- B.C. values from 2014 Berry Production Guide

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Nitrogen Rate - Blueberry

Do not apply too much N

- Long-term studies have found no advantage of higher rates of N in yield
- High rates of N can lead to high salts (EC) in root zone and reduce growth of young plants
- In organic production and conventional studies, plants have often performed better or just as well at low rates of N
- High rates of N increase the decline in soil pH over time
- Excess N nitrifies to nitrate and leaches
- Excess or late fertilization with N can decrease fruit bud set and/or lead to frost damage

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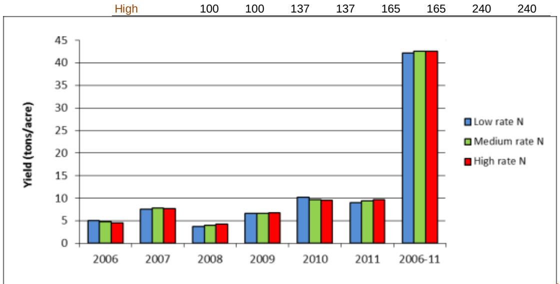
Elliott

Machine-harvested

N fertilizer rates from 2004 (year 1) through 2010 (year 7). Total N was split into thirds and applied as a granular product (usually Ammonium Sulfate) from bloom through June in a broadcast band.

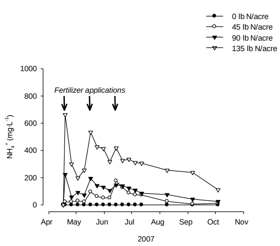
	N fertilizer rate (lb N/a)							
N treatment	2004	2005	2006	2007	2008	2009	2010	2011
Low	20	20	28	28	35	35	50	50
Medium	60	60	85	85	100	100	150	150
High	100	100	137	137	165	165	240	240



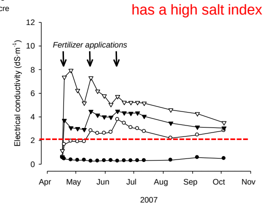
Year: 3 4 5 6 7 8 Total all years

Strik et al., in progress

Caution: granular ammonium fertilizers increase soil salinity



*Ammonium sulfate has a high salt index



Bryla & Machado (2011)

Keep soil pH in desired range

- Fertilization lowers soil pH (every 100 lb N/acre/year drops soil pH 0.1 unit with urea & 0.2 unit with ammonium sulfate)
- It is very difficult to significantly raise soil pH (with lime) after planting
- Monitor soil pH
- Tissue analysis will show leaf Mn increasing over time as pH declines
- Add an annual application of lime to fertilizer program and/or use high pH composts in blueberry and caneberry

Soil pH too low in blueberry – Aluminum toxicity

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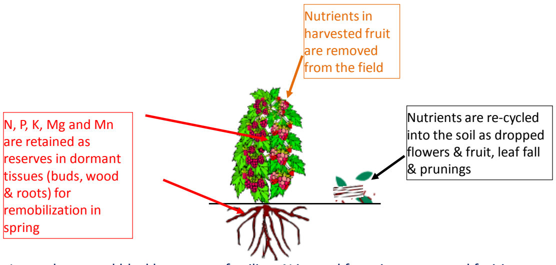
Nutrient Storage & Recycling in Perennial Fruit Crops



In raspberry and blackberry, new fertilizer N is used for primocanes and fruiting lateral growth. Stored nutrients are preferentially used for floricane growth

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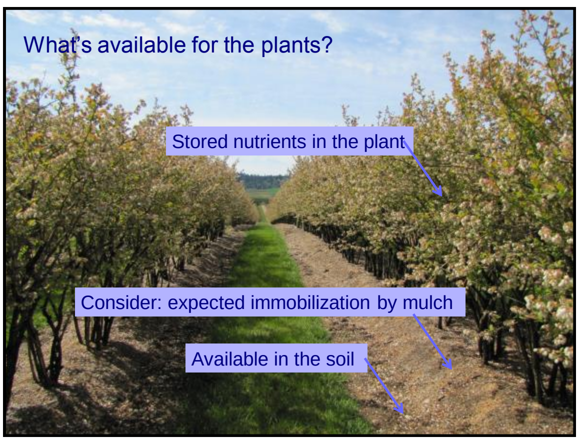


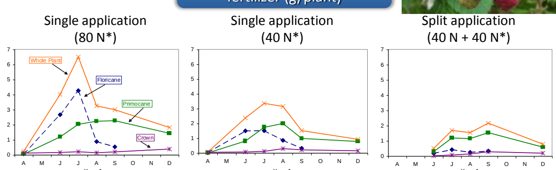
Blackberry types differ in cane morphology/development

Fertilizer N uptake in blackberry

- Fruit and primocanes were strongest sink for new fertilizer N
- Floricane %N declined as tissues dying
- Roots were a large storage site for fertilizer N
- Very little stored N used for primocane growth in the second year
- Primocanes thus dependent on new fertilizer N (or soil-available N)
- 'Kotata' trailing blackberry, field-grown [Mohadjer, Strik, Zebarth, Righetti (2001)]
- 'Arapaho' field-grown [Naraguma, Clark, Norman, MacKown (1999)]
- 'Chester Thornless' in pots [Malik, Archbold, MacKown (1991)]

N fertilizer uptake in red raspberry

Results – N derived from fertilizer (g/plant)



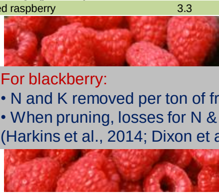
- N fertilizer uptake pattern was similar between 40 N & 80 N
  - Initial uptake was low and mostly allocated to crowns
  - By June most fertilizer N was in floricanes
  - Fertilizer N in floricanes decreased as they died after harvest (movement into other plant parts)
  - Fertilizer N in primocanes increased until leaf fall
- Last half of 40+40 N split went mainly to primocanes

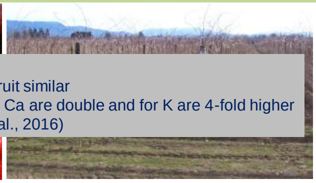
(Rempel et al., 2004)

Nutrients removed per fresh TON of harvested fruit ('Meeker') & per ACRE of prunings (adapted from Rempel & Strik, 2004)

Crop	Macronutrients (lb) N	P	K	Ca	Mg	S
Fruit (per ton harvested)						
Red raspberry	3.5	0.5	3.0	0.3	0.4	0.2
Prunings (per acre)						
Red raspberry	17.3	1.2	9.4	15.3	3.1	0.9

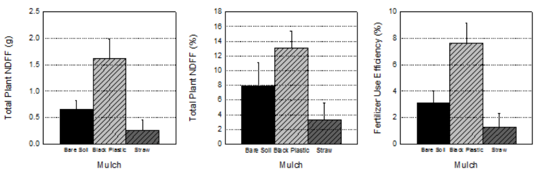
Crop	Micronutrients (oz) B	Cu	Mn	Zn
Fruit (per ton harvested)				
Red raspberry	0.1	0.03	0.11	0.07
Prunings (per acre)				
Red raspberry	3.3	0.2	2.1	0.5





For blackberry:
- N and K removed per ton of fruit similar
- When pruning, losses for N & Ca are double and for K are 4-fold higher (Harkins et al., 2014; Dixon et al., 2016)

Fertilizer recover in 'Meeker' red raspberry
Effect of mulch and N source



- Fertilizer applied as flailed prunings (enriched in ^{15}N) was taken up as efficiently as an equivalent rate of enriched ammonium sulfate 1.5 years after application
- Fertilizer uptake the following growing season was greatest with black plastic and least with 6 inch-deep straw mulch
- Warmer temperatures increased N uptake

Strik, Righetti, and Rempel (2006)

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Replenish nutrients removed in fruit, prunings, add those required for growth & account for fertilizer uptake efficiency

Nutrients removed per TON (fresh) of harvested fruit (range for 7 cultivars) & per ACRE of prunings (Elliott data)

	Macronutrients (lb)					
Part removed	N	P	K	Ca	Mg	S
Fruit (per ton harvested)	1.3 - 2.3	0.1 - 0.3	0.8 - 1.7	0.1 - 0.2	0.05 - 0.1	0.06 - 0.2
Prunings (per acre)	14.0	1.5	6.5	3.0	0.9	1.1

	Micronutrients (oz/ton)				
	B	Cu	Mn	Zn	Fe
Fruit (per ton harvested)	0.02 - 0.03	0.01 - 0.02	0.04 - 0.1	0.01 - 0.04	0.05 - 0.1
Prunings (per acre)	0.2	0.5	12.1	0.5	1.1

Fruit data: Range provided for Duke, Bluecrop, Draper, Liberty, Aurora, Legacy, Elliott
Pruning data: Mature Elliott (average of two years); prunings are a loss to the plant in blueberry (no roots between raised beds) (Strik, in progress)

Blueberry – Timing of N fertilization


- Nitrogen fertilizer uptake studies (using ^{15}N) have shown that blueberry plants take up N fertilizer from bloom through early to mid-July (Throop and Hanson, 1991; Retamales and Hanson, 1989; Bañados, 2006; Bañados et al., 2012; White, 2006).
- Plants use stored N prior to bloom
- Plants need to build "reserves" back up by fall
- Late fertilization with N can reduce fruit bud set and increase cold/frost injury

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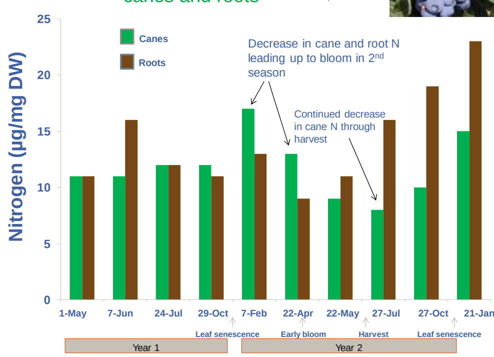
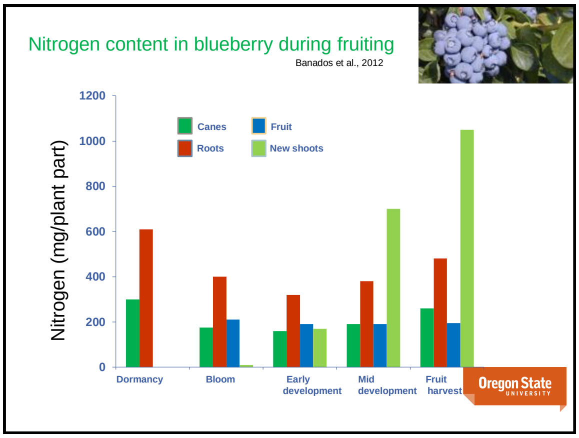
Seasonal N concentration in young blueberry canes and roots Banados et al., 2012




Nitrogen content in blueberry during fruiting
Banados et al., 2012
Nitrogen (mg/plant part)
1200
1000
800
600
400
200
0
Canes
Fruit
Roots
New shoots
Dormancy
Bloom
Early development
Mid development
Fruit harvest
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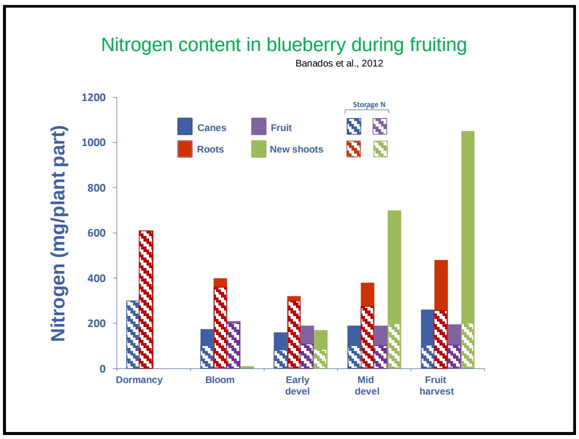
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Nitrogen (mg/plant part)
1200
1000
800
600
400
200
0
Canes
Fruit
Roots
New shoots
Storage N
Dormancy
Bloom
Early devel
Mid devel
Fruit harvest


Late growth (and reduced fruit bud set) due to late fertilization with N
Bluejay
Liberty
Sept. 29
Oregon State University

Late growth is susceptible to frost or winter cold damage

Winter damage, WA

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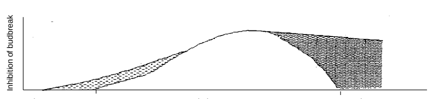
Dormancy

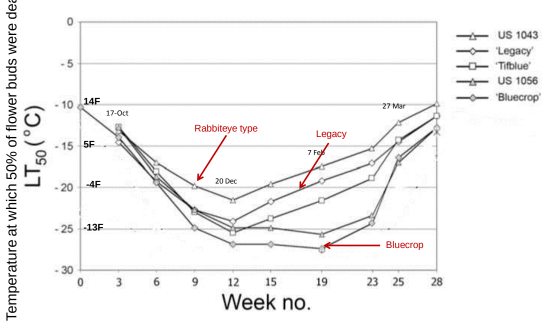
	Ecodormancy	Paradormancy	Endodormancy
	Regulated by environmental factors	Regulated by physiological factors outside affected structure	Regulated by physiological factors inside affected structure
Examples	Temp extremes Water stress	Apical dominance Leaf perception of short days (SD) in fall initiates bud dormancy	SD + cool temps SD alone



A schematic representation of inhibition of budbreak during dormancy. Dormancy begins with paradormancy and deepens during endodormancy. The depth and duration of ecodormancy is environment dependent.

Acclimation phase deep dormancy de-acclimation phase

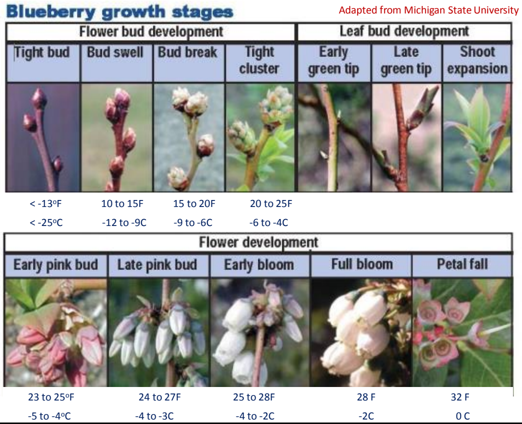
Cold acclimation in blueberry – New Jersey



From Ehlenfeldt et al., 2012

Blueberry growth stages

Adapted from Michigan State University



Blueberry flower buds, winter

Flower bud

Cross section

Longitudinal section

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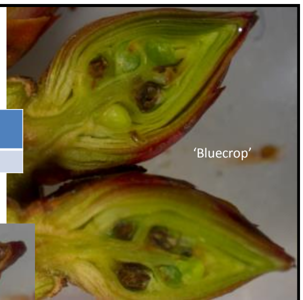
Cold damaged buds

Cold damage can occur at warmer temperatures during acclimation and deacclimation phases of dormancy

-2 to -6 °F (-19 to -21C)	55% had some damage
9 °F (-13 °C)	No damage

Dec. 8-9, 2013



-2 to -6 °F	59% had some damage
9 °F	No damage

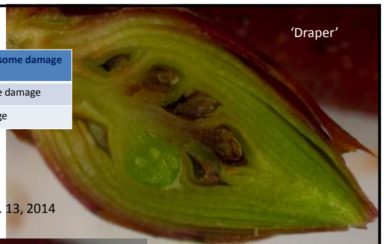
Photos taken Jan. 13, 2014

Cold damaged buds

-2 to -6 °F (-19 to -21C)	48% had some damage
2 °F (-17 °C)	11% some damage
9 °F (-13 °C)	No damage

Dec. 8-9, 2013

Photos taken Jan. 13, 2014



Note: <1% damage in 'Liberty' at -2 to -6 °F

-2 to -6 °F	34% had some damage
9 °F	No damage

Mobility of nutrients in the Plant

- Mobile within the plant (xylem and phloem)
  - N, P, K, Mg, Cl
- Immobile within the plant (xylem, little remobilization in phloem)
  - S, Fe, Mn, Cu, Zn
- Very immobile within the plant (xylem)
  - Ca, B

Mobility of nutrients in the soil is increased by fertigation, especially P and K

Phosphorus

- Mobile in plant, but immobile in soil
- P deficient plants are stunted and often dark green; leaves may have red tinge due to accumulation of anthocyanins
- Excess P will increase root to shoot ratio
- Excess P may lead to micro-nutrient deficiencies

Incorporate prior to planting, if needed. Surface applications of granular P not available to roots. Can apply through drip. Ammonium phosphate fertilizers or super or triple superphosphates; ammonium polyphosphate (drip)

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Potassium

- Mobile in plant, but immobile in soil
- Tissue levels related to crop load or time of fruiting as K levels in fruit high
- K deficient plants have older leaves with necrotic lesions
- High rates of K can lead to “salt” injury
- High soil K and low leaf %K often related to production problems

Incorporate prior to planting, if needed. Apply granular K in the fall. Can apply through drip. Muriate of potash (KCl, 0-0-60) [caution at high rates…high salt] or potassium nitrate (13-0-45) if also need N in caneberries and potassium sulfate in blueberry

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Magnesium

- Mobile in plant, but immobile in soil
- Deficient plants have older leaves with interveinal necrosis or edges starting red and turning brown
- Deficiencies more common on sandy soil with low pH or if soil K is high

Incorporate prior to planting, if needed. Apply granular Mg in the fall (dolomite lime or magnesium sulfate or gypsum); Can apply through drip (magnesium sulfate).

Calcium

Erect blackberry

- Immobile in plant and soil
- Deficiency symptoms in younger leaves; deformed, twisted tissues; low Ca may reduce fruit firmness
- Low soil moisture & cool, cloudy, humid conditions limit %Ca
- With drip irrigation, soil Ca may leach over time

> Incorporate prior to planting, if needed (Ag or dolomite lime). Apply granular Ca in the fall (lime). Can use calcium nitrate if need N in caneberries. Can apply through drip (calcium nitrate; calcium chloride; calcium sulfate; calcium chelate). Foliar Ca?

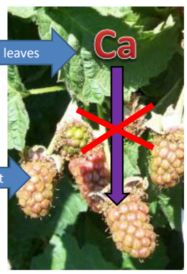
Applying Ca to get to fruit

- Granular applications (lime, gypsum) in fall
- Fertilize through the drip, during growth
- Liquid applications to soil in spring
- Foliar applications

All effective to increase soil Ca and plant Ca

Foliar Ca to leaves

Increasing fruit %Ca difficult



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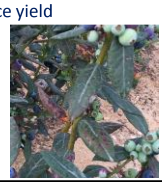
Boron

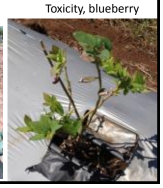
Deficiency

- Very immobile in plant; mobile in soil
- B deficiency reduces percent bud break and increases crumbly fruit in caneberries; decreases fruit set in blueberry
- Toxicity can occur – tip burning of shoots
- Annual applications, without soil or tissue tests not recommended as may reduce yield

> Incorporate prior to planting, if needed. Apply granular B in the fall (borax). Foliar applications effective (e.g., solubor)



Toxicity, blueberry



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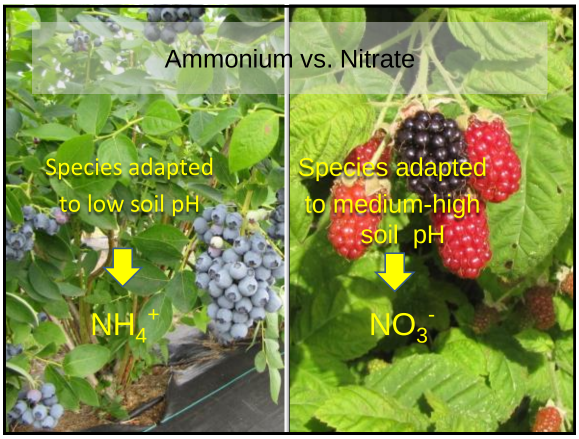
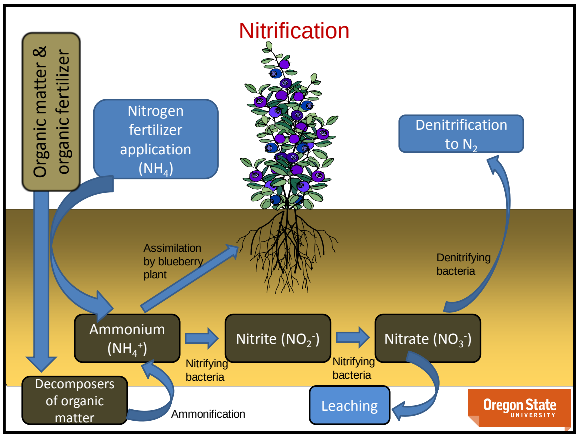


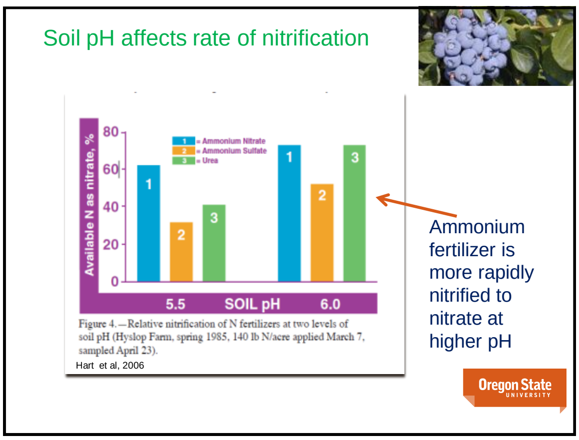
Blueberry plants can only use the ammonium form of N

Fed only NH_4

Fed only NO_3

Courtesy: R. Darnell


Nitrification
Organic matter & organic fertilizer
Nitrogen fertilizer application (NH4)
Denitrification to N2
Assimilation by blueberry plant
Denitrifying bacteria
Ammonium (NH4+)
Nitrite (NO2-)
Nitrate (NO3-)
Nitrifying bacteria
Nitrifying bacteria
Decomposers of organic matter
Ammonification
Leaching
Oregon State University


Soil pH affects rate of nitrification
Available N as nitrate, %
80
60
40
20
0
1 = Ammonium Nitrate
2 = Ammonium Sulfate
3 = Urea
5.5
SOIL pH
6.0
Figure 4.—Relative nitrification of N fertilizers at two levels of soil pH (Hyslop Farm, spring 1985, 140 lb N/acre applied March 7, sampled April 23).
Hart et al, 2006
Ammonium fertilizer is more rapidly nitrified to nitrate at higher pH
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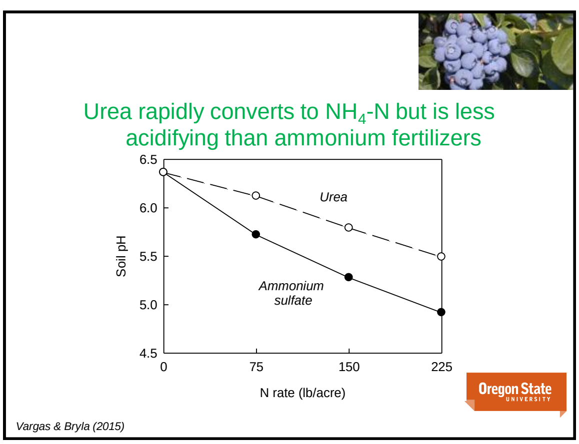
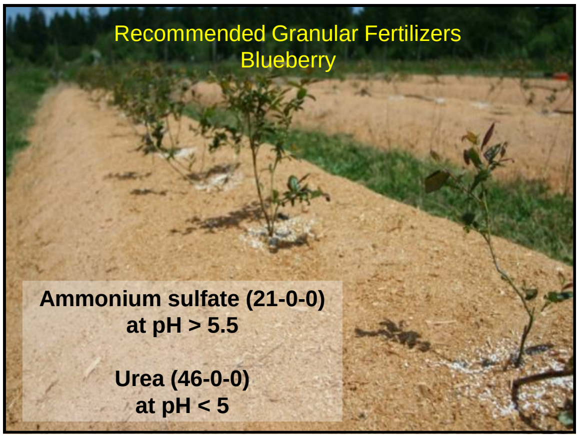

Urea rapidly converts to NH4-N but is less acidifying than ammonium fertilizers
Soil pH
6.5
6.0
5.5
5.0
4.5
Urea
Ammonium sulfate
0
75
150
225
N rate (lb/acre)
Vargas & Bryla (2015)
Oregon State University



Common granular fertilizers

Fertilizer material	Chemical formulation
Ammonium sulfate (21-0-0)	$(NH_4)_2SO_4$
Ammonium phosphate (11-52-0)	$NH_4H_2PO_4$
Ammonium phosphate-sulfate (16-20-0-15)	$NH_4H_2PO_4$ $(NH_4)_2SO_4$
Calcium ammonium nitrate (27-0-0)	$CaCO_3 + NH_4NO_3$
Calcium nitrate* (15.5-0-0)	$Ca(NO_3)_2$
Urea (46-0-0)	$(NH_2)_2CO$
Urea-sul (7-46% N + 4-8% S)	$(NH_2)_2CO + (NH_4)_2SO_4$

*Not recommended for blueberries.

Fertilizer sources (organic)

- Animal based
  - Use of fresh manures not recommended/OMRI approved
  - Animal meal products (e.g. blood, bone, feather, poultry litter)
  - Liquid products (e.g. fish emulsion) – may be fertigated
- Composts (plant or animal based) may be used before planting
  - Always test compost prior to use
- Plant based
  - Liquid distilled products (e.g. corn steep liquor) – may be fertigated
  - Alfalfa or soybean meal
  - Various “teas”, seaweed, humic acids

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Common liquid fertilizers

Fertilizer material	Chemical formulation
Ammonium nitrate solution [AN-20]* (20-0-0)	$NH_4NO_3{\cdot}H_2O$
Calcium ammonium nitrate (Can-17)	$5Ca(NO_3)_2{\bullet}NH_4NO_3{\bullet}10H_2O$
Ammonium polyphosphate† (10-34-0 or 11-37-0)	$(NH_4PO_3)_n$
Ammonium sulfate solution (8-0-0-9S)	$(NH_4)_2SO_4{\cdot}H_2O$
Ammonium thiosulfate§ (12-0-0-26S)	$(NH_4)_2S_2O_3$
Urea solution (20-0-0 or 23-0-0)	$(NH_2)_2CO$
Urea-ammonium nitrate soln. [UN-32]** (32-0-0)	$(NH_2)_2CO{\cdot}NH_4NO_3$
Urea sulfuric acid‡ (various)	$(NH_2)_2CO{\cdot}H_2SO_4$

*Not recommended for blueberries.
†P source; mix with other fertilizers.
§Use with caution.
‡Acidic but safer than sulfuric acid.

Liquid Organic Fertilizers

Product	Price ($/gal)	N cost ($/lb)
Converted Organics 521 5-1-1	$1.45	$5.00
Alaska Salmon Fish Fertilizer	$3.00	$6.67
Phytamin 801	$6.25	$8.00
Eco-Hydro Fish 2-4-0.2	$3.50	$19.50
Aqua Power 100 % Fish Emulsion	$11.98	$24.80
Liquid Fish Soluble Fertilizer 5-1-1	$20.00	$43.40
Converted Organics NC 0.4-1-0	$1.65	$45.00
Liquid Fish Fertilizer 2-4-0.2	$9.99	$50.00
Drammatic ONE 4-4-0.5	$37.20	$77.60
BioFert BioFish 3-1-2	$2.59/lb	$86.33
Organic Gem 3-3-3	$27.95	$109.67
Neptune Harvest Liquid Fish 2-4-1	$30.00	$136.50

From Miles et al. (2009) Fertigation applications and costs in organic vegetables.

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Typical macronutrient concentration of common organic fertilizers

Organic fertilizer product[z]	N	P_2O_5	K_2O	Ca	Mg
	(%)				
Pelletized chicken litter	4	5	3	11	1
Soy bean meal	7	1	3	< 0.5	< 0.5
Feather meal	12	1	0.5	1	0
Fish emulsion/hydrolyzate (liquid)	4	1	5	0	0
Corn steep liquor blend (liquid)	2.5	3	2	< 0.5	< 0.5
Bat guano	10	3	1	na[y]	na
Blood meal	12 - 15	1	1	na	na
Bone meal	1 - 4	12 - 24	0	na	na
cotton seed meal	6 - 7	2	1	na	na
Rock phosphate	0	25 - 30	0	0	0
Kelp meal	1	< 0.5	2 - 5	na	na

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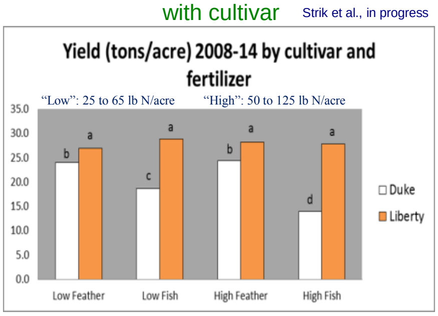
Effects of organic fertilizer source & rate varied with cultivar

Strik et al., in progress



Liberty yield unaffected by fertilizer source or rate whereas Duke yield higher with feather meal than fish

High rate of fish worse than low rate in Duke

Foliar application of liquid fertilizers

- Micronutrients (B, Cu, Zn)
- Often mixed with fungicides
- Avoid foliar application of macronutrients (N, P, K, Ca, Mg)
- Also avoid foliar Fe applications

Summary

- Use organic matter carefully – be aware of material properties and plant requirements
- Test soil & maintain pH in desirable range
- Test tissue annually
  - In caneberries, test primocane leaves in late July/early Aug. for raspberry and floricane-fruiting blackberry and during green fruit stage for primocane-fruiting blackberry
  - In blueberries, collect lateral shoot leaves in late-July/early August, regardless of cultivar
  - Choose most recent fully-expanded leaf
  - Test cultivars separately
  - Check sufficiency levels

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Summary, Cont.

- Apply the right amount of fertilizer
  - Be aware of fertilizer losses
  - Replace losses & add some for growth (adjust as needed using tissue test results)
  - Monitor growth & look for symptoms
- Apply the right source of fertilizer
- Apply fertilizer at the right time of year
- Apply to increase accessibility or plant uptake
- Be aware of plant growth and keep records

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Questions?

Nutrient Management of Blueberry, Raspberry, and Blackberry – A Supplement to the PowerPoint Presentation
January 7, 2016

Bernadine C. Strik
Professor, Extension Berry Crops Specialist
Department of Horticulture
Oregon State University

This summary is a supplement to the PowerPoint Presentation (provided separately). Tables are provided here so they are more visible and can serve as a reference. Refer to local nutrient management guides for blueberry, raspberry and blackberry (caneberries) for more complete information. For example, the nutrient management guides available online at Oregon State University (https://catalog.extension.oregonstate.edu/): *Nutrient Management for Blueberries in Oregon*, EM 8918; *Caneberries: Nutrient Management Guide*, EM 8903-E).

Key questions that need to be answered with regard to any nutrient management program are: How much nutrient should be applied? When is the best time to apply the nutrient? What source of the nutrient or what material is best to apply? And what method of application is best?

How much nutrient should be applied is often estimated using soil and plant tissue testing, experience, observations of plant growth, and information on the amount of nutrient generally required for good growth and production. Nutrient availability and plant nutrient status are assessed by soil and tissue testing.

Soil testing

In perennial crops, soil testing is important to adjust soil nutrient status prior to planting. Take representative soil samples well in advance of planting so that pH can be adjusted (e.g. sample in early fall for spring planting of caneberries or a year in advance for blueberries) – it takes time for incorporated lime or sulfur to react and change soil pH.

Base nutrients to be incorporated prior to planting on target or recommended soil levels (Table 1). In blueberry, be conservative on addition of sulfur to acidify the soil, as raising the pH to the target range if too much sulfur (S) was incorporated is difficult. Be aware that standard fertilization programs lead to acidification of the soil in the row – the pH will thus decrease over time in all perennial berry crops. For these reasons the target pH for newly planted berry crops should be at the top of the recommended range (Table 1).

Annual soil sampling is not needed in perennial berry crops unless you are correcting a problem. We recommend soil samples be collected every two to three years to monitor changes in soil nutrient status. In established fields, sample at the same time of year so that years can be more easily compared. Collect soil samples in the plant row (where the fertilizer is applied) and, in drip irrigated fields, sample at a similar distance from the emitter and plant in all sub-sample locations. Do not collect soil samples in spring right after fertilization has occurred. If mulch is present, remove the mulch layer before taking the soil sample. Sample 1 to 1.5 ft deep.

Table 1. Suggested critical levels for **soil** nutrient content in Oregon. Results may vary with soil tests used by labs and with region.

	Blueberry	Raspberry & Blackberry
pH (2:1; in water)	4.5 to 5.5	5.6 to 6.8
Nutrient	Deficient at less than (ppm)	
Phosphorus (P; Bray)	25 to 40	20 to 40
Phosphorus (Olsen)	10 to 20	10 to 20
Potassium (K)	100 to 150	150 to 350
Calcium (Ca)	1000	1000
Magnesium (Mg)	60	120
Manganese (Mn)	20 to 60	20 to 60
Boron (B)	0.5 to 1.0	0.5 to 1.0

Note. Soil EC (salt) should be below 2 dS/m

Keep soil pH in the range considered ideal for the berry crop (Table 1). If pH is below or above recommended levels, plant symptoms of nutrient deficiencies or toxicities often occur; in such situations the problem is best fixed by correcting soil pH.

Tissue testing

Leaf tissue analysis provides information on the nutrient content of the plant – sometimes even when soil nutrient content is adequate, the plant is not able to take up the nutrients required.

Tissue standards have been developed using results from research experiments and estimated from large databases that relate tissue nutrient levels to good yielding fields for each crop (OSU).

In all berry crops, **tissue nutrient concentration changes throughout the season**; for example, leaf N concentration (%N) is always highest in the early season and lowest before leaf fall in autumn. The opposite is found for leaf calcium concentration. The recommended time of sampling leaves for tissue analysis is related to a period of time when the leaf nutrient concentration is most stable.

Tissue nutrient levels will also change with location or age of the leaf and what type of leaf it is. For example, in caneberries results from floricane leaves will be different than primocane leaves and in blueberry, leaves from whips will have different nutrient levels than those from lateral shoots.

Sample floricane-fruiting blackberry and raspberry primocane leaves and leaves of various blueberry cultivars (from lateral shoots) in late-July/early August. Sample cultivars separately.Sample primocane-fruiting blackberry at the green fruit stage of development. Leaves should not be washed, but may be quickly rinsed and then air dried prior to sending to a lab. Compare tissue nutrient results to the sufficiency ranges (Table 2 and 3). For "problem diagnosis" plants can be sampled at any time as long as a "control" (asymptomatic plant) is also collected for comparison.

Table 2. Recommended primocane leaf nutrient sufficiency levels for caneberries when sampled in late-July to early-August in Oregon, May to August in California, and the first week of August in the eastern, midwestern and northeastern USA.

Nutrient	Oregon[z]	California[y]	Eastern, Midwestern, and Northeastern U.S.[x]
Nitrogen (%)	2.3 to 3.0	2.0 to 3.0	2.0 to 3.0
Phosphorus (%)	0.19 to 0.45	0.25 to 0.40	0.25 to 0.40
Potassium (%)	1.3 to 2.0	1.5 to 2.5	1.5 to 2.5
Calcium (%)	0.6 to 2.0	0.6 to 2.5	0.6 to 2.0
Magnesium (%)	0.3 to 0.6	0.3 to 0.9	0.6 to 0.9
Sulfur (%)	0.1 to 0.2	-	0.4 to 0.6
Manganese (ppm)	50 to 300	50 to 200	50 to 200
Boron (ppm)	30 to 70	30 to 50	30 to 70
Iron (ppm)	60 to 250	50 to 200	60 to 250
Zinc (ppm)	15 to 50	20 to 50	20 to 50
Copper (ppm)	6 to 20	7 to 50	6 to 20

[z] In Oregon, the recommendations are to use whole leaves – petioles included – and to leave them unwashed (Hart et al. 2006).

[y] In California, there are no specifications for leaf petioles or washing (Bolda et al. (2012) .

[x] In the northeast, recommendations include petiole removal and leaf washing. (Bushway et al. 2008).

Table 3. Recommended leaf nutrient sufficiency levels for blueberry types when sampled in late-July to early-August in Oregon and after fruiting in the southeastern USA[z].

Nutrient	Northern Highbush Current standards	Southern Highbush Current standards	Rabbiteye Current standards
Nitrogen (%N)	1.76 to 2	1.8 to 2.1	1.2 to 1.7
Phosphorus (%P)	0.11 to 0.4	0.12 to 0.40	0.08 to 0.17
Potassium (%K)	0.41 to 0.7	0.35 to 0.65	0.28 to 0.60
Calcium (%Ca)	0.41 to 0.8	0.4 to 0.8	0.24 to 0.7
Magnesium (%Mg)	0.13 to 0.25	0.12 to 0.25	0.14 to 0.2
Sulfur (%S)	0.11 to 0.16	0.12 to 0.25	na
Manganese (ppm Mn)	31 to 350	50 to 350	25 to 100
Boron (ppm B)	30 to 80	30 to 70	12 to 35
Iron (ppm Fe)	60 to 200	60 to 200	25 to 70
Zinc (ppm Zn)	8 to 30	8 to 30	10 to 25
Copper (ppm Cu)	5 to 15	5 to 20	2 to 10
Aluminum (Al)	na	na	na

[z]Adapted from Hart et al. (2006), Blueberry Nutrient Management Guide OSU and Krewer and NeSmith, Blueberry Fertilization in Soil Fruit Pub. 01-1, Univ. GA

Fertilizer information

Typical nutrient concentration of common organic fertilizers

Organic fertilizer product[z]	N	P_2O_5	K_2O	Ca	Mg
	(%)				
Pelletized chicken litter	4	5	3	11	1
Soy bean meal	7	1	3	< 0.5	< 0.5
Feather meal	12	1	0.5	1	0
Fish emulsion/hydrolyzate (liquid)	4	1	5	0	0
Corn steep liquor blend (liquid)	2.5	3	2	< 0.5	< 0.5
Bat guano	10	3	1	na[y]	na
Blood meal	12 - 15	1	1	na	na
Bone meal	1 - 4	12 - 24	0	na	na
cotton seed meal	6 - 7	2	1	na	na
Rock phosphate	0	25 - 30	0	0	0
Kelp meal	1	< 0.5	2 - 5	na	na

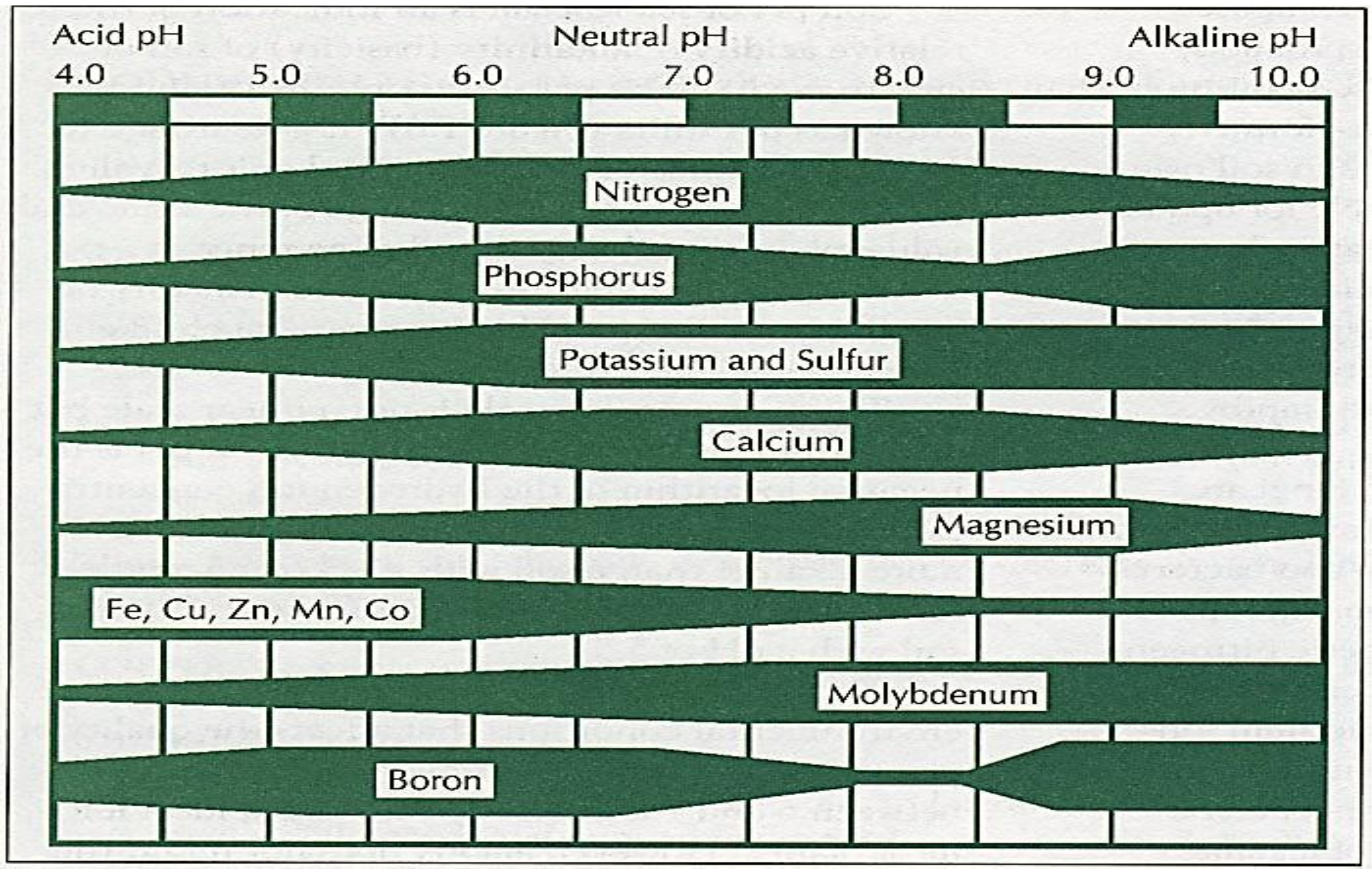
Small Fruit Crops Fertility Programs

- Liming & Fertilization
  - What to use
    - (soil testing & tissue analysis)
  - When to use it
  - How to apply it
- Tissue analysis for grapes
- Is it SNAKE OIL or the REAL DEAL?

Dave Lockwood – UT/UGA 1/7/16

A Little Lime May Be Needed

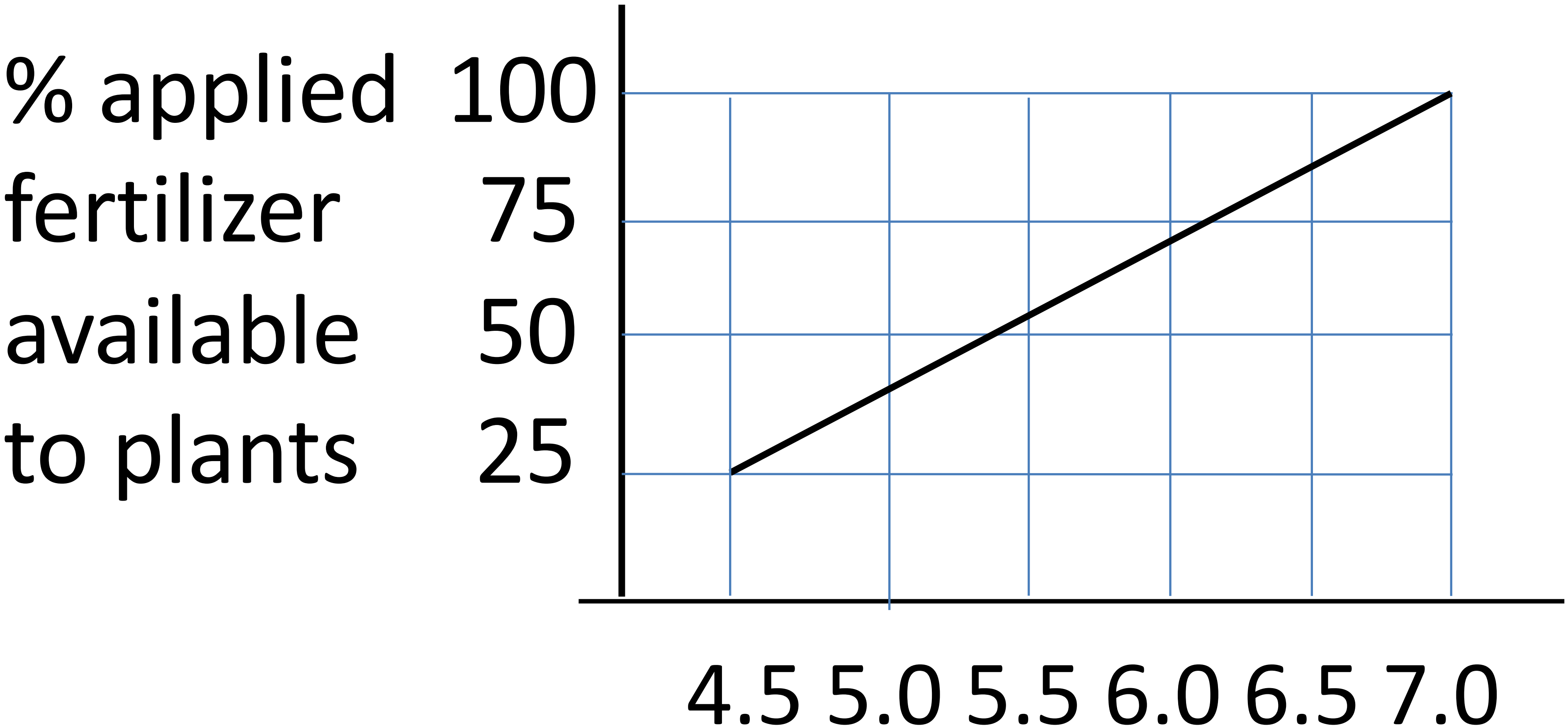
Effects of Soil pH on Nutrient Availability



pH < 6.0 starts to limit macronutrient availability

pH > 7.0 starts to limit micronutrient availability (except for Mo)

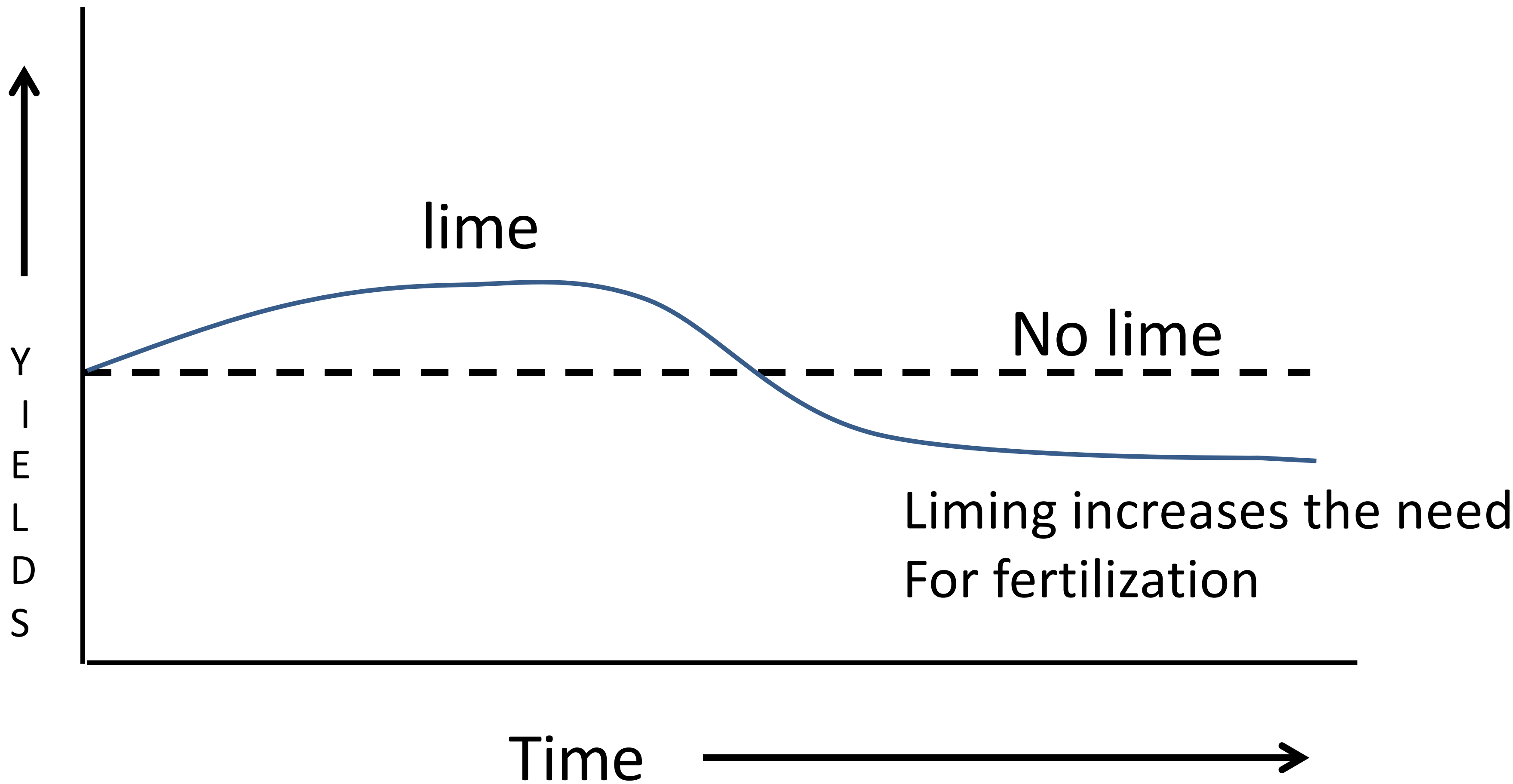
Soil pH Effect on Nutrient Uptake



Common Liming Materials

- Agricultural lime – quality determined by the content of base-forming elements calcium and magnesium and by particle size
  - Calcitic lime (calcite) – calcium carbonate ($CaCO_3$)
  - Dolomitic lime (dolomite) – $CaMg(CO_3)_2$
- Pelletized lime – reaction rate in soil = to ag lime, both in rate of time & neutralizing effect
- Hydrated lime (quicklime) – calcium oxide - $Ca(OH_2)$ – neutralizing value of 136% of that of calcitic lime

Liming without fertilization makes the farmer rich and the son poor.



Acidifying Effect of Some Common Fertilizers & Soil Amendments

Material	Lbs. of pure $CaCO_3$ needed to neutralize the acidity in 100# of material *
Ammonium nitrate	60
Ammonium sulfate	110
32% liquid N	55
Urea	81
Sulfur-coated urea	118
Diammonium phosphate	70
Elemental sulfur	312
Aluminum sulfate	45

*neutralizing value of calcitic limestone is ~ 50 to 55%

“ “ “ dolomitic limestone is ~ 56%

Benefits of Liming

- Improve soil pH:
  - Provides better soil environment for plant growth
  - Prevents toxicity due to excess Al & Mn
  - Increases availability of P & Mo
  - Microbiological processes such as nitrification and nitrogen fixation also improve
    - Therefore, may also indirectly improve the physical condition of the soil

How Long Does It Take for Lime to Work?

- Often takes 1 year or more before a response can be measured under perfect conditions
- May take 2 – 3 years to get the full effect of liming
  - Reactivity time depends on type of lime used & fineness of grind
    - Calcitic lime probably reacts a little faster than dolomitic because it has a higher calcium carbonate equivalent
    - Water is required for reactions to occur

Liming

Movement in the soil:

- Lime moves down in the soil at the rate of about 1 inch per year to a maximum depth of 2 – 4 inches
- Often limited to the zone of incorporation

How long does the effect of liming last?

- By the 3rd year following application, reacidification will often equal or exceed the effect of liming

Liming: surface broadcast vs. incorporation

- Whenever possible, incorporate
- Surface applied lime reacts slower than incorporated lime
  - Moves into the soil at a slow rate
    - similar to non-mobile nutrients

Pre-Plant Site Preparation

- Goal is to prepare a soil environment that favors plant survival and growth
  - the **only** opportunity to modify the pH or increase the phosphorus (and to a lesser extent, potassium) content of the subsoil for the life of the planting

Taking Soil Samples

- Sample at 2 depths
  - Upper 8 inches
  - 8 to 16 inches
- pH*
- P
- K
- Ca
- Mg
- Organic Matter

Preplant Application
- Lime & Phosphorus

Sum of the topsoil and the subsoil requirement

=

Amount to use in upper 16 inches of soil

(thoroughly disk into surface soil & plow to get it as deep as possible)

Where large amounts of lime are needed, apply ½ to ⅔ of total amount as outlined above & thoroughly work remainder into topsoil after plowing

Stiles & Reed, 1991

Preplant Applications
-Potassium

(desired level topsoil – actual topsoil level)

+

(desired level subsoil – actual level subsoil)

=

lb./acre K2O per 16-inch depth


MENCI
MENCI
MENCI

Postplant options for pH adjustment in subsoil

- ***<u>Once the plants are in the ground, no economically feasible technique exists to adjust subsoil pH</u>***

  - Gypsum ($CaSO_4$-$2H_2O$) – may merit consideration
    - Not a liming agent
    - Moves down faster & further than lime
    - Will aid in leaching Al^{+++} out of root zone

Once the plants are in the ground:

- Utilize:
  - Soil testing for pH determination
    - The correlation between soil test results and what is actually in the plant tends to be poor
  - Tissue analysis
  - Visual observations of leaf color, shoot growth, fruiting
  - Records from the previous year
    - Crop yields & quality
    - Events (i.e. weather) that may have impacted growth & fruiting

Acidifying Soils

- Start a minimum of 6 months to 1 year prior to planting
- Elemental sulfur – least expensive & most effective
  - Must be oxidized by soil microorganisms
    - No activity with cold soil temperatures
- Iron sulfate (ferrous sulfate, ferric sulfate)
  - lowers soil pH by a chemical reaction, not as temp dependent as elemental S
  - Requires about 6 to 8 times more material to give an equivalent reaction as elemental S
- Aluminum sulfate – Al toxicity with soil pH <5.0
  - Same as iron sulfate in reaction & rate
- Ammonium sulfate – the most acidifying N fertilizer
  - Works best in helping to maintain soil pH

Uses of Tissue Analysis

- To confirm or deny a suspected nutrient problem
  - Sample "normal" vs "affected" vines
    - Same cultivar
    - Close proximity
    - Can be done at any time during growing season
- To monitor nutrient status of vineyard & detect trends (deficiencies, toxicities, imbalances) before they become yield/quality limiting
  - Conduct over a period of years
  - Soil test to monitor pH

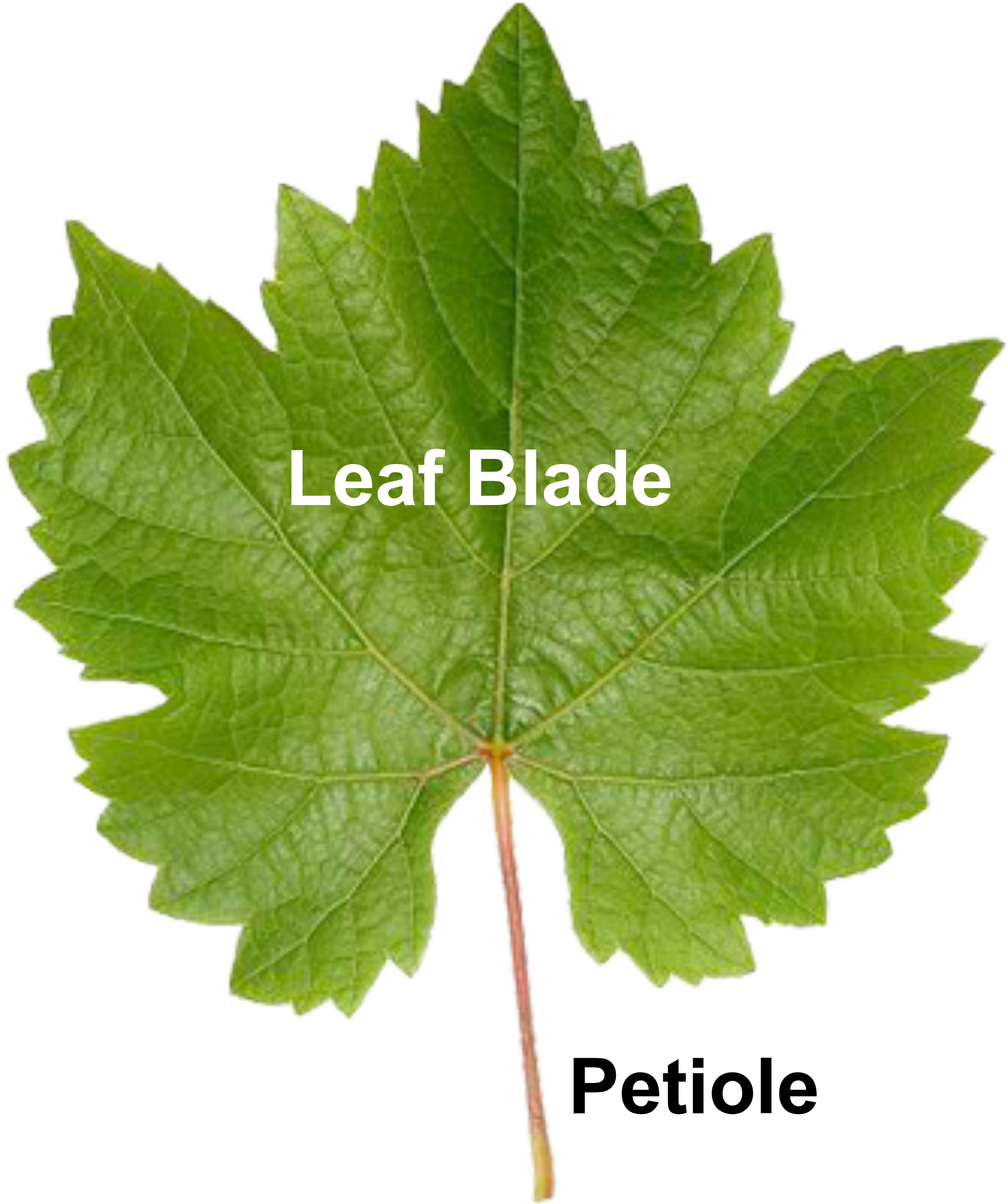
Collecting a "valid" sample

1. Right time & tissue for the crop being sampled
2. One variety/rootstock combination per sample
3. Sample vines of about the same age
4. Sample only "healthy" vines
5. Avoid areas showing growth differences
6. Select leaves from the same relative positions on plants – avoid outside rows & plants on the end of rows
7. Sample many plants – sampling a large number of plants increases the validity of the results but restrict sample size to not over 5 – 10 acres, depending on conditions
8. Sample before applying a spray to reduce contamination
9. If a recent soil test (3 yrs.) has not been taken, do so.

Care of Samples

- If petioles or leaf blades are being analyzed, separate tissues to be saved immediately
- Store in a clean paper bag 7 allow to air dry in a clean, dust-free environment
- Be sure samples are clearly identified for the lab & keep a copy of the key for your records
- Make a map of where samples were collected so you can treat areas based on their needs
- Keep results of testing. Include notes on leaf color, shoot growth, yields and weather

What tissue to sample?



Petioles vs. Leaf Blades

- Petioles
  - Easier to handle & collect in large quantities
  - Good indicator of K, Cl & Na def/tox
  - Provides a good average for blocks being sampled
  - Foliage is usually in better condition than later in the season

- Leaf Blade
  - Better indicator of N than petioles
  - May be better for Mg, Zn, B, Ca, Cu & Mn def/tox

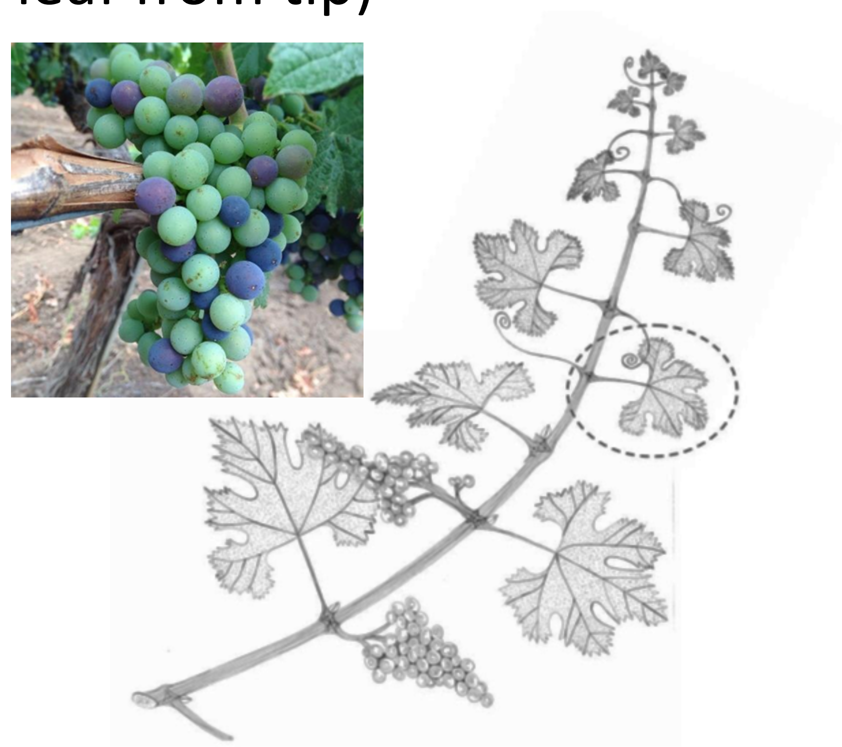
When to collect petiole samples

At full bloom

Select the leaf opposite the basal cluster on a shoot

At veraison

Select the most recently matured leaf on a shoot (5th to 7th leaf from tip)



Grape Petiole Analysis Sufficiency Ranges

Element	Full Bloom	Veraison
N	1.6 – 2.8%	0.9 – 1.3%
P	0.20 – 0.60	0.16 – 0.29
K	1.50 – 5.00	1.50 – 2.50
Ca	0.40 – 2.50	1.20 – 1.80
Mg	0.13 – 0.40	0.26 – 0.45
Mn	18 – 100 ppm	31 – 150 ppm
Fe	40 – 180 ppm	31 – 50 ppm
B	25 – 50 ppm	25 – 50 ppm
Cu	5 – 10 ppm	5 – 15 ppm
Zn	20 – 100 ppm	30 – 50 ppm
Mo	0.13 – 0.40 ppm	0.3 – 1.5 ppm

Location & Quality of Samples Affect Results

- Petiole Analysis Results - Merlot

Tissue	Tmt.	N %	P %	K %	Ca %	Mg %	S %	B ppm	Cu ppm	Fe ppm
Petiole	Not topped	1.25	0.34	3.25	1.50	0.62	0.12	39.0	25.5	67.0
	Topped	0.98	0.37	4.25	1.45	0.53	0.15	32.0	23.0	46.5
Blade	Not topped	3.47	0.26	1.23	1.24	0.32	0.09	29.0	13.0	72.5
	Topped	3.14	0.22	1.39	1.26	0.26	0.11	27.0	11.5	84.0
Petiole	No powdery	1.13	0.11	1.85	0.78	0.23	0.09	16.3	14.5	23.5
	Powdery mildew	1.26	0.25	4.80	1.44	0.24	0.18	31.0	21.0	62.0

16 Essential Mineral Nutrients

Macronutrients
(major elements)

Nitrogen (N)
Phosphorus (P)
Potassium (K)
Magnesium (Mg)
Calcium (Ca)
Sulfur (S)

Micronutrients
(minor elements)

Iron (Fe)
Manganese (Mn)
Copper (Cu)
Zinc (Zn)
Boron (B)
Molybdenum (Mo)
Chlorine(Cl)

Carbon, hydrogen and oxygen are gotten from the atmosphere

Muscadine Tissue Sampling – NC State

- **Frequency:** annually to monitor plant status
  - 1 time in mid-May or prebloom (boron)
  - 2nd or 3rd week in June (determine need for a late-June N application)
- **Size of sample:** 12 – 15 leaves of 1 variety that are representative of the entire vineyard
- **Location of leaf on vine:** opposite flower/berry clusters
  - Avoid shoots with no flowers or newly set berries
  - Choose the 3rd to 5th leaf back from the growing point
- **Handling sample:** immediately twist of the petiole (discard) & place in a clean paper bag or envelope

Nutrient Ranges for Muscadine

Element	Deficient	Sufficient	Excessive
Nitrogen %	1.65	1.65 – 2.15	>2.15
Phosphorus %	0.12	0.12 – 0.18	>0.18
Potassium %	0.80	0.80 – 1.20	>1.20
Calcium %	0.70	0.70 – 1.10	>1.10
Magnesium %	0.15	0.15 – 0.25	>0.25
Boron ppm	<15	15 – 25	>25
Copper ppm	<5	5 – 10	>10
Iron ppm	<60	60 – 120	>120
Manganese ppm	<60	60 – 150	>150
Molybdenum ppm	<0.14	0.15 – 0.35	>0.35
Zinc ppm	<18	18 – 35	>35

University of Florida

Methods of Nutrient Application

- **Preplant**, deep incorporation; Lime, P & K
- **Soil applied:** Macronutrients – needed in large amounts
  - **Broadcast** in weed-free strip down the tree row – N & K (in some soils)
  - **Banding** (4 – 6” band 2 to 3’ each side of trunk for postplant P, and possibly K
  - **Fertigation** (microsprinklers or drip) down tree row – quick response, similar results to broadcast, but with a 40% + reduction in rates
- **Foliar –** micronutrients & late season N applications

Spring Nitrogen Application

- All nitrogen used for new growth in peach during the first 25 to 30 days of the growing season came from storage (primarily in the buds and the aboveground woody tissues). Remobilization of nitrogen continues until about 75 days after bud break.
  - Rufat and DeJong. 2001. Estimating seasonal nitrogen dynamics in peach trees in response to nitrogen availability. Tree Physiology 21:1133-40.

Fertilization Methods

- Foliar feed micronutrients
- Soil apply macronutrients
  - Fertigation gives immediate availability
    - Apply only small amounts of N at a time
    - Fertigate during daytime on sunny days so materials will be taken up with the transpiration stream at the time of application
  - Granular application provides little control over availability
    - Reliance on precipitation to dissolve & distribute nutrients

Nitrogen –

- When to apply:
  - Optimum time is from bloom to 6 weeks after bloom
    - (much of vine's early season N needs supplied by N stored in the vine from the previous season's growth)
    - Split application – half shortly after bloom, half at fruit set
- Where to apply:
  - weed-free strip under the trellis
- How to apply:
  - Around base of vine, band under trellis
  - Fertigation: same response with about 50 - 70% of N
  - Foliar: for short-term correction

After Harvest

- Trees begin to lose their ability to take up moisture and nutrients from the soil
- When trees are dormant, relatively little soil uptake of moisture and nutrients occurs
  - Nutrients taken up by roots late in growing season tend to be stored in the roots and are not available for the first flush of growth in spring

Resorption

- Movement of nutrients from leaves back into the tree in fall for storage in buds and woody tissues
- In a ***healthy*** tree the rate of resorption is generally sufficient to satisfy the needs of the tree for the initial flush of growth in spring

Resorption

- Growth & fruit production are positively correlated to levels of winter N reserve in apple, grape, pear, peach and nectarine
- Resorption cannot proceed without photosynthetically functional leaves to provide the needed energy

Phosphorus

- Phosphorus should be applied & incorporated prior to planting
- Surface applications of P in established plantings:
  - Nearly impossible to reach roots through broadcast application
    - Does not leach readily
    - Contribute to water pollution through runoff
- If leaf analysis indicates a need for P, apply in a 4" band 2 – 3 ft. each side of tree trunk

When to Use Which Form of Nitrogen?

- If applying early
  - Use ammonium form
    - ammonium sulfate
    - Urea
    - diammonium phosphate
    - ammonium nitrate
- If soil pH is low
  - Use nitrate form
    - calcium nitrate
    - potassium nitrate

Potasssium

- If muriate of potash is applied, put it down in the fall
- Recent research suggests:
  - Do not use a foliar application of potassium nitrate during the 2nd half of the growing season
    - nitrate nitrogen has a large adverse effect on K uptake

Micronutrient Mixtures – is it a good idea?

- Apply a micronutrient only when you know there is a need
  - Tissue analysis
  - The gap between "too little" and "too much" is very narrow
  - Only apply the needed nutrient; avoid "shotgun" mixtures
  - Do not apply with pesticides unless the label states it can be done
  - Frequently, the visible response (darker green foliage) can be attributed to nitrogen in the product


Coal Grove, Ohio
wt ~ 1,500 tons
size of a 2-story house

Strawberry Nutritional Needs
SRSFC Agent In-Service

R. Allen Straw
Area Specialist
SW VA AREC
Virginia Cooperative Extension

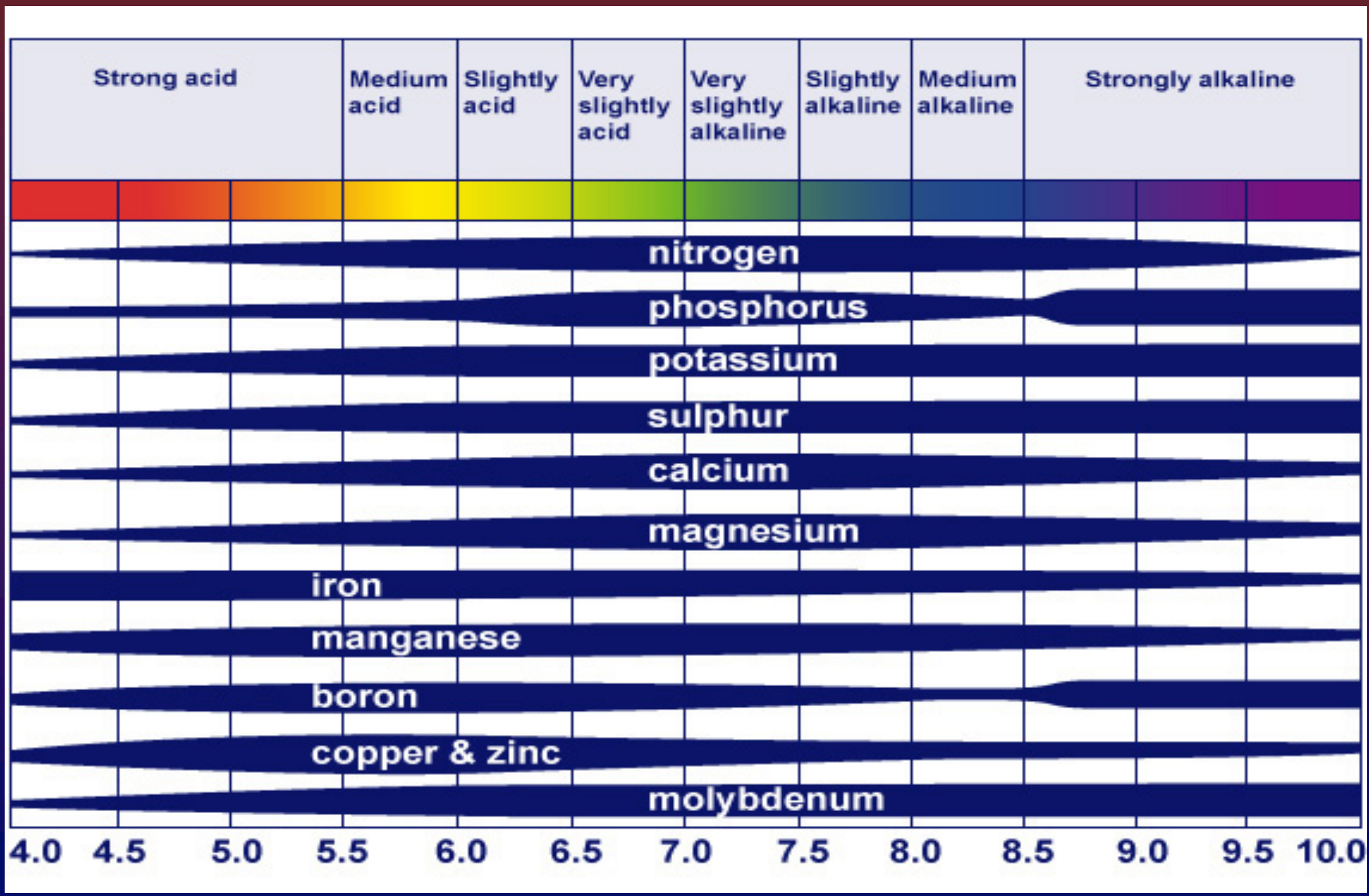
Soil Sampling

- Sample as soon as possible
  - 6 months prior to transplanting
    - Allows time for lime to react
    - Calcium Carbonate equivalent
    - Particle size
  - Slow reaction
  - Over-application
  - pH over 8.2
- Take representative samples from the field
  - 10 to 12
- Sample 6” to 8” deep
  - Sample as deep as beds are to be raised.

pH

- 6.0 to 6.5
  - 6.2
- This gives us optimum nutrient availability
  - pH above 6.2 makes micro-nutrients unavailable
  - pH below 6.2 makes macronutrients and some micronutrients unavailable
- Mineral-Organic Soils
  - 5.5
- Organic Soils
  - 5.0

pH and Nutrient Availability



Nutrients for Plant Growth

- Macro-Nutrients
  - N Nitrogen
  - P Phosphorus
  - K Potassium
  - Ca Calcium
  - Mg Magnesium
  - S Sulfur

- Micro-Nutrients
  - Fe Iron
  - Cu Copper
  - B Boron
  - Mn Manganese
  - Zn Zinc
  - Mo Molybdenum

Nitrogen (N)

- Function:
  - Primary building block for amino acids, protein, and protoplasm
  - Critical for flower differentiation, vegetative growth, bud vigor, fruit set
  - Acts as a catalyst for other elements
- Deficiency Symptoms
  - Yellowish foliage
  - Poor / stunted growth
  - Small fruit
  - Low yields
- Accented by:
  - pH extremes
  - Low O.M.
  - sandy soils
  - Leaching of nutrients

Phosphorus (P)

- Function:
  - Important in energy transfer and storage
  - Formation of nucleic acids
  - Promotes root, flower, and seed production
  - Hastens maturity
- Deficiency Symptoms
  - Severe stunting
  - Purpling of tissue
  - Delayed maturity
  - Poor seed development
- Accented by:
  - pH extremes
  - Low O.M.
  - Cold, wet conditions
  - Poor root development
  - High [Fe], low available [P]

Potassium (K)

- Function:
  - Necessary for the development of sugars and starches
  - Essential for oil production
  - Enzyme activator
  - Improves cold weather tolerance
- Deficiency Symptoms
  - Leaf distortion and curling
  - Marginal leaf necrosis
  - Poor fruit color / development
  - Flower abortion
- Accented by:
  - Acid soils
  - Sandy soils
  - Leaching of nutrients
  - Clayey soils with low [K]
  - High [Ca], [Mg]

Calcium (Ca)

- Function:
  - Aids in cell wall structure
  - Membrane integrity
  - Necessary for early root growth
  - Regulates nutrient uptake and movement through the plant

- Deficiency Symptoms
  - Poor root development
  - Blossom end rot (BER)
  - Premature shedding of blossoms and buds
  - Dead or deformed terminal leaves and buds
- Accented by:
  - Acid soils
  - Sandy soils
  - Sodic soils
  - High [Al]
  - Drought

Magnesium (Mg)

- Function:
  - Enzyme activator
  - Chlorophyll synthesis
  - Aids in seed germination
  - Aids in use of phosphorus
- Basic building block of the chlorophyll molecule

- Deficiency Symptoms
  - Interveinal leaf chlorosis, necrosis, esp. older leaves
  - Drooping leaves
  - Excessive premature fruit drop
- Accented by:
  - Acid soils
  - Very sandy soils
  - High [K] or [Ca]
  - High rates of K fertilization
  - Cold, wet conditions

Sulfur (S)

- Function:
  - Component of amino acids and proteins
  - Aids in nodule formation in legumes
  - Stabilizes nitrogen
- N:S ratio
  - 15:1
- Deficiency Symptoms
  - Yellowish foliage, esp. new foliage
  - Poor / stunted growth
  - Delayed maturity
- Accented by:
  - Acid soils
  - Sandy soils
  - Low O.M.
  - Poor soil aeration

Iron (Fe)

- Function:
  - Chlorophyll formation
  - Activator for respiration enzymes
- Deficiency Symptoms
  - Interveinal chlorosis, young leaves first
  - Stunted growth
- Accented by:
  - Alkaline soils
  - Water logged soil
  - Calcareous soils
  - High [Cu], [Mn], [Zn]

Copper (Cu)

- Function:
  - Critical for photosynthesis
  - Necessary for seed development
  - Component for several enzymes
- Deficiency Symptoms
  - Marginal chlorosis
  - Shoot die-back
  - Stunted growth
  - Necrotic areas on terminal leaves
- Accented by:
  - Organic soils
  - Very sandy soils
  - High N applications

Boron (B)

- Function:
  - Pollen tube formation
  - Necessary for cell division
  - Aids in calcium translocation
  - Important for early growth
- Deficiency Symptoms
  - Death of terminal growth
  - Thick brittle leaves
  - Poor fruit set
  - Malformed fruit
- Accented by:
  - Alkaline soils
  - Sandy soils
  - Low O.M.
  - High [N]
  - High [Ca]

Manganese (Mn)

- Function:
  - Essential for phosphorus and magnesium uptake
  - Aids in nitrogen utilization and assimilation
  - Aids in chlorophyll synthesis
- Deficiency Symptoms
  - Mottled chlorosis, first on older leaves and moving to new growth
  - Crop stunting
- Accented by:
  - Very alkaline soils
  - Organic soils
  - Heavily leached, acid, sandy soils
  - Prolonged cold, wet periods

Zinc (Zn)

- Function:
  - Synthesis of Auxins and protein
  - Required for uniform maturity
  - Important in calcium translocation

- Deficiency Symptoms
  - Stunted growth, small malformed leaves
  - Interveinal chlorosis, striping in grass sp.
  - Twig die-back
- Accented by:
  - Alkaline soils
  - Organic soils
  - High [P]
  - High rates of P fertilization
  - Cold, wet soils

Molybdenum (Mo)

- Function:
  - Nitrogen fixation
  - Nitrogen metabolism
  - Phosphorus metabolism
  - Iron metabolism
- Deficiency Symptoms
  - Reduced nodulation on legumes
  - Poor growth
  - Pale green leaves
- Accented by:
  - Acid soils

Strawberry Production Systems

- Annual Plasticulture
  - Predominate System
  - Carry-over of Annual Plasticulture System
- Matted Row
  - Still some production
    - Arkansas
    - Tennessee
    - Virginia
    - Northern States
- Ribbon Row
  - Bare Ground
  - Raised Beds
  - High Planting Populations

Matted Row Fertility

- Pre-Plant (establishment)
- P_2O_5 and K_2O
  - Low 150 – 200 lb/A
  - Medium 75 lb/A
  - High 0 lb/A
- N
  - 25 – 40 lb/A in a 15 inch band over the row, 2 to 3 weeks after planting.
- N (continued)
  - On sandy soils 40 – 60 lb/A in a 15 in band over the row, in August.
  - Spring applications of N are generally not recommended.
  - However, on extremely sandy soils, 15 to 20 lb/A of N can be applied in February.

Matted Row Fertility (cont.)

- 2^{nd} to 5^{th} Years
- P_2O_5 and K_2O
  - Low 150 – 200 lb/A
  - Medium 75 lb/A
  - High 0 lb/A
  - Applied at renovation
- N
  - 40 – 70 lb/A in a 15 inch band over the row, at renovation
- N (continued)
  - On sandy soils, 40 – 80 lb/A in a 15 in band over the row, in August
  - Spring applications of N are generally not recommended.
  - However, on extremely sandy soils, 15 to 20 lb/A of N can be applied in February.

Annual Plasticulture Production

- Fall Fertilization
- P_2O_5 and K_2O
  - Low 150 – 200 lb/A
  - Medium 75 lb/A
  - High 0 lb/A
- N
  - 50 – 60 lb/A

- Spring Applications
- N
  - ½ - ¾ lb of N/A/day though the drip
  - Usually a total of 60 lb of N/A is applied through the drip
  - A total of 120 lb of N/A combined

Fall Fertilization

- Apply fertilizer in the fall according to soil test recommendation.
- The problem is in many states: **Where is such a recommendation?**
- Many strawberry growers utilize NC recommendations.
- Rule of thumb:
  - Apply 1/3 to 1/2 of total N in the fall (50 – 60 lb/A)
  - Apply all of the phosphate in the fall (75 – 150 lb/A)
  - Apply 1/2 of potash in the fall (75 – 150 lb/A)
- Boron response on sandy soils? (1 to 2.5 lb/A Boron)

High Phosphate Starter

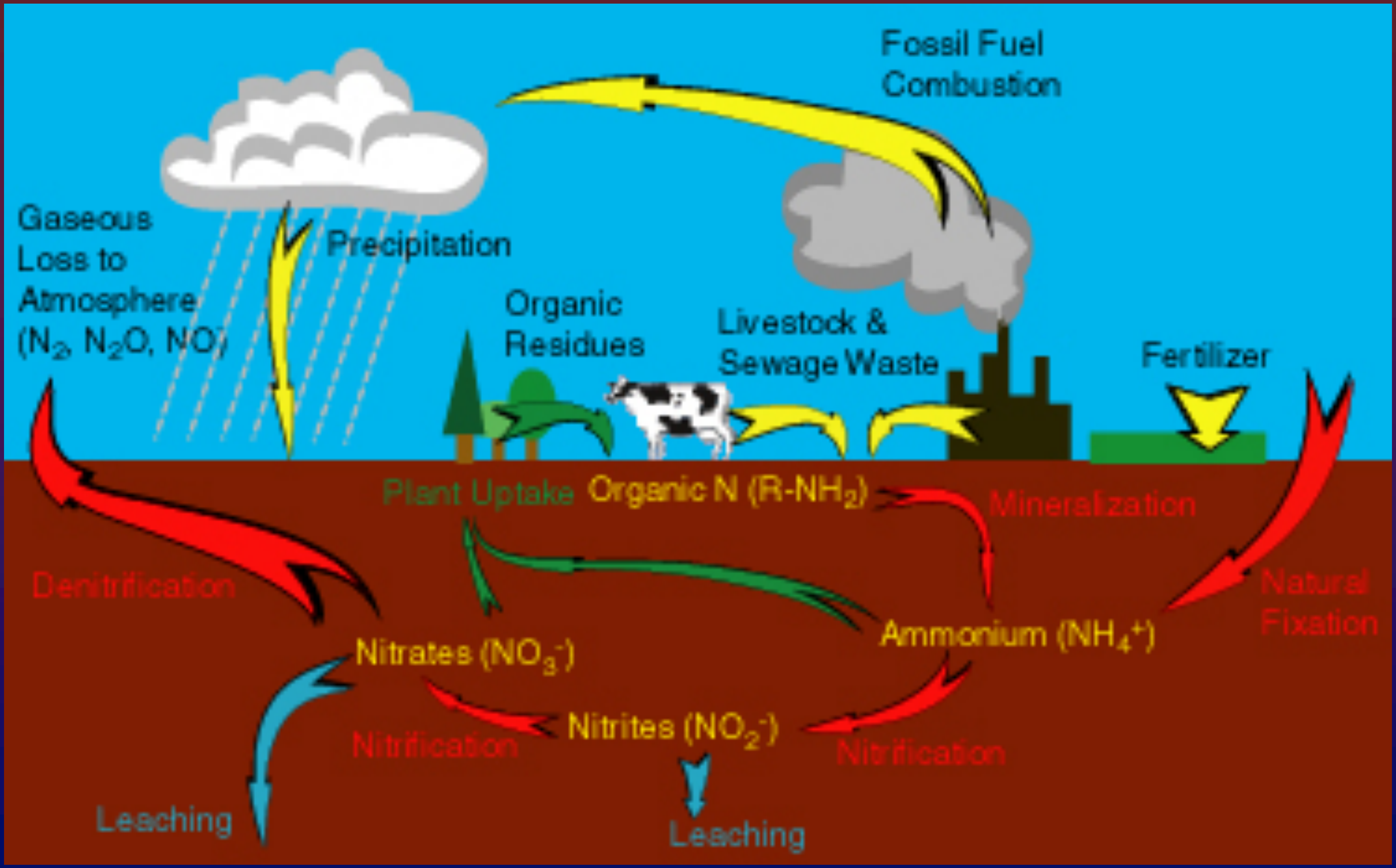
- Many annual plasticulture strawberry growers will utilize a high phosphate starter fertilizer in their transplant water.
- Most formulations recommend 6 lb or product/A.
- Common Formulations
  - 10-52-8
  - 12-48-8
  - 9-45-15
- Works well with plug plants.
- Helps with root development
- Drip (?)

Preplant Nitrogen Sources

- Urea
- Ammonium Nitrate
- Ammonium Sulfate
- Calcium Nitrate
- Ammonia toxicity when using urea (?)

- Fumigation with MeBr or chloropicrin does kill nitrifying bacteria
- Fumigation with MeBr or chloropicrin does not influence the urease enzyme that converts urea to ammonia

N Cycle



Fossil Fuel
Combustion
Gaseous
Loss to
Atmosphere
(N_2, N_2O, NO)
Precipitation
Organic
Residues
Livestock &
Sewage Waste
Fertilizer
Plant Uptake
Organic N ($R\text{-}NH_2$)
Mineralization
Denitrification
Natural
Fixation
Ammonium (NH_4^+)
Nitrates (NO_3^-)
Nitrites (NO_2^-)
Nitrification
Nitrification
Leaching
Leaching

Tissue Sampling

- Take tissue samples in the late winter or early spring when plants begin to actively grow
  - Take a representative amount of samples from each field (20 to 25 samples)
  - The most recent fully expanded trifoliate is the best indicator of nutritional status
  - Remove petioles near the crown of the plant, partial petioles do not yield reliable results

Tissue Sampling (cont.)

- Remove the leaves from the petioles
  - The leaves are used to determine concentrations of essential nutrients
    - Unless there are deficiencies, this could be the only sample of leaves you will need to take
    - Some growers continue on a bi-weekly schedule
  - Petioles are used to measure Nitrate Nitrogen
    - Measures nitrate concentration
    - Should be sampled on a weekly or bi-weekly basis

Tissue Analysis Labs

- Public
  - North Carolina Department of Agriculture, 1040 Mail Service Center, Raleigh, NC 27699-1040 or 4300 Reedy Creek Rd, Raleigh, NC 27607
  - Other State Universities
- Private
  - Micro-Macro International, Inc., 183 Paradise Blvd., Suite 108, Athens, GA 30607

    Phone: 706-548-4557

    Fax: 706-548-4891
  - A & L Analytical Labs
    - Richmond, VA
    - Memphis, TN

Sufficiency Ranges

❖ N	3.0 – 4.0 %	❖ Fe	50 – 300 ppm
❖ P	0.2 – 0.4 %	❖ Mn	30 – 300 ppm
❖ K	1.1 – 2.5 %	❖ Zn	15 – 60 ppm
❖ Ca	0.5 – 1.5 %	❖ Cu	3 – 15 ppm
❖ Mg	0.25 – 0.45 %	❖ B	25 – 50 ppm
❖ S	0.15 – 0.40 %		

Petiole Nitrate Nitrogen Levels

Week	Low	High
1	600	1,500
2 - 3	4,000	6,000
4	3,500	6,000
5 – 8	3,000	5,000
9	2,000	4,500
10	2,000	4,000
11	1,500	3,000
12	1,000	2,000

Petiole Levels – Cardy Meter

- Nitrate Nitrogen (NO_3-N)
  - October 800 – 900
  - November 600 – 800
  - March 600 – 800
  - April 10 300 – 500
  - May 10 200 – 500
  - June 1 200 – 500
- Potash (K_2O)
  - October 3000-5000
  - November 3000-3500
  - March 2500-3500
  - April 10 2000-2500
  - May 10 1800-2500
  - June 1 1500-2000

Irrigation and Fertigation

- Irrigation
  - Spring
    - Once growth begins in late winter or early spring
- Fertigation
  - Once growth begins in late winter or early spring or at least by early bloom
    - Apply 5 lb of N/A/week
    - ¾ lb of N/A/day
    - For 8 to 10 weeks

Common Questions

- How often do I fertilize?
  - Every week?
  - Every other week?
- How much fertilizer do I apply?
  - How often are you going to fertilize?

Answer

- Fertilize every two weeks
  - Too much N at one time
  - Soft berries
  - Poor Flavor
- Fertilize every week
  - Rotation
    - 50 lb of calcium nitrate / A
    - 50 lb of potassium nitrate / A
    - 50 lb of 20-20-20 /A
  - Lower rate once harvest begins (?) (25 lb/A)

Spring Irrigation / Fertigation

- Irrigation
  - 1” to 1.5” / A / week
    - Monday
      - 1/3” to ½”
    - Wednesday
      - 1/3” to ½”
    - Friday
      - 1/3” to ½”
- Fertigation
  - Monday
    - 12.5 – 15 (25) lb of calcium nitrate/A
  - Wednesday
    - 12.5 – 15 (25) lb of potassium nitrate/A
  - Friday
    - 12.5 – 15 (25) lb of 20-20-20/A

Spring Irrigation / Fertigation Carry-Over Plants

- Irrigation
  - 1” to 1.5” / A / week
    - Monday
      - 1/3” to 2/3”
    - Wednesday
      - 1/3” to 2/3”
    - Friday
      - 1/3” to 2/3”
- Fertigation
  - Monday
    - 25 (50) lb of calcium nitrate/A
  - Wednesday
    - 25 (50) lb of potassium nitrate/A
  - Friday
    - 25 (50) lb of 20-20-20/A

Micronutrients in Spring

- Boron
  - Drip applications
  - 1/8 to ¼ lb of actual B / A / application
    - 1/8 lb of actual B/A is common
    - Never apply more than ¼ lb of actual B/A in a single application.
- Mg / S
- Epson Salts
  - Foliar
    - 2 to 4 lb of Epson Salt /A every 1 to 2 weeks
  - Drip
    - 25 lb of Epson Salts / A every 2 weeks

Soil vs. Foliar Applications

- Soil Applied or Drip Applied
- Generally when we need large amounts of nutrients
- Macro Nutrients
  - N, P, K, Ca, Mg, S
- Micro Nutrients
  - B

- Foliar Applied
  - Generally when we need a fast response
  - Micro Nutrients
    - Fe, Cu, Zn, Mn, B, Mo
  - Macro Nutrients
    - N, only limited amounts
    - Ca (?)
    - Mg

Resources

- Your State Recommendations
- Southern Region Small Fruit Consortium
  - *www.**smallfruits**.org*
- NCDA
  - Strawberry Fertility Management
  - www.ncagr.gov/agronomi/documents/StrawberryFertility-Feb2015.pdf

N:S Ratio

- As we said earlier, Sulfur is important in the stabilization and metabolism of Nitrogen
- We want a N:S ratio of about 15:1
- If N:S ration gets to 18:1 then we need Sulfur
- NC Recommendations
  - If N:S ratio is > 18:1 then apply 7 lb of S/A
  - If N:S ratio is > 18:1 and S is Low then apply 14 lb of S/A
    - Epson Salts
    - Potassium Sulfate (0-0-50)

Potassium Sources

- Preplant
  - Many pre-blended fertilizers are formulated using 0-0-60 (muriate of potash)
  - It is better to use 0-0-50 (sulfate of potash)
    - Firmer fruit, overall better fruit quality
    - Twice the cost per acre
- Drip Applications (Spring)
  - Potassium Nitrate
  - Water Soluble 20-20-20
  - Potassium Sulfate (0-0-52), water soluble
  - Liquid Sources
    - Many formulations
    - Potassium acetate
    - 3-0-20 has shown higher K levels in plant tissue

Questions?

- R. Allen Straw

  SW VA AREC

  12326 VPI Farm Road

  Glade Spring, VA 24340

Mobile: (931) 261-0973

Fax: (276) 475-3588

Email: astraw@vt.edu