

Nitrogen-Deficient
Tomato Plant

Nitrogen-Sufficient
Tomato Plant

How to Recognize Visual Signs of Nutrient Issues in Vegetable Crops

Ellie Andrews, PhD

UC Cooperative Extension Specialty Crops Advisor
Sonoma, Marin, Napa Counties

My Background

- Always loved plants, local food & ag
- Bachelors in Plant Biology / Field Ecology
- Worked on organic vegetable farms
- Masters in Plant Health Management
- PhD in Horticulture & Agronomy at UC Davis
 - Area of expertise is organic nutrient management



What's wrong with my crops?



(Ellie Andrews, UCCE)



(Ellie Andrews, UCCE)

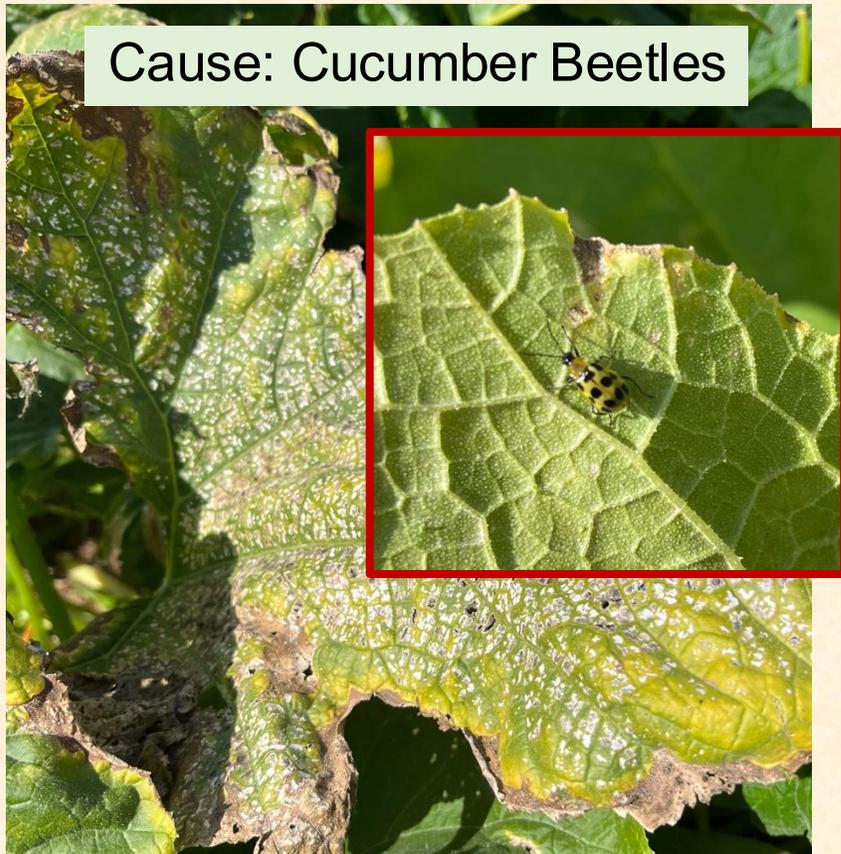


(Ellie Andrews, UCCE)



(Jon Umble, ATTRA publication)

What's wrong with my crops?



Cause: Cucumber Beetles

(Ellie Andrews, UCCE)



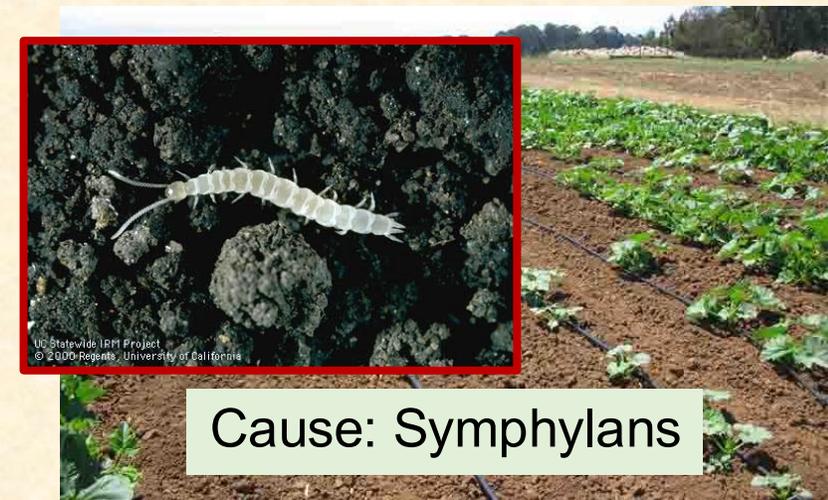
Causes: Whiteflies, Spider Mites, Aphids, Fusarium

(Ellie Andrews, UCCE)



Cause: Powdery Mildew

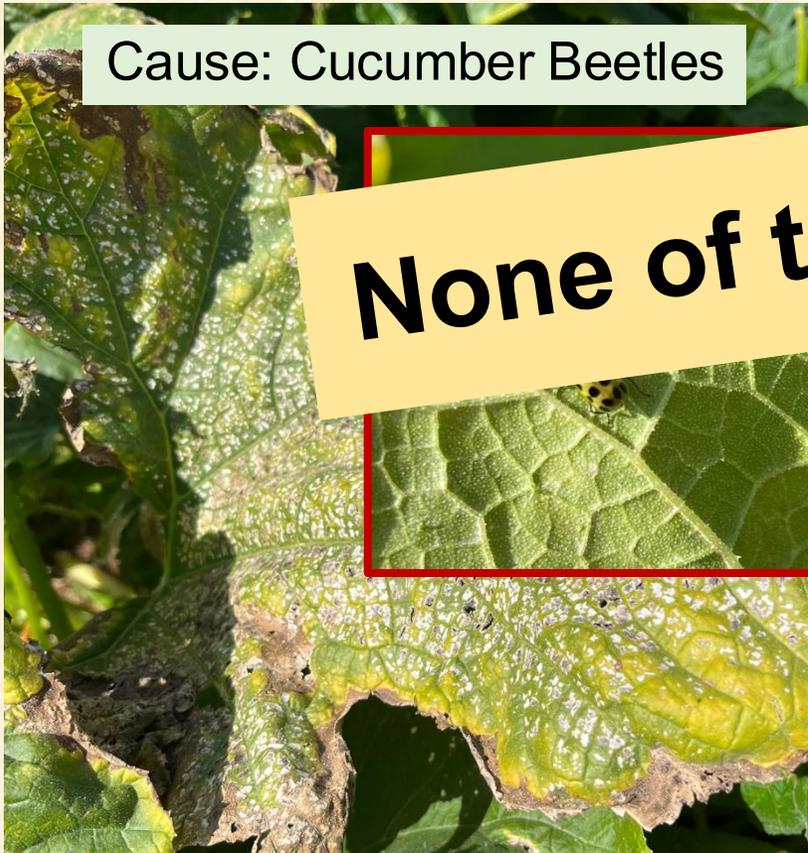
(Ellie Andrews, UCCE)



Cause: Symphylans

(Jon Umble, ATTRA publication)

What's wrong with my crops?



Cause: Cucumber Beetles

None of these are nutrient issues!



Causes: Whiteflies



Cause: Powdery Mildew

(Ellie Andrews, UCCE)



Cause: Symphylans

(Umble, ATTRA publication)

(Ellie Andrews, UCCE)

(Ellie Andrews, UCCE)

What's wrong with my crops?



(Haifa)



(Ellie Andrews, UCCE)

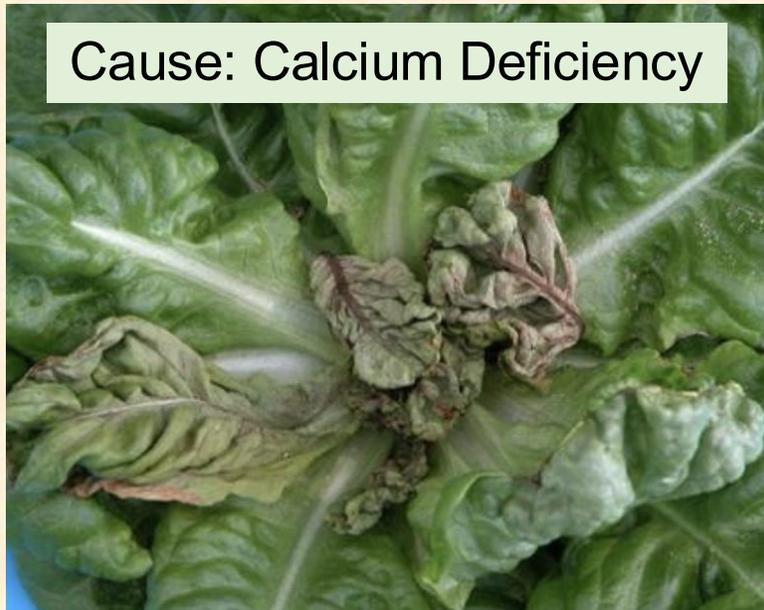


(Haifa)



(Haifa)

What's wrong with my crops?



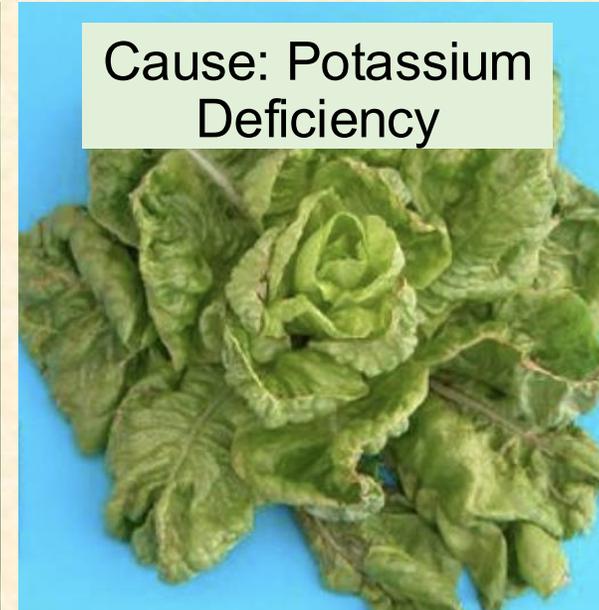
Cause: Calcium Deficiency

(Haifa)



Cause: Calcium Deficiency

(Ellie Andrews, UCCE)



Cause: Potassium Deficiency

(Haifa)



Cause: Potassium Deficiency

(Haifa)

These are all nutrient issues!

Nutrient Management

- Need to maintain enough nutrients for healthy plant functioning & good yield



(UC ANR)

Nutrient Management

- Need to maintain enough nutrients for healthy plant functioning & good yield
- Get nutrient status into a healthy range
- Replace the amount of nutrients that move out of the field at harvest



(UC ANR)

Nutrient Management

- Which nutrients to vegetable crops need?



(UCR)

Nutrient Management

- Which nutrients to vegetable crops need?



(UCR)

Macronutrients (need large amount)

Nitrogen
Phosphorus
Potassium
Sulfur
Calcium
Magnesium

Micronutrients (need small amount)

Iron
Manganese
Copper
Zinc
Molybdenum
Boron
Chloride
Nickel

Nutrient Management

- Which nutrients to vegetable crops need?



(UCR)

*translocated
(moved)
across plant*

*nutrient uptake
by roots*

Macronutrients
(need large amount)

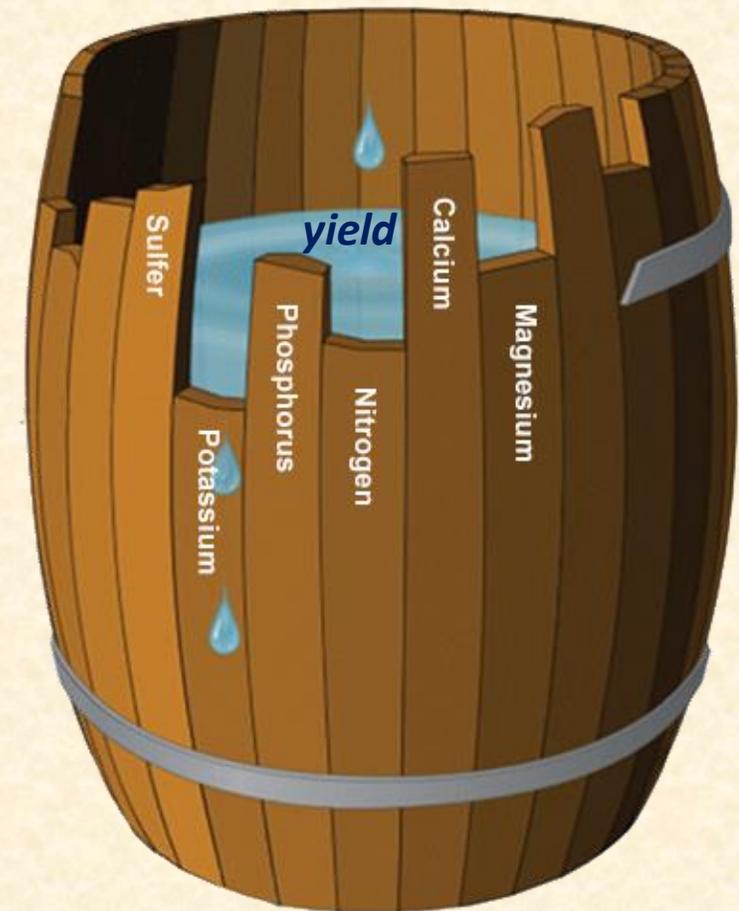
Nitrogen
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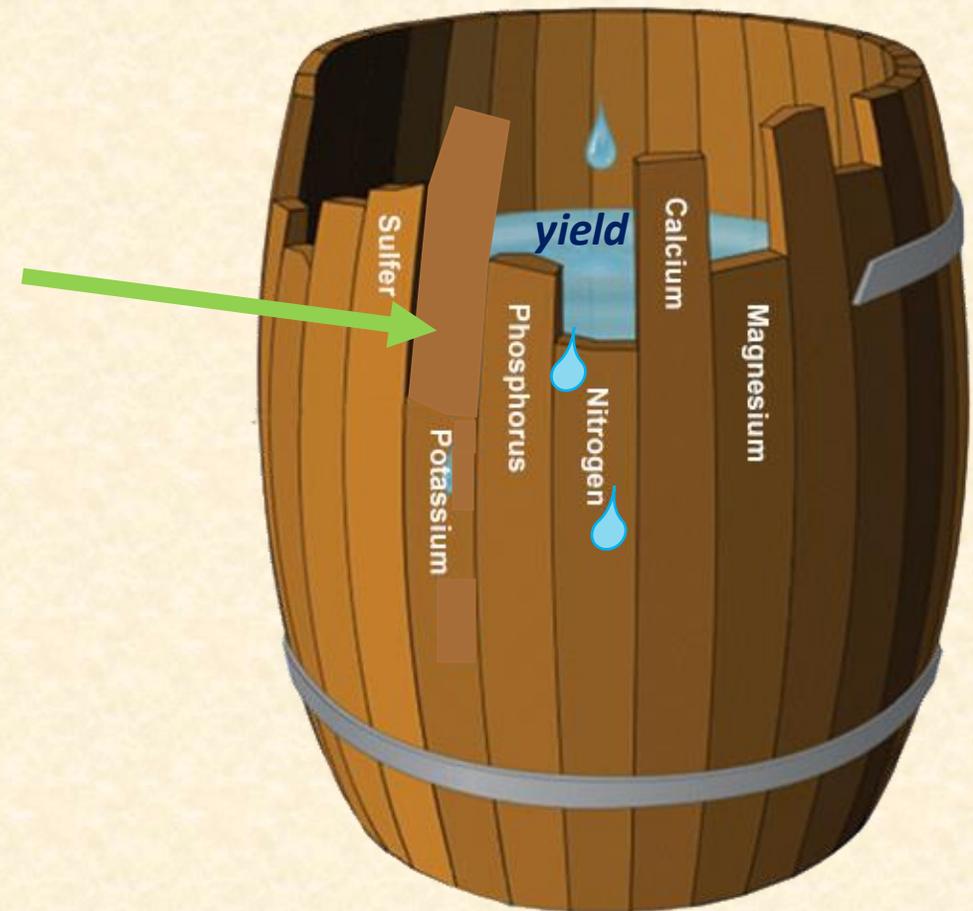
Nutrient Management

- Law of the Minimum
 - If one of the essential elements is low, plant health & yield will be low until that deficiency is lifted
 - Barrel metaphor: lowest stave represents the most limiting nutrient, water in the barrel represents yield potential

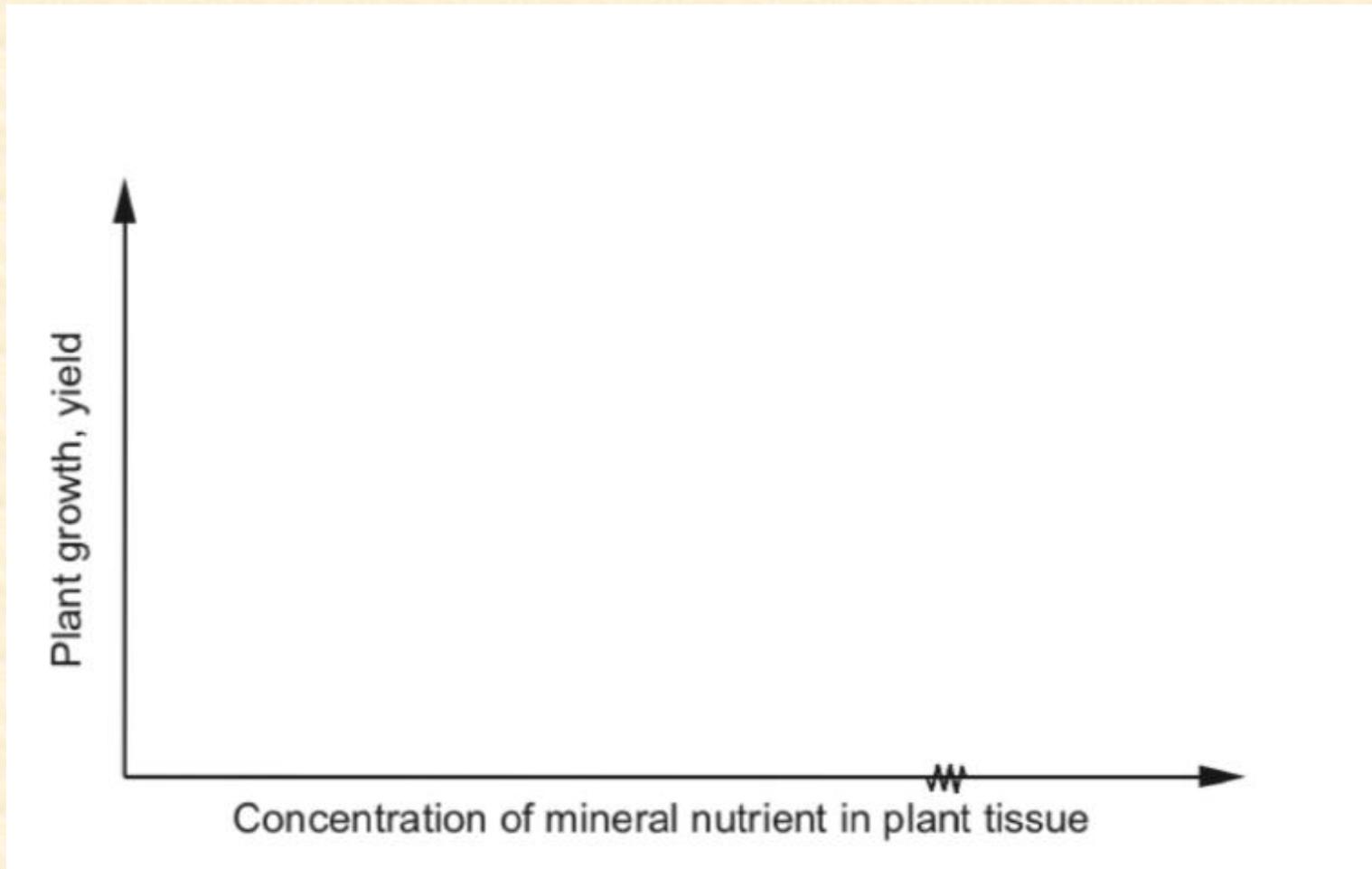


Nutrient Management

- Law of the Minimum
 - Supplying the most limiting nutrient increases the yield potential to the next most limiting factor

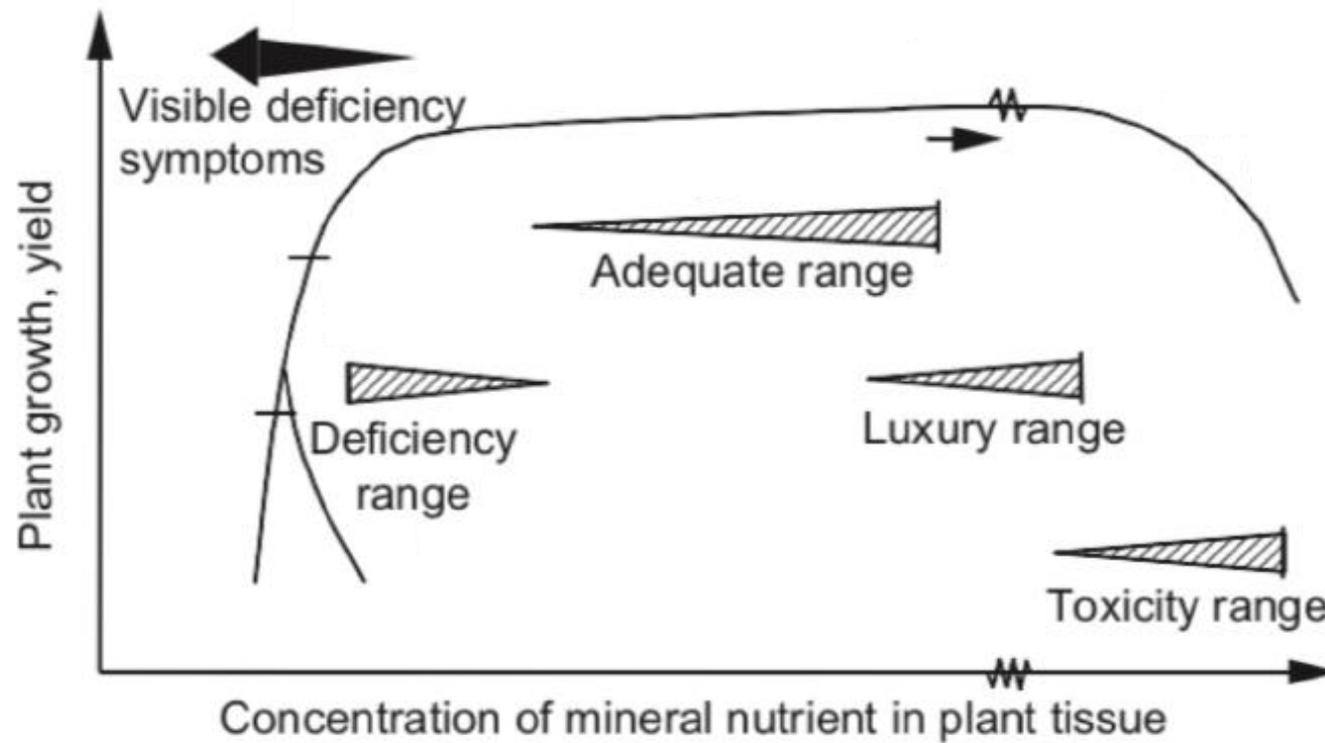


Rate

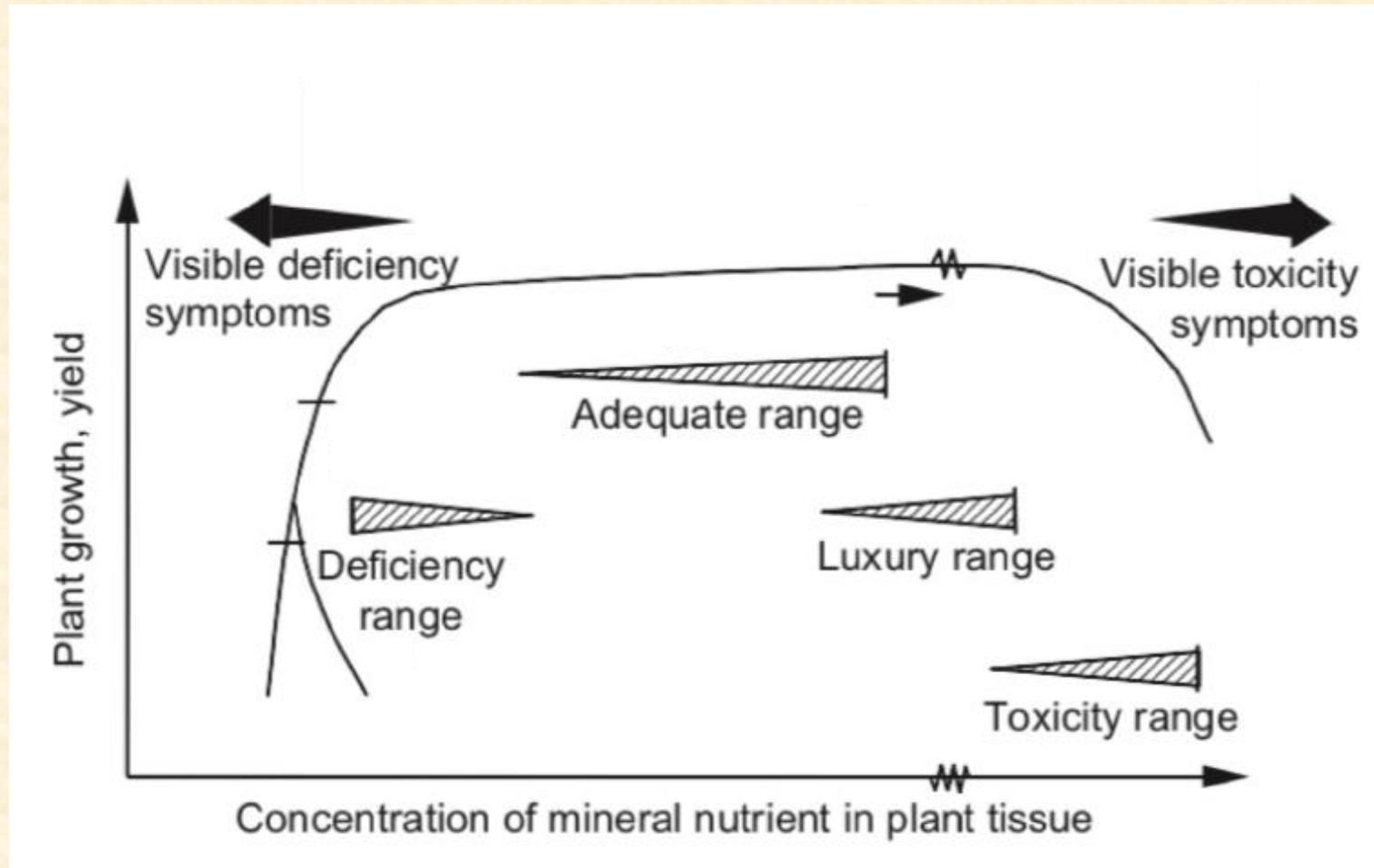


Rate

Deficiencies impair plant functioning & yield



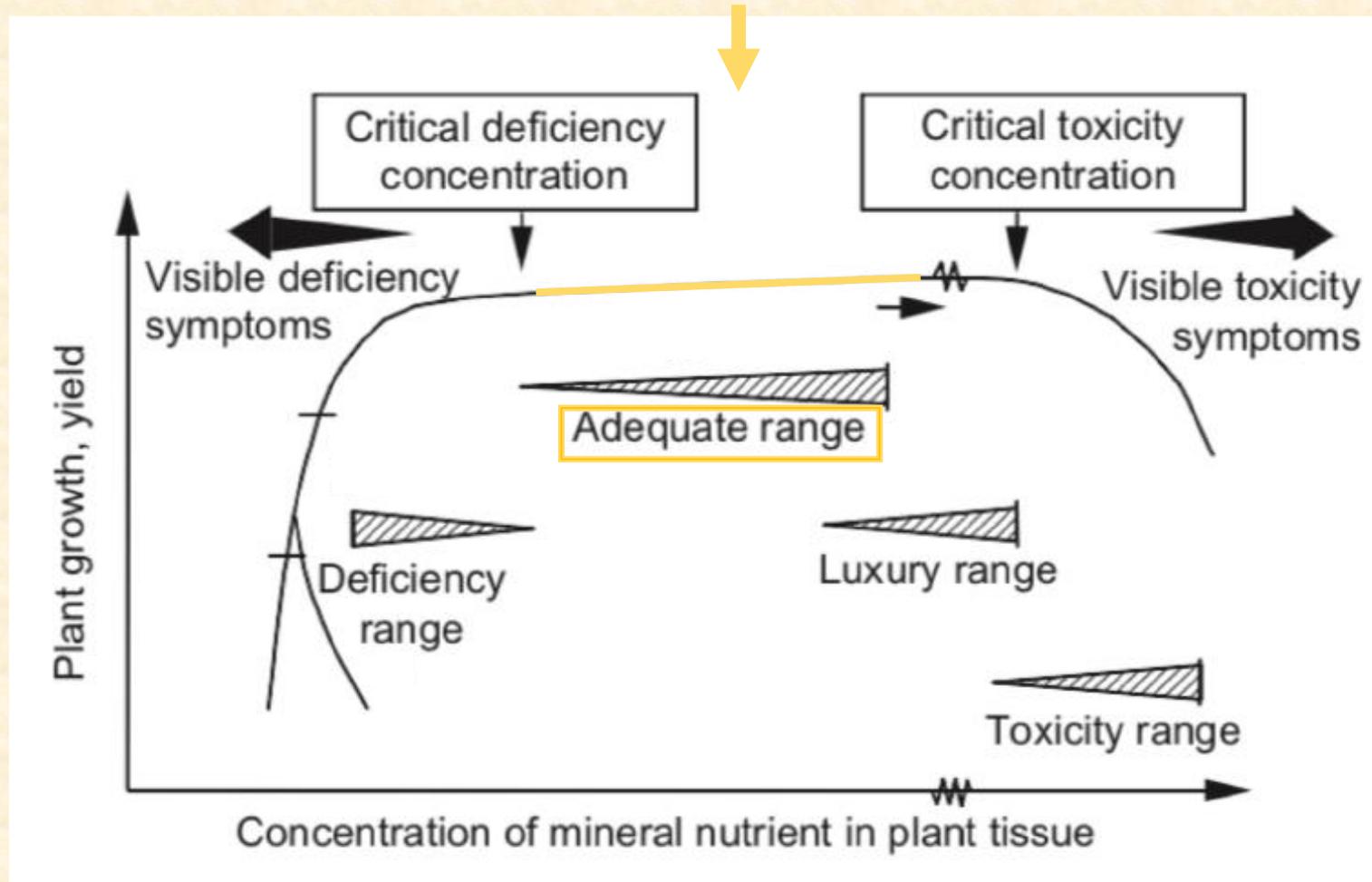
Rate



- Over fertilizing can lead to
- excess vigor
- lower yield & quality
- environmental damage
- wasted money

Rate

Visual assessments & diagnostic tools help you keep plant nutrient status in the safe range

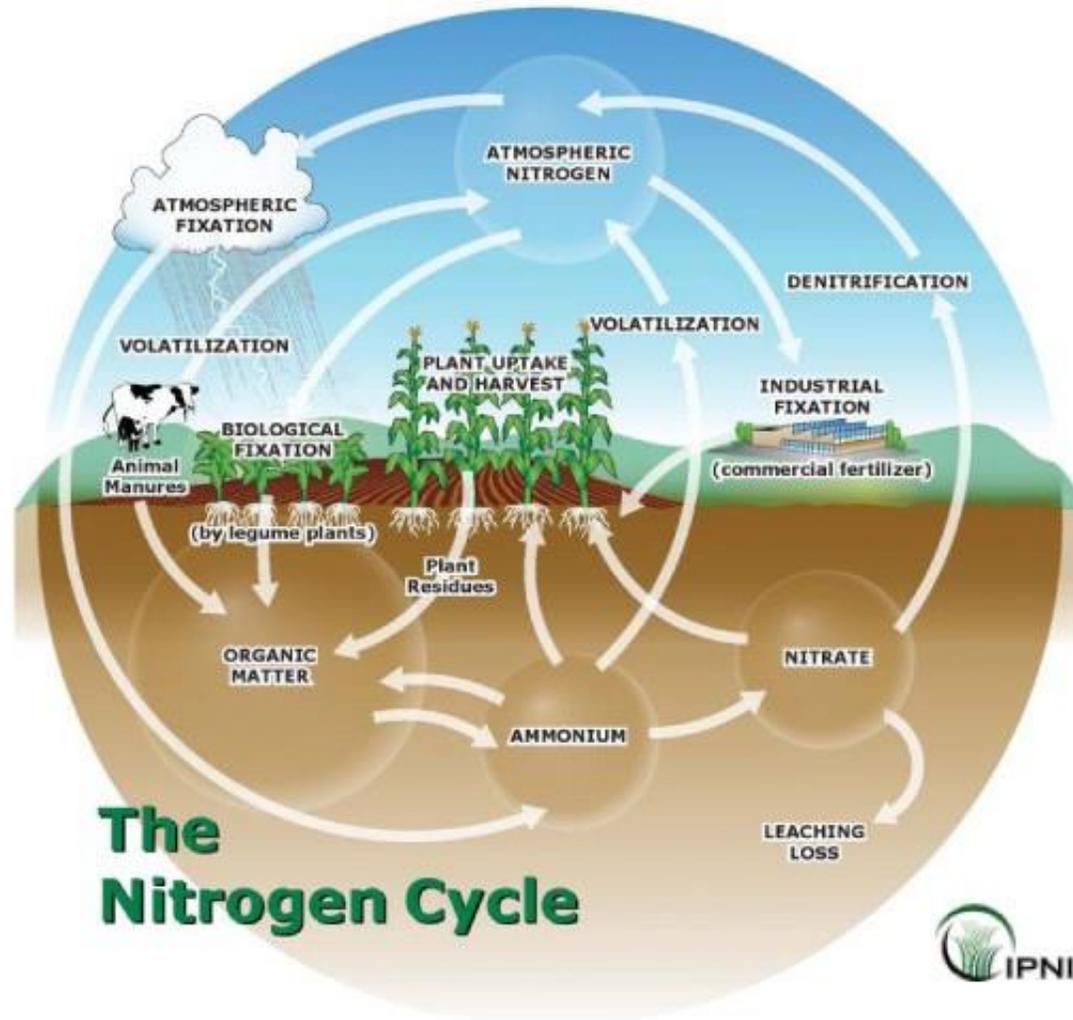


Rate

- Amount of nutrients needed depends on:
 - Crop type
 - Plant age & size
 - Soil & plant nutrient status
 - Irrigated vs. dry farmed
 - High input vs. low input system
 - Yield demand
 - Nutrient concentration of sources



Nitrogen



- It's ephemeral, “leaky”
...moves around a lot in ag systems
- Needed for plant
 - growth
 - chlorophyll
 - amino acids
 - proteins
 - DNA
 - photosynthesis
 - cell division
 - etc.

Nitrogen

“Nitrogen can be thought of as protein for plants – it is essential for healthy and vigorous growth and may be supplied via several different sources: soil organic matter, cover crops, compost, and fertilizers.”

-Lucas Hill, farmer

Examples of Sources

Compost



Cover
Crops



Pelletized
Chicken
Manure



Nitrogen

- Typically, N is the biggest nutrient challenge on organic veg farms
- Organic sources like compost & cover crops only release a fraction of their N slowly
- Nitrogen gradually accumulates in the soil & is cycled & released over years
- So supplementing with organic fertilizers is often needed to meet crop needs

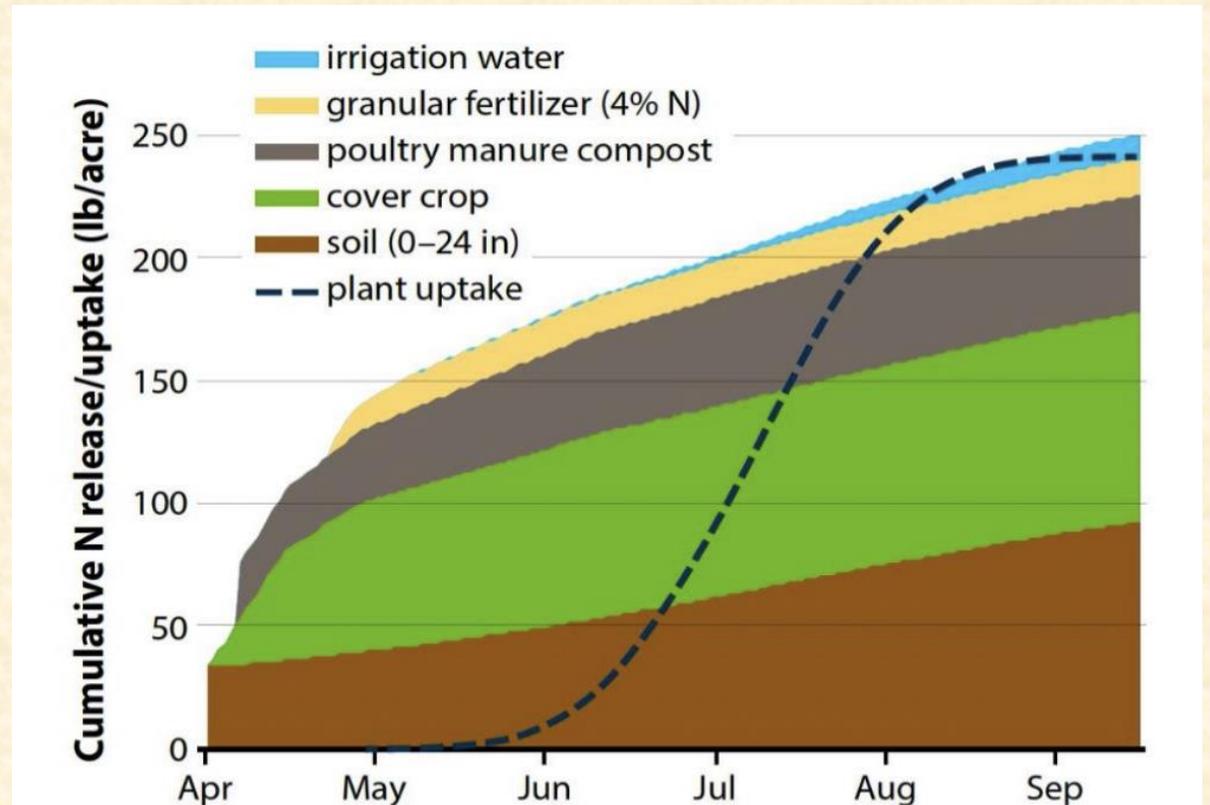


Figure 1. An example of nitrogen uptake and nitrogen supply in an organic tomato field (fresh-market tomato cv 'Brandywine'). Data are based on a field trial in Davis, California.

Organic Matter Amendments & Microbes



(source unknown—thank you whoever made this)

- The high carbon to nitrogen ratio (C:N) of wood chip mulch or woody compost means there's not much N to go around, and microbes may outcompete crops for N
- Lower C:N of high-quality, well-decomposed compost means microbes have access to more N, less likely to have as severe N deficiency symptoms in plants

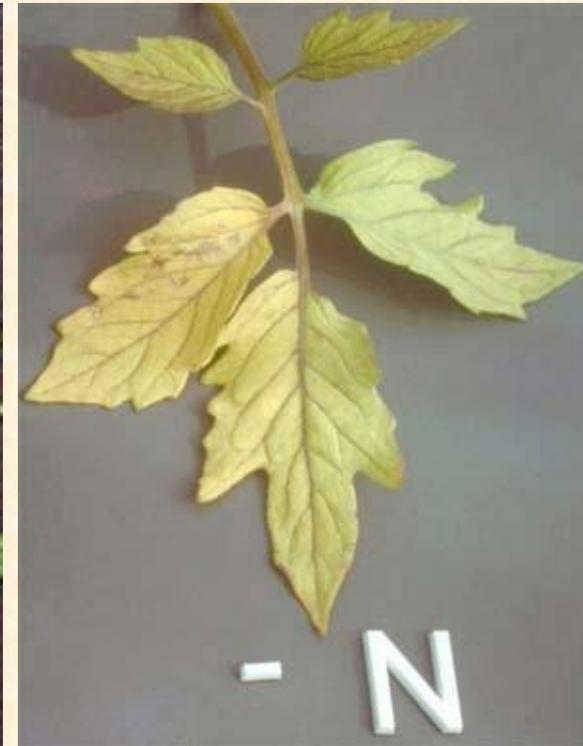
Nitrogen Deficiency Symptoms

- Appear on older, lower leaves first
- Uniform light green/yellow leaves (chlorosis)
- Reduced leaf size
- Thin, spindly, stunted shoot growth
- Short terminal shoots

Sufficient Nitrogen



Deficient Nitrogen

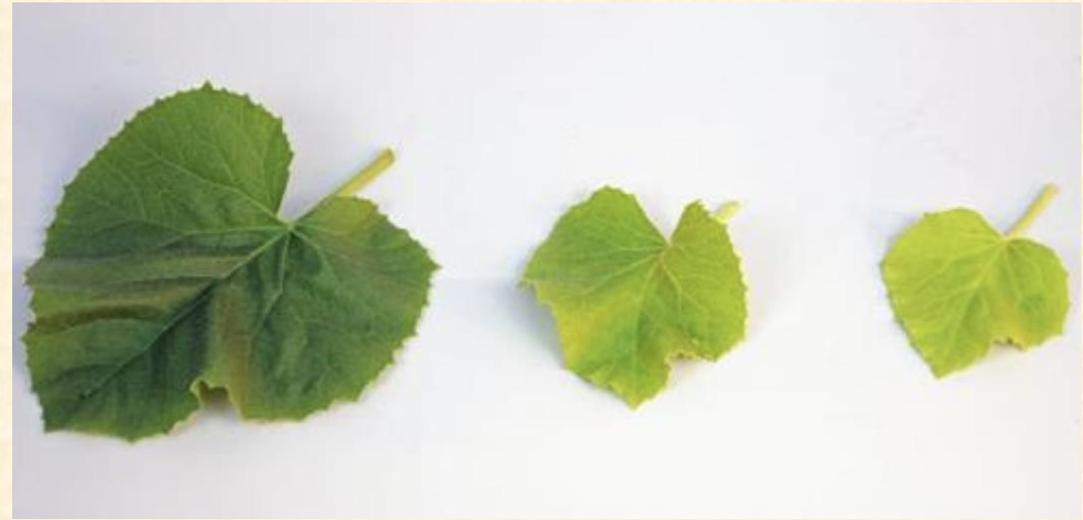


(Haifa Group)

Nitrogen Deficiency



(Yara)

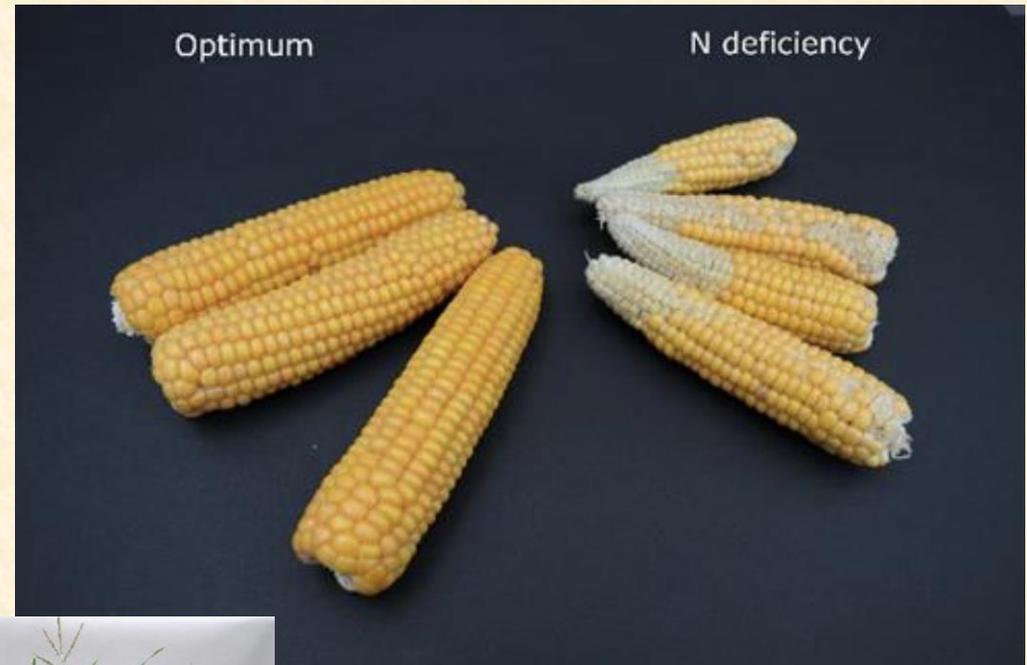


(Yara)



(Yara)

Nitrogen Deficiency



(Yara)



Nitrogen Deficiency

- If severe, older leaves may die
- Reduced bud formation & fruit set
- Small fruit size
- Fruit that mature early
- Reduced yield quantity & quality



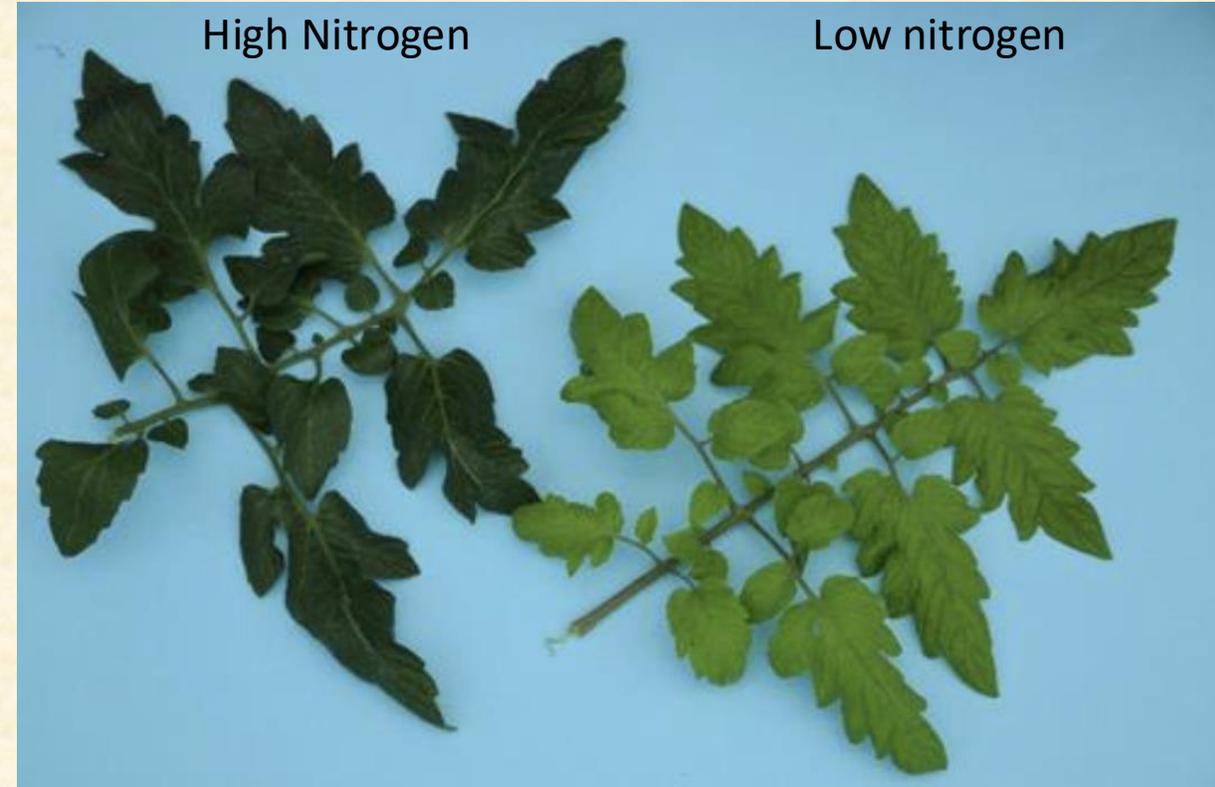
(Yara)



(Gerald Holms, Cal Poly SLO)

Nitrogen Excess

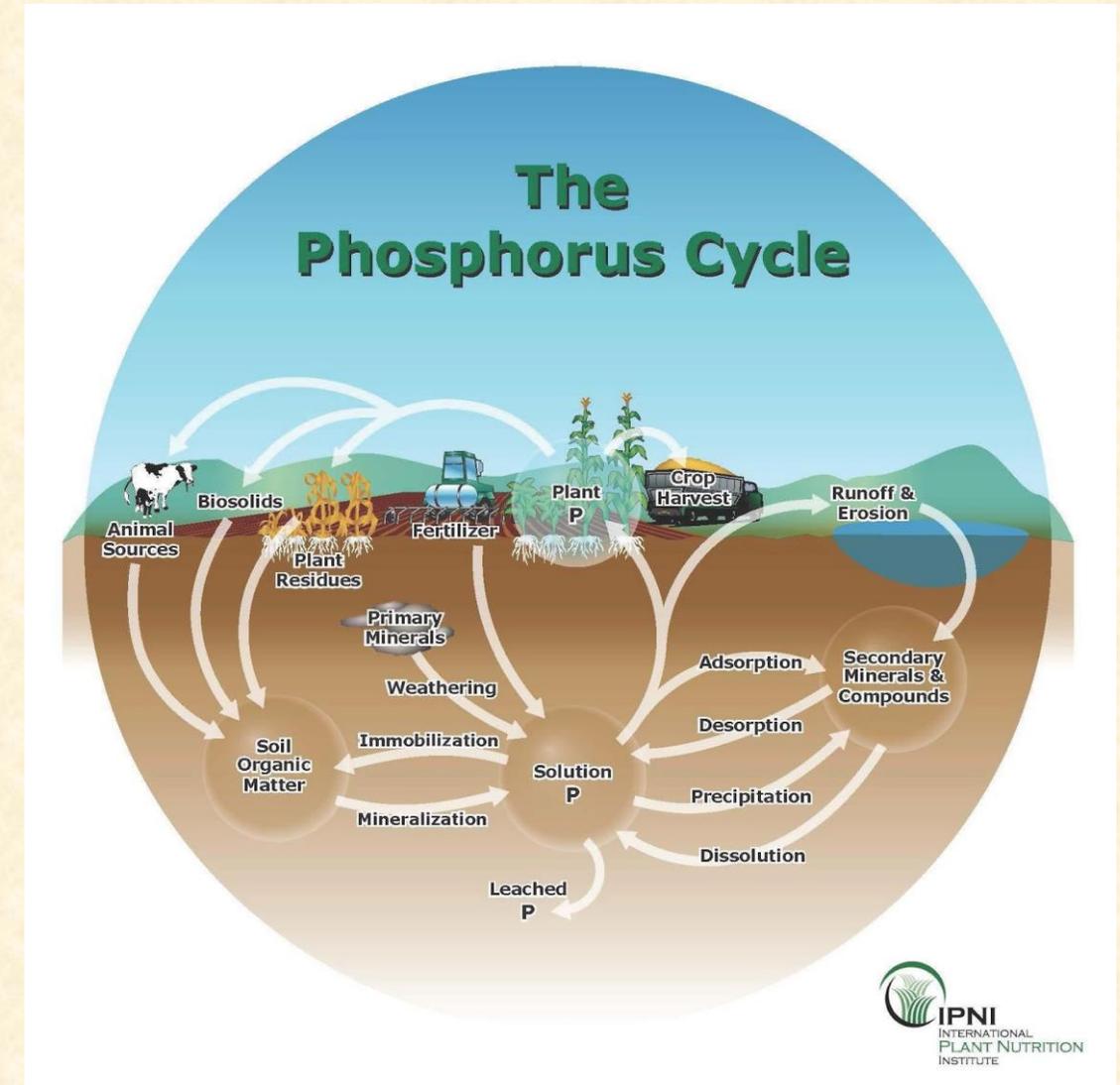
- Large, dark green leaves
- Excess foliage & vegetative growth
- Increased susceptibility to insect pests & diseases
- Reduced flowering, fruit set, fruit quality



(Yara)

Phosphorus

- Often comes from manure-based compost in organic veg systems, usually deficiencies aren't a problem
- Needed for plant
 - energy transfer (ATP)
 - DNA & RNA
 - root & seed development
 - metabolic processes
 - stress tolerance
 - etc.



Phosphorus Deficiency

- Causes purplish or dark green leaf discoloration, especially on the underside of older leaves
- Stunting & slow growth
- Dead leaves, premature leaf drop
- Poorly developed roots
- Delayed flowering, poor fruit set
- Reduced yield



(Yara)

Phosphorus Deficiency



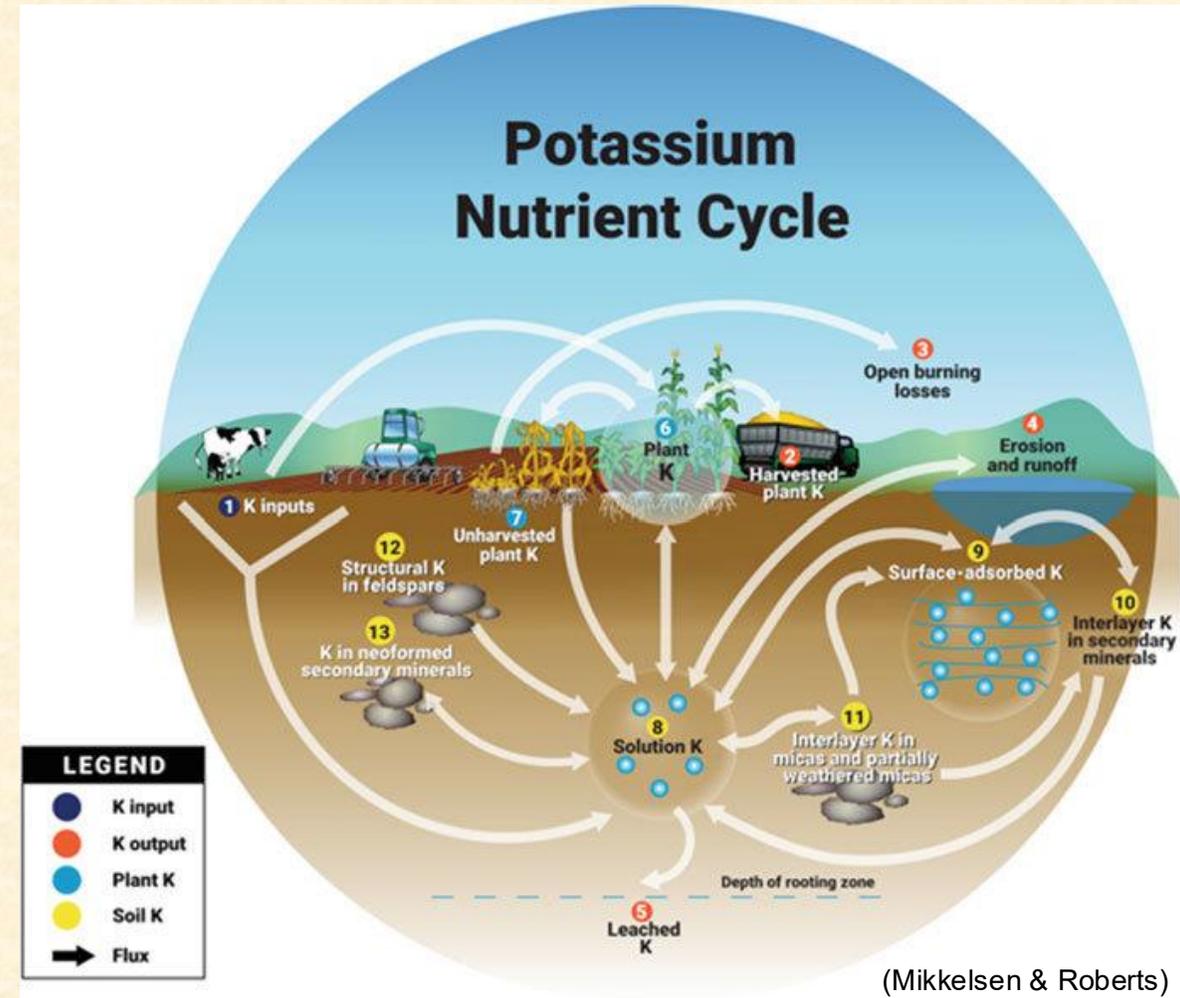
(Haifa)



(Alabama & Auburn Extension)

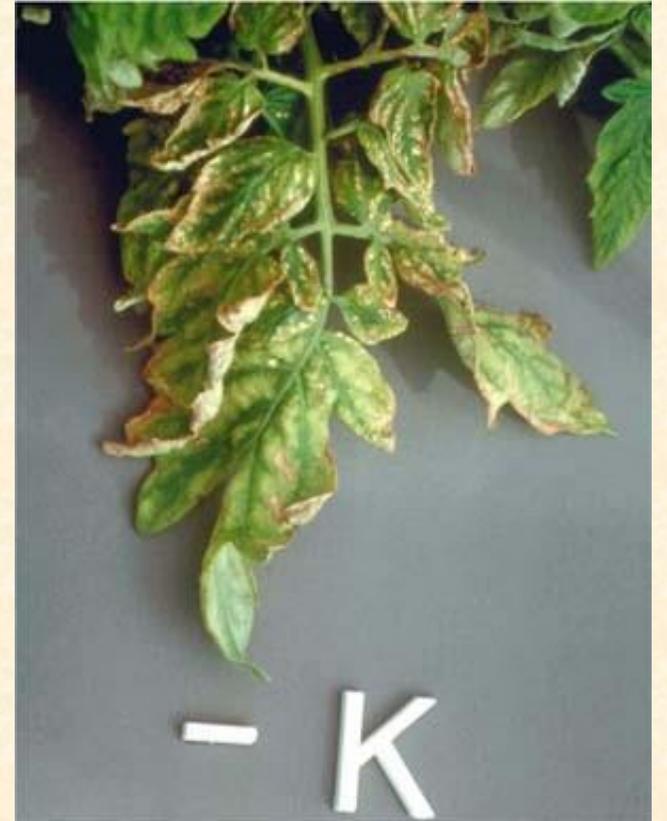
Potassium

- Comes from approved potash (mineral) products, kelp meal, wood ash, organic matter amendments
- Needed for plant
 - water uptake
 - stomatal regulation
 - photosynthesis
 - nutrient transport
 - enzyme activation
 - starch & protein synthesis
 - fruit & root development
 - etc.



Potassium Deficiency

- Appear on older leaves first, but can affect young leaves when severe
- “Scorched” yellow leaf margins, can turn brown & crispy over time
- Interveinal chlorosis, moves inward from edges
- Causes leaf crinkling, cupping, or rolling upwards



(Haifa)

Potassium Deficiency



(Yara)

- Plants become stunted with weakened stems & poor root development
- Reduced yield quantity & quality, such as uneven fruit ripening in tomatoes
- Leaf symptoms may appear as fruit reaches maturity (fruit accumulate a lot of K)

Potassium Deficiency



(Yara)



(Eric Sideman, Maine Organic)

Potassium Deficiency



(Yara)



(Yara)

Potassium Deficiency



(PowerAg)



(Yara)

Potassium Deficiency

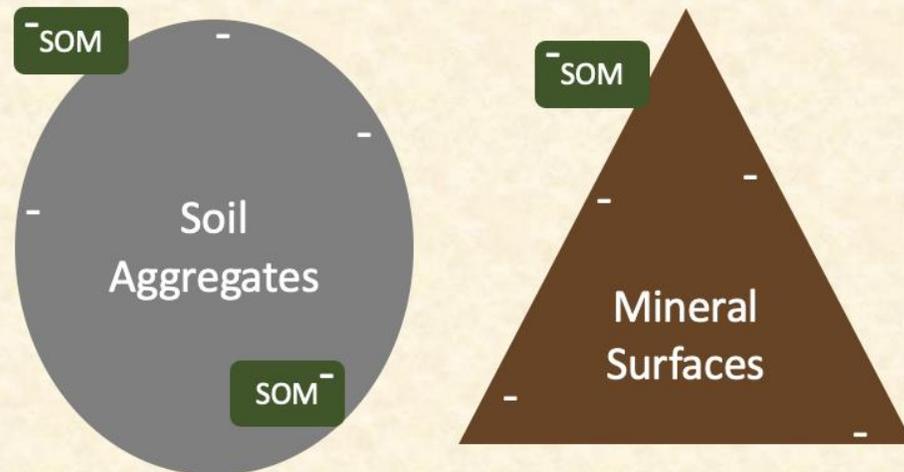


(Yara)



Soil Texture & Potassium

- Potassium (K) deficiency is more common in sandy soil than clayey soil
- Low CEC + high crop K demand → K deficiency
- Amend with K fertilizer, increase SOM for more “parking spots” (negative charges) for cations like K⁺



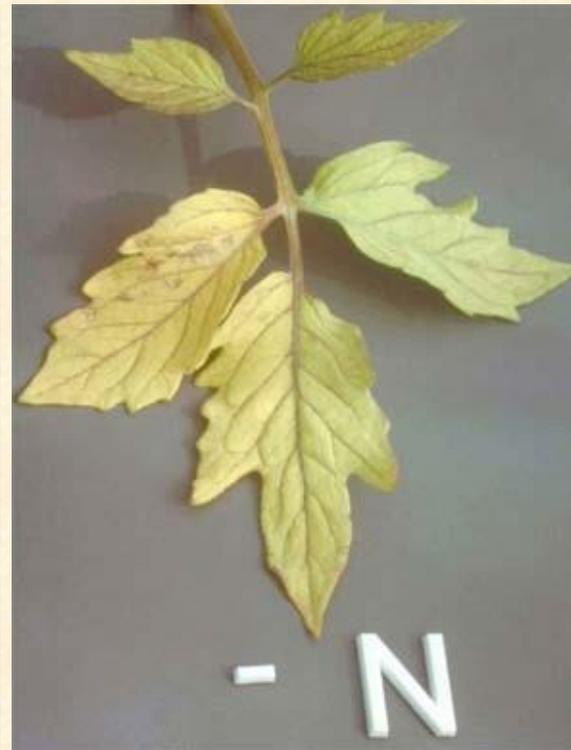
Soil Texture	Typical CEC Range (meq/100 g soil)
Sand & loamy sand	2 – 6
Sandy loam	3 – 8
Loam	7 – 15
Silt loam	10 – 18
Clay	15 – 30

Recap: NPK Deficiencies

Tomato with sufficient nutrients



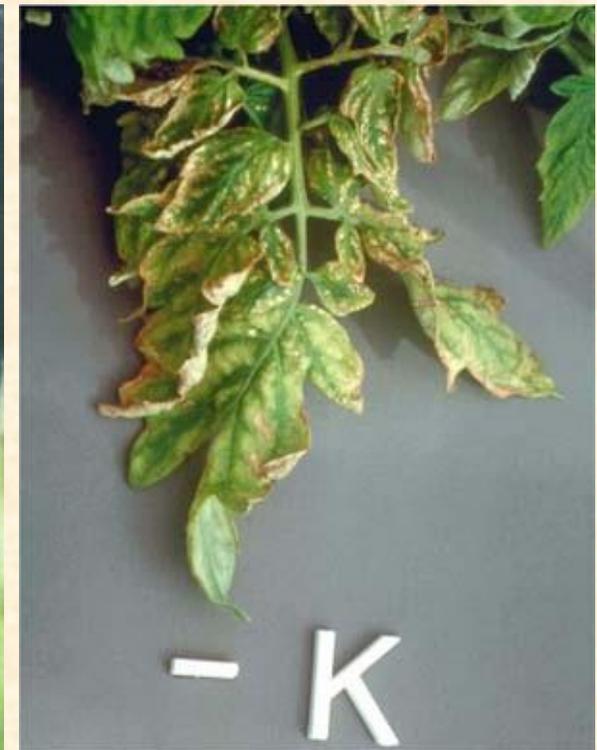
Nitrogen deficiency symptoms



Phosphorus deficiency symptoms



Potassium deficiency symptoms



(Haifa)

Calcium

- Supplied from amendments like lime, gypsum, animal-based products like bone or shell meal
- Needed for plant
 - cell wall strength
 - structural stability
 - cell division & elongation
 - root & shoot development
 - nutrient transport
 - stress resilience
 - fruit quality
 - etc.



Calcium Deficiency



(Yara)



- Symptoms appear on young leaves first
- Distorted or stunted new growth
- Leaf curling
- Necrotic leaf margins
- Tip burn
- Stunted root growth
- Weak stems

Calcium Deficiency



(Ellie Andrews)



(Yara)



(Iowa State)

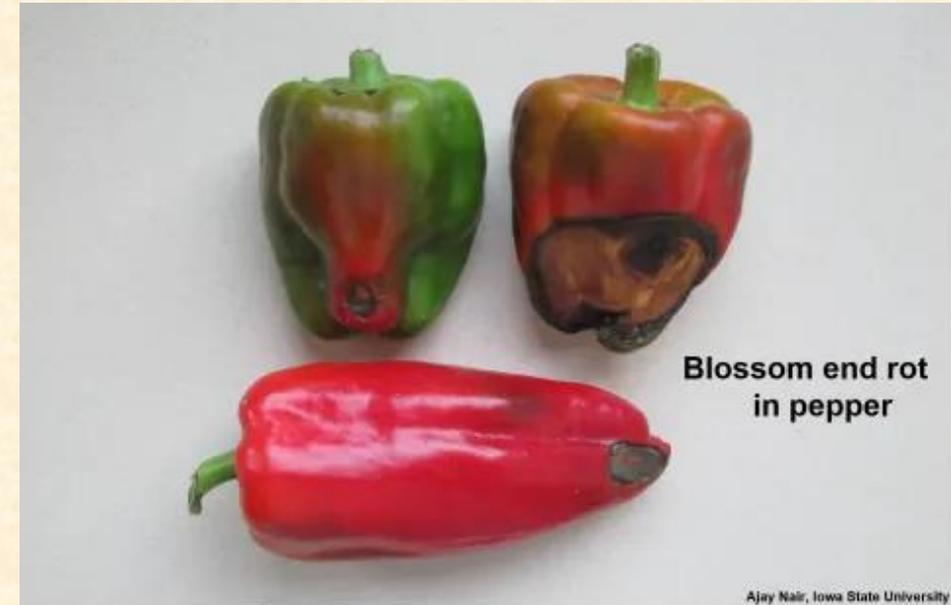


(University of Florida)



- Blossom end rot in tomatoes, peppers, eggplant, squash: dead fruit tips
- A physiological disorder caused by calcium deficiency
- Can be triggered by uneven or insufficient irrigation, rapid growth

Calcium Deficiency



(Iowa State)



(Illinois Extension)



USU Extension

(Utah State)

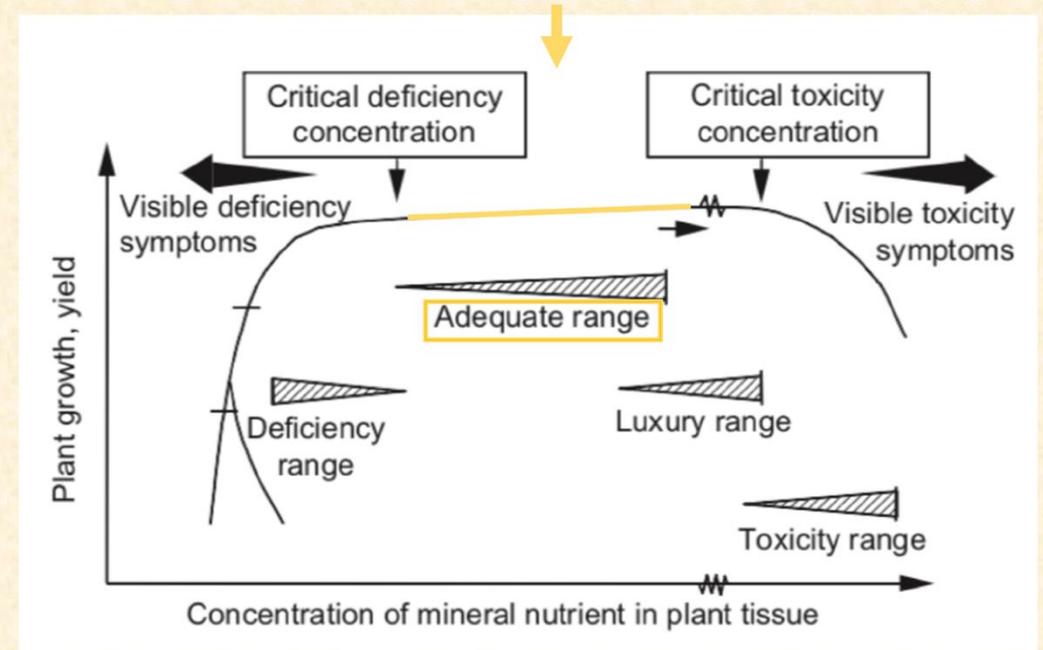


USU Extension

(Utah State)

Boron

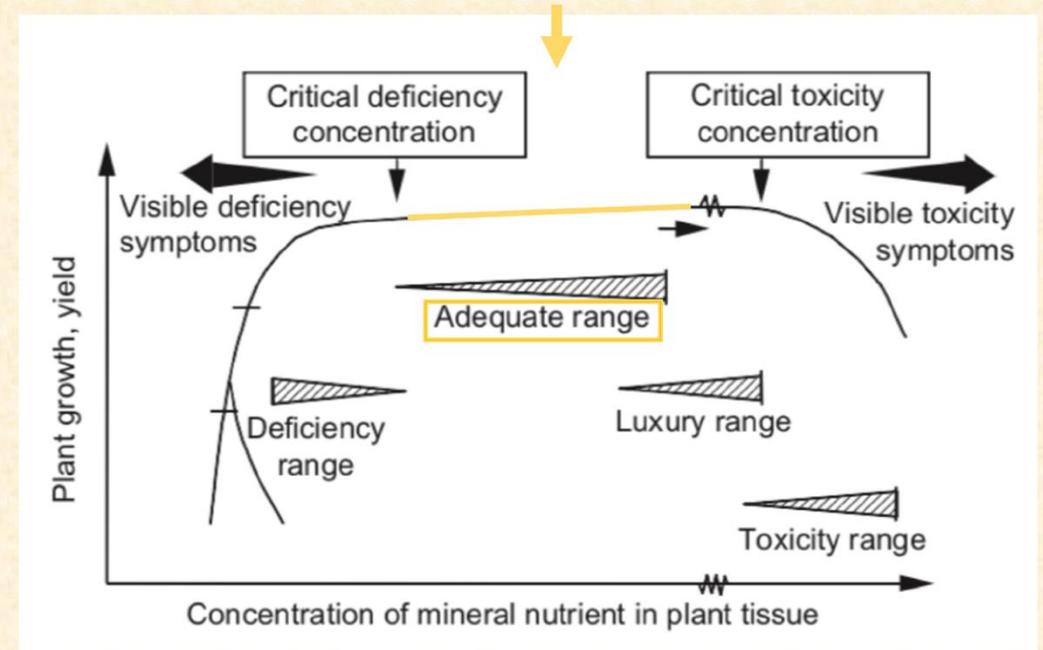
- Typically, enough is supplied through compost, can apply B fertilizer if needed
- Needed for plant
 - cell wall & membrane formation
 - cell division
 - sugar & carb metabolism
 - pollen germination
 - flower & fruit development
 - root growth
 - calcium uptake
 - etc.



Boron

- Typically, enough is supplied through compost, can apply B fertilizer if needed
- Needed for plant
 - cell wall & membrane formation
 - cell division
 - sugar & carb metabolism
 - pollen germination
 - flower & fruit development
 - root growth
 - calcium uptake
 - etc.

Not too much, not too little
 ...this “safe zone” is especially narrow for B
 (20-100 ppm leaf tissue)



Boron Deficiency

- Distorted young leaves & growing points
- Brittle, small, darker green leaves
- Necrotic mottling on margins & between veins
- Brittle petioles that fall off easily
- Overall plant stunting, rosette appearance
- Fruit cracking
- Discolored or hollow rotted tissues in roots & stems
 - hollow broccoli/cauliflower stems
 - watery centers in root veg



(Yara)



(Yara)

Boron Deficiency



(Yara)



(Yara)



1A

(Ben Phillips, MSU Extension)

Boron Toxicity (too much)

- Leaf cupping, crinkling, interveinal chlorosis on older leaves
- Necrotic spots develop along leaf edges
- Scorched leaf margins
- Defoliation if severe, premature leaf drop
- Can happen if:
 - you over-apply boron fertilizer
 - boron levels in irrigation water exceed 1ppm B



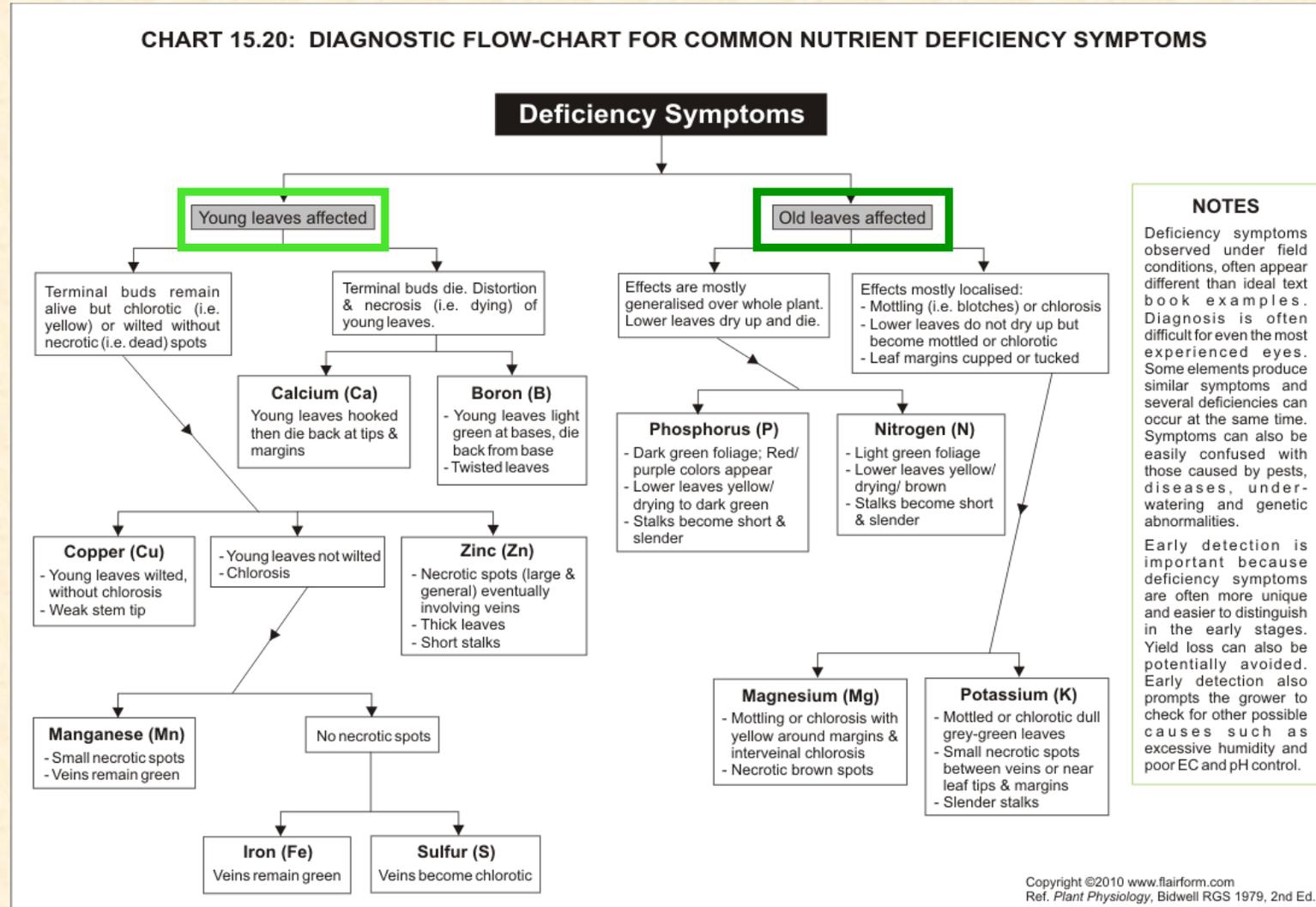
(Nathan Mueller, University of Nebraska-Lincoln)

Boron Toxicity (too much)



(Ben Phillips, MSU Extension)

There are many more!



Leaf Tissue Testing

- How do I know for sure if my plants have nutrient deficiencies?
- Collect leaves, send to a lab, compare your results to suggested ranges for the specific crop
- Gives us the concentration of nutrients in leaves which tells us plant nutrient status

A collaboration between:





Plant Tissue Sampling

Daniel Geisseler, Patricia Lazicki and William R. Horwath

Background

- Plant analyses are useful to diagnose nutritional problems and to monitor the fertilization program. Tissue testing is most effective when used together with soil testing ^[13].
- Nutrient concentrations change as plants grow and also differ between plant parts ^[6]. It is therefore important to sample specific plant parts at a particular growth stage (Table 1). For information on optimal nutrient concentrations at different growth stages, see the fertilization guidelines for the different crops (<http://apps.cdfa.ca.gov/frep/docs/Intro.html>)
- Archiving the results from the analyses allows tracking changes in the same field over time ^[6]. Plant analyses together with soil analyses and nutrient budgets allow evaluating the fertilization program on the long term ^[4].

General Sampling Instructions

- When plant development differs within a field, the field should be divided into different management areas with similar characteristics and a sample from each area should be taken. To facilitate interpretation, fields are best divided into the same areas as is done for soil samples.
- Randomly select plants throughout the field or management area and sample the correct plant parts ^[4, 13]. For plant parts and number of plant parts to sample, see Table 1.
- Collect the specific plant parts and place them into a clean paper bag ^[13]. Do not use places where plants are under water stress or where nutrient availability is atypical ^[6].
- Dust or soil covered plant parts should also be avoided, especially when the samples are used for micronutrient analysis ^[6].
- Small amounts of dust can be removed by gently brushing the samples with a soft brush ^[13]. Alternatively, the samples may be cleaned with a damp cloth, but should not be rinsed or washed to prevent leaching of nutrients from the sample ^[13, 14].
- Deliver the samples immediately to the lab ^[13, 14].

Leaf Tissue Testing

- The most reliable, direct assessment of plant nutrient status
- A quantitative assessment anyone can do
- Prices vary depending on lab & how many nutrients you test, ~\$20-50 per sample
- See directions →

A collaboration between:





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Soil & Water Sampling

- Helps you understand issues prior to planting & over time
- Tells you about nutrient availability & soil constraints
- Provides complementary info with leaf sampling, a full picture
- Helps guide fertilizer & amendment applications



California Crop Fertilization Guidelines



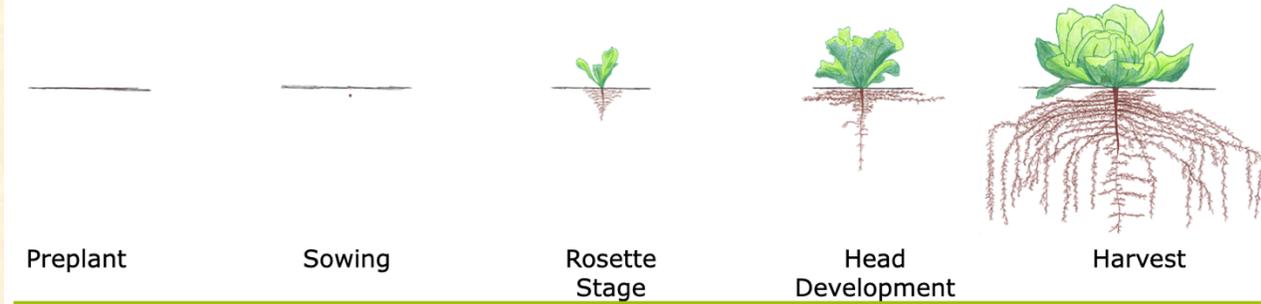
A collaboration between CDFA, FREP and UC Davis

Field crops and vegetables

Alfalfa 	Barley 	Dry Beans 	Broccoli 	Carrot
Cauliflower 	Celery 	Corn 	Cotton 	Lettuce
Melons 	Onion <i>Cebolla (en Español)</i>	Potato 	Rice 	

California Fertilization Guidelines

Lettuce



Nitrogen (N) ⌵

Soil Test ⌵ **Leaf Analysis** ⌵

Preplant N ⌵ **Starter N** ⌵ **Sidedress N** ⌵

Phosphorus (P₂O₅) ⌵

Soil Test ⌵ **Leaf Analysis** ⌵

Preplant P ⌵ **Starter P** ⌵

Potassium (K₂O) ⌵

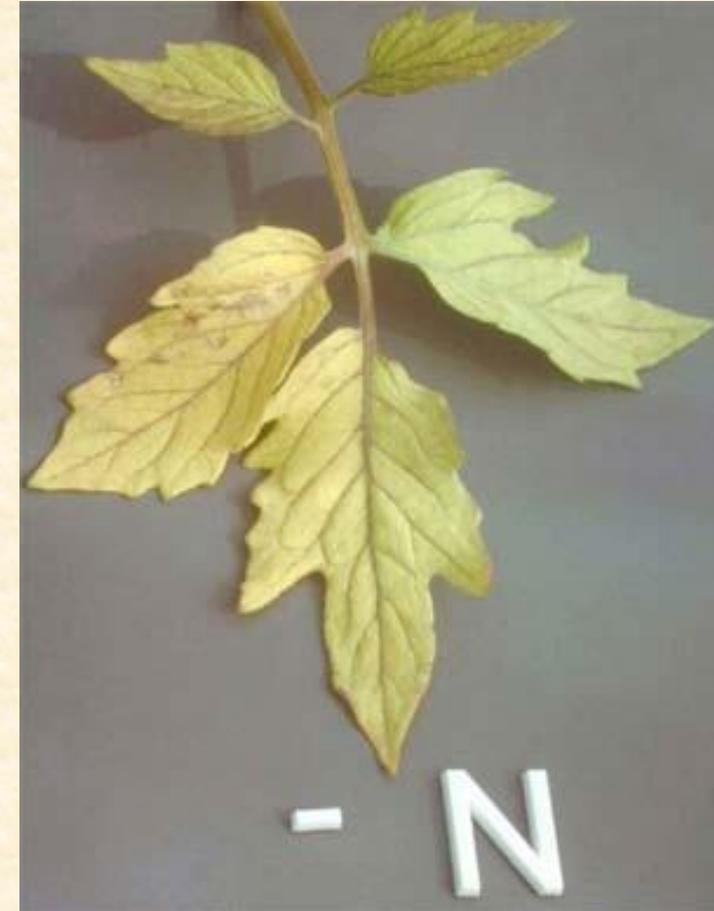
Soil Test ⌵ **Leaf Analysis** ⌵

Preplant K / K Fertigation ⌵

Acknowledgments ⌵ **Additional Information** ⌵ **Take a Quiz!** ⌵ **Links** ⌵

Start by Focusing on Nitrogen

- Nitrogen deficiency: most common nutrient problem in organic veg crop systems
- Nitrogen is the main nutrient being removed in harvest, leached, and immobilized by microbes
- If you see N deficiency symptoms out in the field, consider side-dressing with N fertilizer (there are organic options)



(Haifa)

A Strong Start

- Check out this factsheet:
 - Nitrogen Deficiency in Veg Starts
 - Sources & Availability
 - Product Examples
 - Different Crops, Different Needs
 - Choosing a Fertilizer Product
 - Action Steps
 - Lots of quotes from farmers who you'll probably recognize!

A Strong Start: Organic Nutrient Management for Vegetable Transplants



Authors: Ellie Andrews, Emma Volk, Patricia Lazicki, Margaret Lloyd
Internal review provided by: Daniel Geisseler

The Challenge: Nutrient deficiencies are common on organic vegetable farms and can limit plant health and yield. Nitrogen (N) deficiency is typically the biggest nutrient challenge on organic vegetable farms. This is because organic sources of N (such as cover crops and compost) only release a fraction of their total N gradually for plant uptake. Nitrogen slowly accumulates in pools in the soil and is cycled and released over several years. As a result, supplementing with organic N fertilizers is often necessary to meet crop nutrient needs. Nitrogen is essential for plant growth as it is a key component of proteins, amino acids, and chlorophyll. It regulates growth,

Thank you!

