Regen Aquaculture

Plant Sap Analysis Short Course

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26+ CLIENTS | 21+ CITIES | 9+ COUNTRIES

Feasibility Assessments

Engineering

Design

Equipment Sourcing

Enterprise management software

Certification assistance

Recruiting

Farm Assessments

Product Development

Training

Operational Improvements

Upcycling Waste

Water Treatment

Operational Development

Custom Workshops

Lab Integrated Crop Management

Our role in Plant Sap Analysis

Create the bridge between researchers & farmers with laboratories specialised in plant sap testing to bring it into the field of aquaponics.

Plant sap results on over 200 different crops (organic, sustainable, conventional)

- Fruit (strawberry, raspberry, blueberry, apple, pear, cherry)
- Vegetables (lettuce, kale, tomatoes, peppers, cucumbers, eggplants,
- Nursery crops (trees, flower bulbs, cut flowers)

International testing (Active in 15+ countries)

- We offer Independent research trials

Why do we test plant nutrition and health?

Improve farm economics through improvements in managements

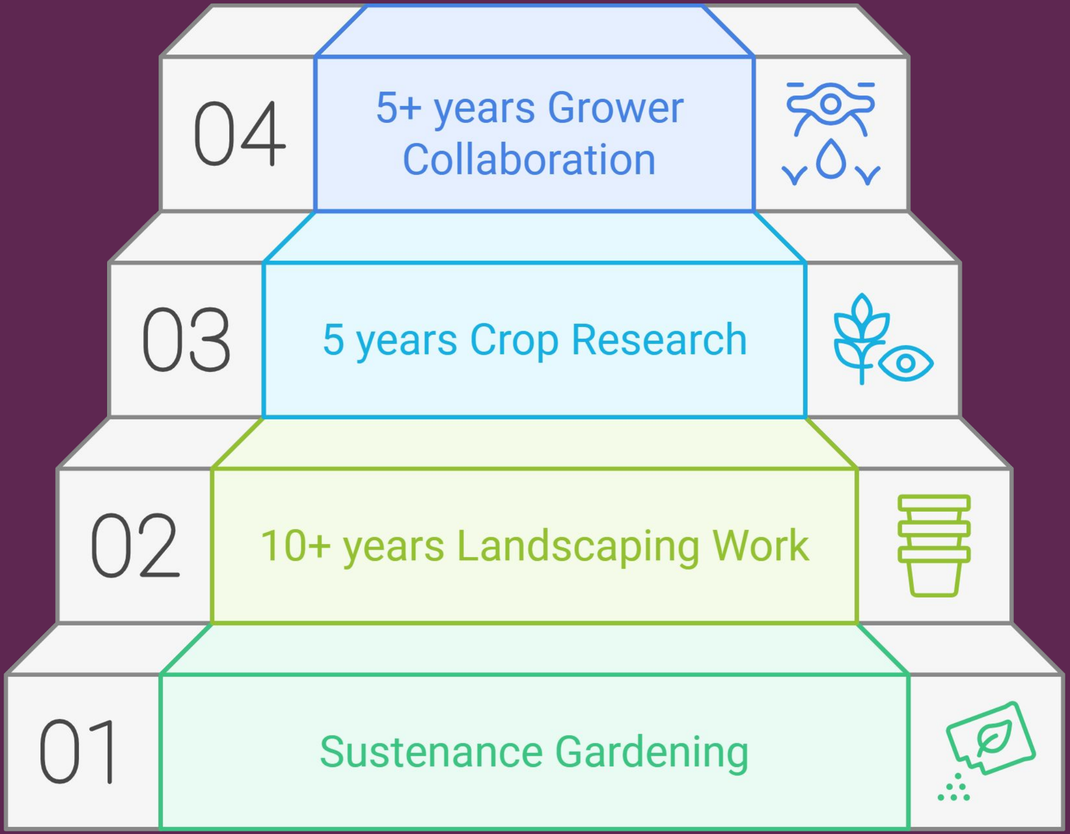
How?

- Improve crop health (healthier crops are more productive and resistance to pest and diseases)
- Improve salable crop metrics (size, color, shape, etc,)
- Minimize Over-fertilization -> Increase your sustainability/efficiency

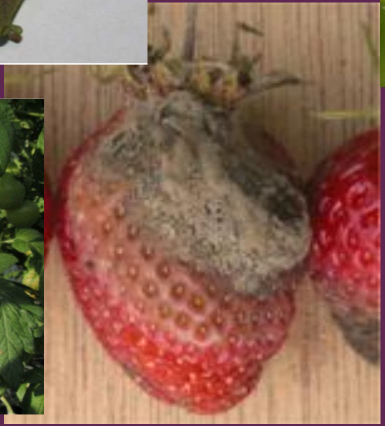
Agenda For Today

1. Teach you what a healthy plant means
2. Teach you how to analysis that health
3. Teach you how to interpret analysis
4. Teach you how to how to apply recommendations

My journey towards understanding plant health as a grower



The lows

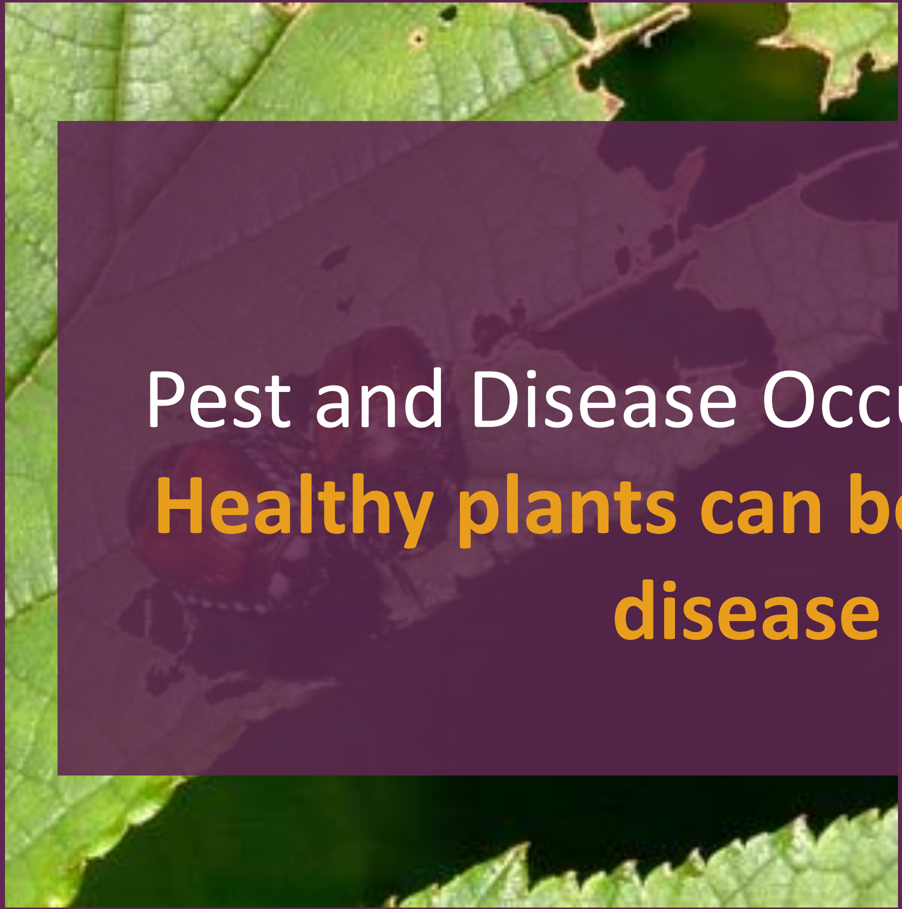
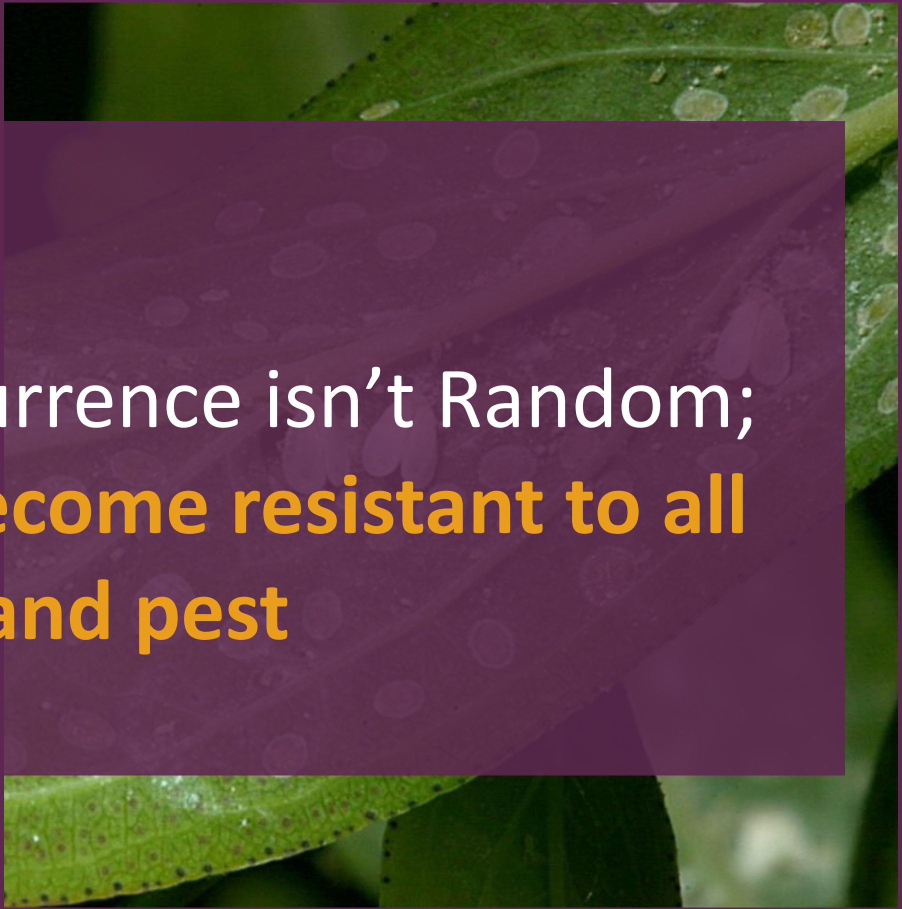


Changing my perspective on pest and disease

What do phytophagous insects want?

Plant eating insects aren’t our enemy.

They are nature's recyclers.

Pest and Disease Occurrence isn't Random;

Healthy plants can become resistant to all disease and pest

My journey towards improving plant health as a consumer

The scale of “healthy food”

Bionutrient institute is focused on quantifying what it means to be healthy.

Report in 2020 found

- Minerals variance ~25% variance,.
- Plant secondary metabolites Variance was 1,400% difference

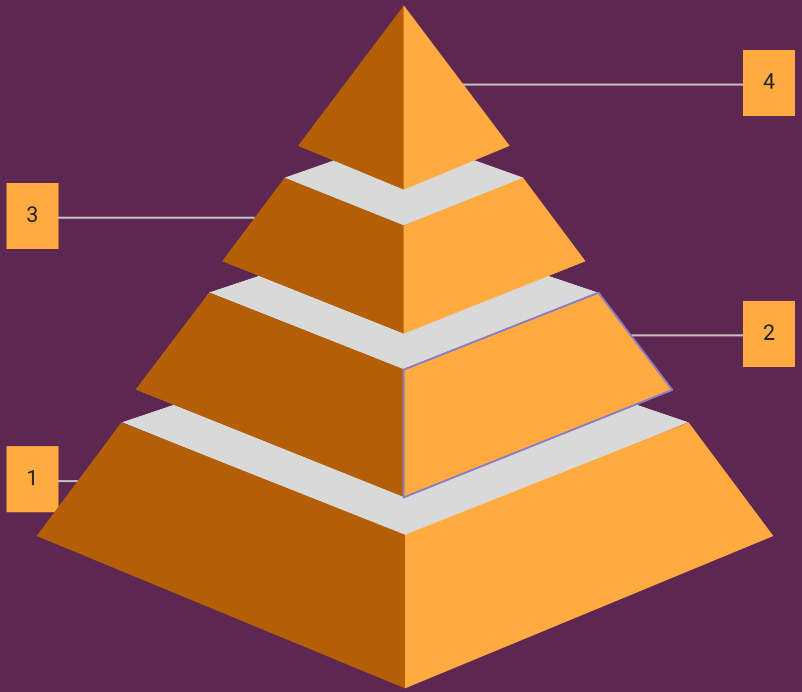
The Plant Health Pyramid

Increased Lipid Synthesis

Increasing microbial metabolites leads to increasing lipid production and stored in the form of waxes and oils

Complete Carbohydrate Synthesis

Shifting the carbohydrate profile to more complex carbohydrates and fewer non-reducing sugars



Increased Plant Secondary Metabolite Synthesis

Increases in lipids allows for greater production of PSM which enhance plant immune pathways (SAR and ISR)

Complete Protein Synthesis

Conversion of free nitrogen compounds into amino acids peptides, polypeptides, and proteins.

Assessing Crop Health

Physical Traits - Weight

Organoleptic Traits - (taste, sight, smell, touch, sound)

Mineral Nutrients - Macros, Micros, Beneficial

Protein Content - Crude Protein

Carbohydrates - Complex vs. Simple Sugars

Lipid Content - Energies or fats

Plant Secondary Metabolites - 500,000+ Compounds

Conventional Testing Methods

Assessing **Crop Quality** Post Harvest

a. Dry Tissue
b. Forage Analysis
c. Metabolomic Analysis

Assessing Crop's **Access to Nutrients** During Production

a. Soil Analysis
b. Water Quality

Post-Harvest Quality Assessment

Dry Tissue | Forage Analysis | Metabolomic Analysis

Minerals within the plant

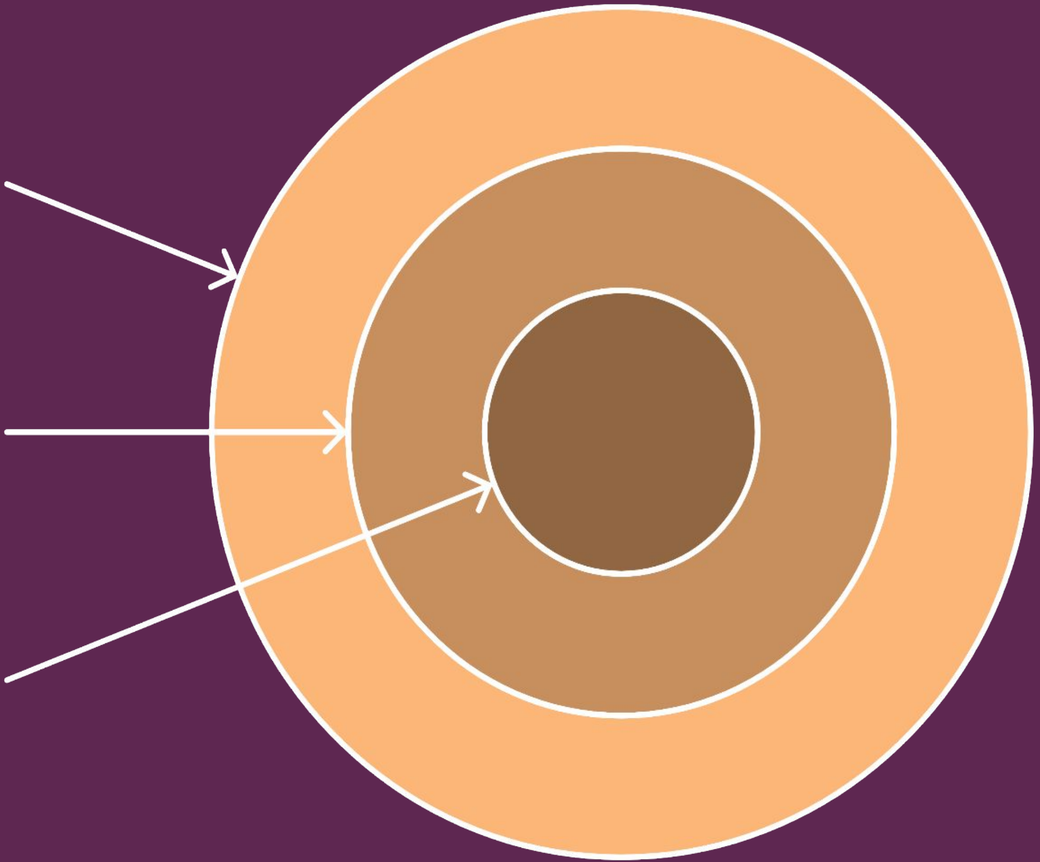
Total Uptake by Plant

Fixed Minerals

Bound within organic compounds, hardly bioavailable

Dissolved Minerals

Current uptake for plant development



Dry Tissue Analysis vs. Plant Sap Analysis

— **Plant sap measurement** measures mostly dissolved minerals and a small part of the fixed minerals.

— **Dry matter** test counts the total of both (total uptake by plant)

Tells us what's in the dry sample of material - Not the Whole Plant

Nutrient wise: Calcium measurement is one of the biggest differences, a small portion of the total amount is used for active “growth”. Sap analysis will the “real” Calcium availability.

Benefits of Dry tissue

1. Can tell us the mineral nutritional value of the end product
2. Evaluating the differences in fertilizer treatments from a high level perspective
3. Estimating nutritional demand

Estimating nutrient demand w/ Dry Tissue Analysis

Useful for predicting nutrient demand - Gets us in the ballpark!

Example:

1 kg of lettuce @ 95% moisture and 6% N Dry weight (DW)

= (1000g *(1-.95)) * (6g N /100g DW)

= 3g of N / 1kg Wet Weight Lettuce

Sample Description: BIBB1
Mid Growth (~12 leaves from new growth)

Systematic: Lactuca sativa (Bibb Lettuce)

MACRO NUTRIENTS:	---%--	Low	Medium	High	Sufficiency Ranges
Nitrogen (N)	6.13			X	4.50 - 5.60
Phosphorus (P)	0.79			X	0.45 - 0.77
Potassium (K)	4.87		X		3.00 - 8.50
Calcium (Ca)	1.15		X		0.80 - 1.30
Magnesium (Mg)	0.34		X		0.30 - 0.70
Sulfur (S)	0.16	X			0.25 - 0.35

MICRO NUTRIENTS:	--ppm--	Low	Medium	High	Sufficiency Ranges
Iron (Fe)	78.98		X		50 - 150
Manganese (Mn)	88.16		X		55 - 110
Boron (B)	25.20		X		15 - 45
Copper (Cu)	3.51	X			6 - 16
Zinc (Zn)	51.06		X		25 - 60
Molybdenum (Mo)	1.69			X	0.33 - 0.58
Nickel (Ni)	0.13				no data

Forage Analysis

Provides a Low Cost View of the Nutritional Quality of a Crop

Used as an indicator of Proteins and Lipids

Track Changes in Crop Quality

Description: Grass Hay	Analysis as Recieved	Analysis dry Basis
Moisture, %	14.85	0.00
Dry Matter, %	85.15	100.00
PROTIEN		
Crude Protien, %	11.0	12.9
FIBERS		
Acid Detergent Fibers, %	35.8	42.1
Neutral Detergent Fibers, %	50.7	59.6
NDFD (digestibility) 48 hr, % of NDF	-	20
IVTDMD (in vitro true digestibility) 48 hr, %	49.6	58.2
ENERGIES		
TDN Est., %	46.5	54.6
Net Energy Lact, MCal/lb	0.4709	0.5531
Net Energy Maint, MCal/lb	0.4359	0.5119
Net Energy Gain, MCal/lb	0.2201	0.2585
QUALITY VALUE		
Relative Feed Value	-	88
Relative Forage Quality	-	85
Starch, %	-	-
MINERALS		
Calcium, % Ca	1.03	1.21
Phosphorus, % P	0.13	0.15
Potassium, % K	1.31	1.54
Magnesium, % Mg	0.12	0.14
Ash, %	1.05	1.23
OTHER ANALYSIS		
Fat, %	10	12
Lignin, %	9.55	11.21
Non Fiber Carbohydrates, %	21.9	25.8
Water Soluble Carbohydrates, %	5.0	5.9

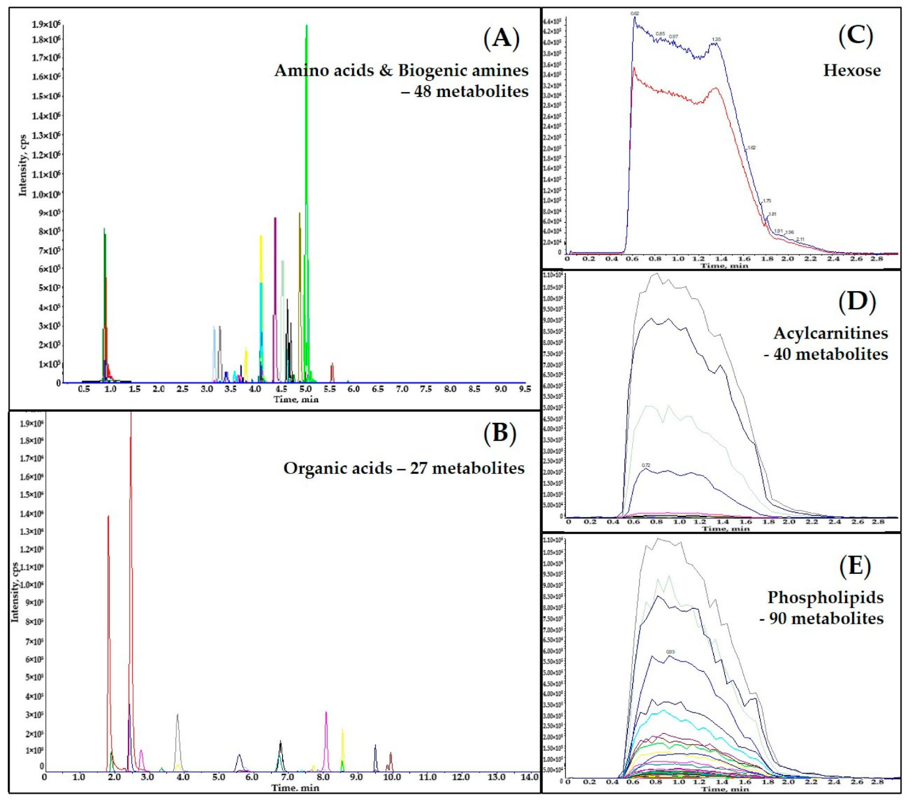
Metabolomic Analysis

Analysis of Plant Metabolites (Primary + Secondary)

High Cost - hundreds to thousands per test

Used mostly in advanced crop breeding programs and research studies

Isn't practical without a deep understanding of metabolites and their roles



Use lipids as a proxy for increased plant metabolites

Assessing Crop’s Access to Nutrients During Production

Soil Analysis

Determines Soil Composition

Identifies Nutrient Deficiencies

Guides Fertilization Plans

Assists in Crop Planning

Water Quality

Analyses for each nutrient in the aquaponic system water, at regular intervals, across the growing period of the plants

Water quality should be collected the same day as plant sap analysis, with additional test, as needed.

Frequency of Testing: recommended monthly for first year, and quarterly thereafter.

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CLIENT	Date of Testing	Date of Review	Sampling Number	Growing Method and Crop(s)	Advisor
[redacted]	2/15/2023	02/16/2023	JR PETERS	Aquaponic - Leafy Greens (General)	Jenna Smith

Water Analysis Report

Sampling Description	CW-2	#N/A			AquaBuddy Recommendation*
System Details		***Low***	***Target***	***High***	
Feeding Rate (g/m2/day)	60	15.0	20.0	25.0	Increase the number of plants or discharge a portion of culture water.
System Volume (L)	14,000				
Water parameters					
pH [H+aq]	6.69	6.5	6.8	7.0	No action needed.
EC (mmhos/cm)	1.48	0.6	0.8	2.2	No action reccomended.
Sodium Adsorption Ratio (SAR) meq/l		0.0	1.5	3.0	Missing Data
Alkalinity (mg CaCO3/l)	43.06	30	50	100	No action reccomended.
Carbonates (CaCO3)		-	-	-	In waters with pH less than 9, the majority of akalinity is in the form of Bicarbonates rather than carbonates. Therefore, no action reccomended.
Bicarbonates (HCO3)		30	70	100	Missing Data
Residual Sodium Carbonate (RSC) meq/l		0.00	0.00	1.25	Missing Data
Macro Minerals					
Calcium (Ca) ppm	69.81	50	100	200	Apply 1.82 kg Calcium sulfate (23.3% Ca) addition direct to water.
Magnesium (Mg) ppm	24.79	25	50	100	Apply 3.66 kg Magnesium Sulfate (9.86% Mg) addition direct to water or as foliar spray according to Crop Fertilization Schedule.
Potassium (K) ppm	200.80	50	100	200	Getting Abnormally high, add more plants, decrease feeding/ Nutrient Supplementation, or discharge a portion of waste/culture water
Sodium (Na) ppm	32.22	10	25	100	No action recommended.
Ammonium-Nitrogen (NH4-N) ppm	1.15	2	4	12	Increase feeding rates, decrease number of plants or add nitrogen source to Crop Fertilization Schedule.
Nitrate-Nitrogen (NO3-N) ppm	103.27	30	40	80	Getting Abnormally high, add more plants, decrease feeding/ Nutrient Supplementation, or discharge a portion of waste/culture water.
Fluoride (F) ppm		0	0	3	Missing Data
Chloride (Cl) ppm	56.37	10	30	100	No action recommended.
Sulphate-Sulphur (SO4-S) ppm	118.10	2	10	400	No action recommended.
Phosphate-Phosphorus (PO4-P) ppm	29.09	20	40	60	Apply 0.68 kg Monopotassium Phosphate (22.7% P or 52% P2O5) addition direct to water. For a foliar spray, apply WS-CaP or WS-P per according to Crop Fertilization Schedule. Additionally increasing feeding rates, mineralzation of solids, and addition of phosphorus solublizing microbies (ex. Mammoth P) are alternative methods to further increase phosphorus in the water column.
Micro Minerals					
Aluminum (Al) ppm	0.01	0.00	0.00	0.02	No action recommended.
Iron (Fe) ppm	3.48	2.50	3.00	5.00	No action recommended.
Manganese (Mn) ppm	0.18	0.30	0.50	0.60	Apply 14.15 g Manganese sulfate (32% Mn) addition direct to water or apply foliar spray according to Crop Fertilization Schedule.
Zinc (Zn) ppm	2.59	0.05	0.10	0.20	Getting Abnormally high, add more plants, decrease feeding/ Nutrient Supplementation, or discharge a portion of waste/culture water.
Copper (Cu) ppm	0.03	0.05	0.10	0.20	Apply 3.96 g Copper Sulfate (Pentahydrate) (25% Cu) addition direct to water or apply foliar spray according to Crop Fertilization Schedule.
Boron (B) ppm	0.42	0.30	0.50	0.60	No action recommended.
Molybdenum (Mo) ppm	0.32	0.20	0.30	0.50	Apply -0.71 g Sodium Molybdate (39.65% Mo) addition direct to water or apply foliar spray according to Crop Fertilization Schedule.
Trace Minerals					
Silicon (Si) ppm	16.99	40	60	100	If pH is less than 7 then silicon can be managed by replacing potassium bicarbonate with potassium silicate for pH additions following the 'pH adjustments SOP'. Alternatively, if pH is high apply foliar spray according to the crop fertilization schedule.
Key Nutrient Ratios					
NO3: NH4 : S	10 : 0.1 : 11.4	10 : (1-3): 1			
NO3 : K : Ca : Mg: P	2 : 3.9 : 1.4 : 0.5 : 0.6	(2-4) : (2-4) : (2-4) : 1 : 1			

Low
Within Acceptable Ranges
Optimal Range
High

Comments:

R-3 FOR CLEARWELL CW-2

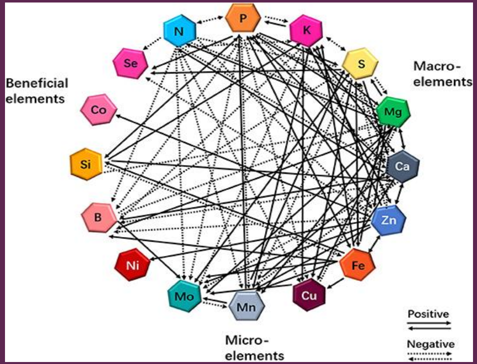
***AquaBuddy our Natural Intelligence assistant was developed to help growers simplify the decision process. AquaBuddy uses input from human experts to generate recommendations, based on simulated scenarios. Nutrient composition are based on nutrient additions found in the FAQ section. If percentage of nutrient is different then stated in your report, let us know and we can customize your nutrient inputs for future reporting.**
Disclaimer: All efforts have been made to ensure the accuracy of AquaBuddy. If for any reason you suspect an error please contact your dedicated Regen Aquaculture Consultant. Please check for certifer Chemical Compliance Reference Chart

Example of Water quality analysis using AquaBuddy

Limitations in Conventional Testing Methods

- Just because it's in the water or soil doesnt mean its in the Plant
- Just because it's in the dry tissue, doesn’t mean a plant was able to use it
- Dry tissue optimal levels are based on approximate values of a limited sample pool
- Large range of sufficiency ranges which are not always cultivar specific
- Sufficiency Ranges are often based on yield and do not reflect plant immunity

Nutrient interactions, antagonistic and synergistic, Mulder Chart updated 2023 Fan et. al



Plant Sap Analysis A New Tool For Crop Management

Why Measure plant sap?

- pH
- Water availability
- Imbalance in mineral
- Release of fertilizers (organic vs. minerals)
- Media or soil structure / root quality
- Soil life
- Climate, temperature, light, moisture, etc.
- Crop Genetics, Stage of life

“Sap” Analysis

Garlic Press Extraction

In field or makeshift lab

1-5 analytes

Ion selective electrodes

Cheap, Easy, Real Time

*Limitations in accuracy, analytes,

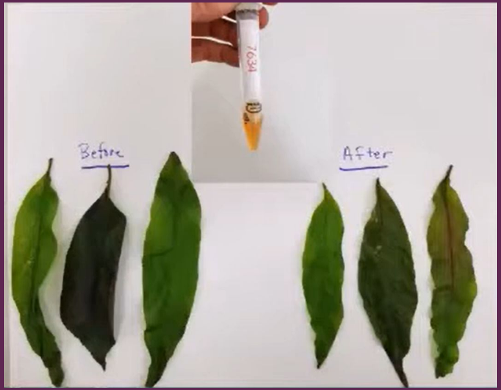
Time to test

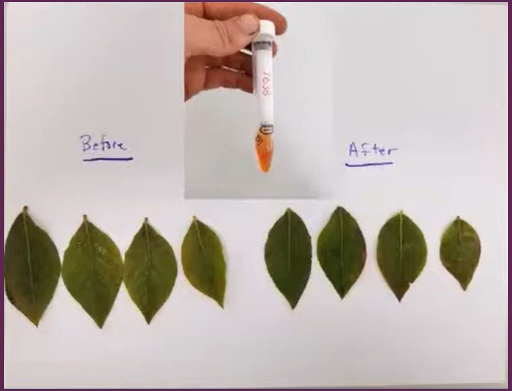
Leaf Extract aka Advanced Plant Sap Analysis

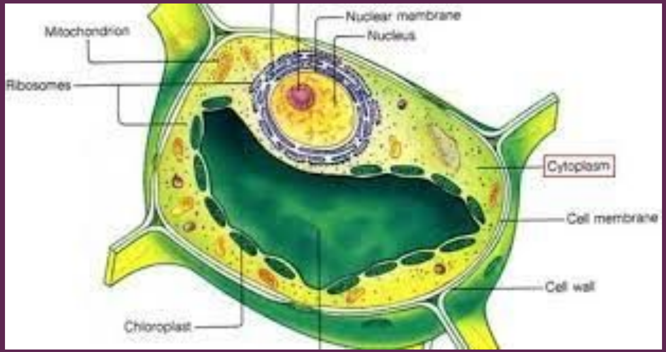
Leaves are sampled and fluid preserved

Pure cytoplasmic fluid is extracted from leaves

Fluid is analyzed on lab equipment for 24 analytes





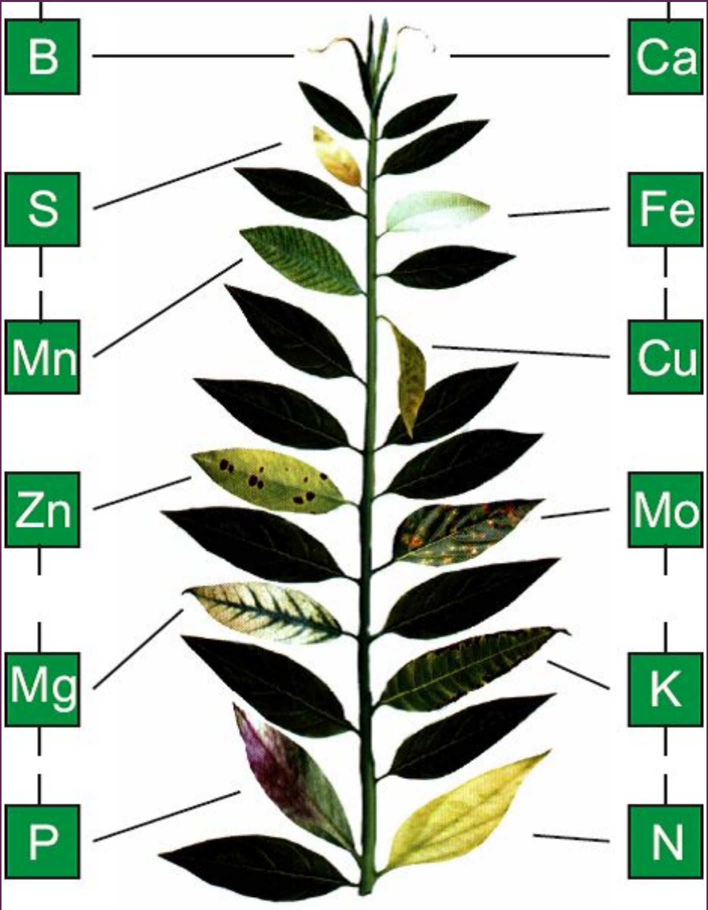


What A Plant Sap Analysis tells you

- Current uptake of nutrients
- Mineral deficiencies and/or excesses
- Nutrient imbalances in the soil or water
- Plant nutrient reserves
- Reflects plant health and vitality
- Fruit quality

Equivalent to “A blood test for a plant”

Understanding Mineral mobilization within the plant



<u>Phloem immobile minerals:</u>

**Ca, **Mn, Si

<u>*Variable phloem mobility:</u>

- Young Leaf (B, S, Fe, Zn, Cu, Ni, Co, Al)
- Old Leaf (K, Mg, P, Mo, Na, Cl, I, Se)

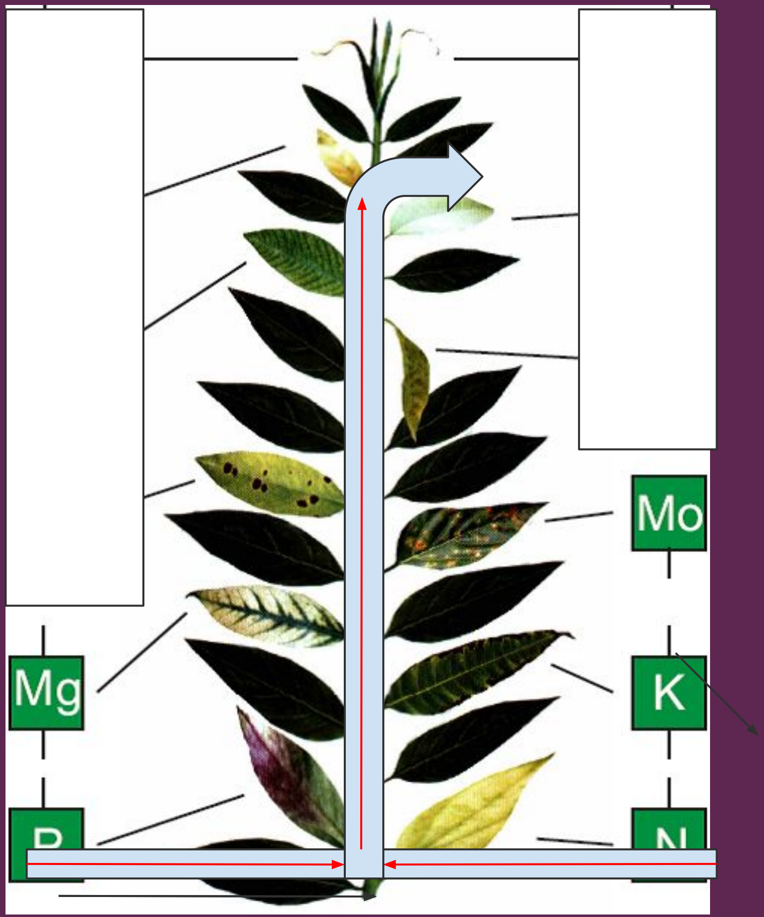
<u>High phloem mobility minerals:</u>

- N

*nutrient mobility is species, and life stage dependent (Millard 2015).

** Phloem Immobile minerals can be mobilized via xylem leaching in some crops during senescence. (Millard 2015)

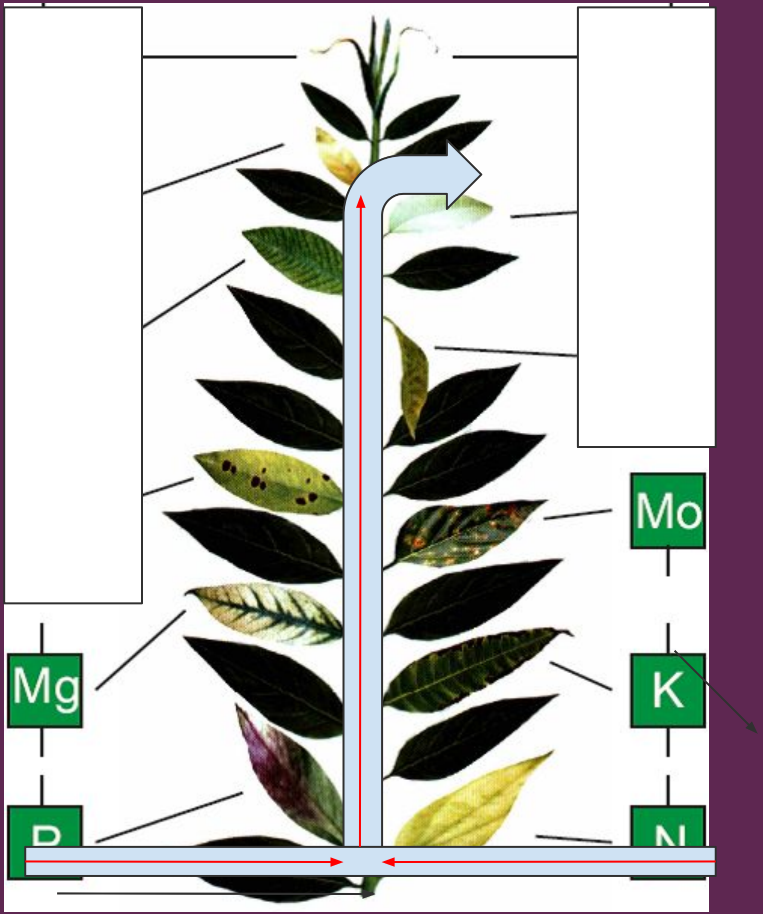
Mineral mobilization within the plant



Old leaves, act as a reserve for mobile nutrients

When roots can't deliver N,P,K or Mg, the plant will use it reserves

Mineral mobilization @ Critical Points of Influence



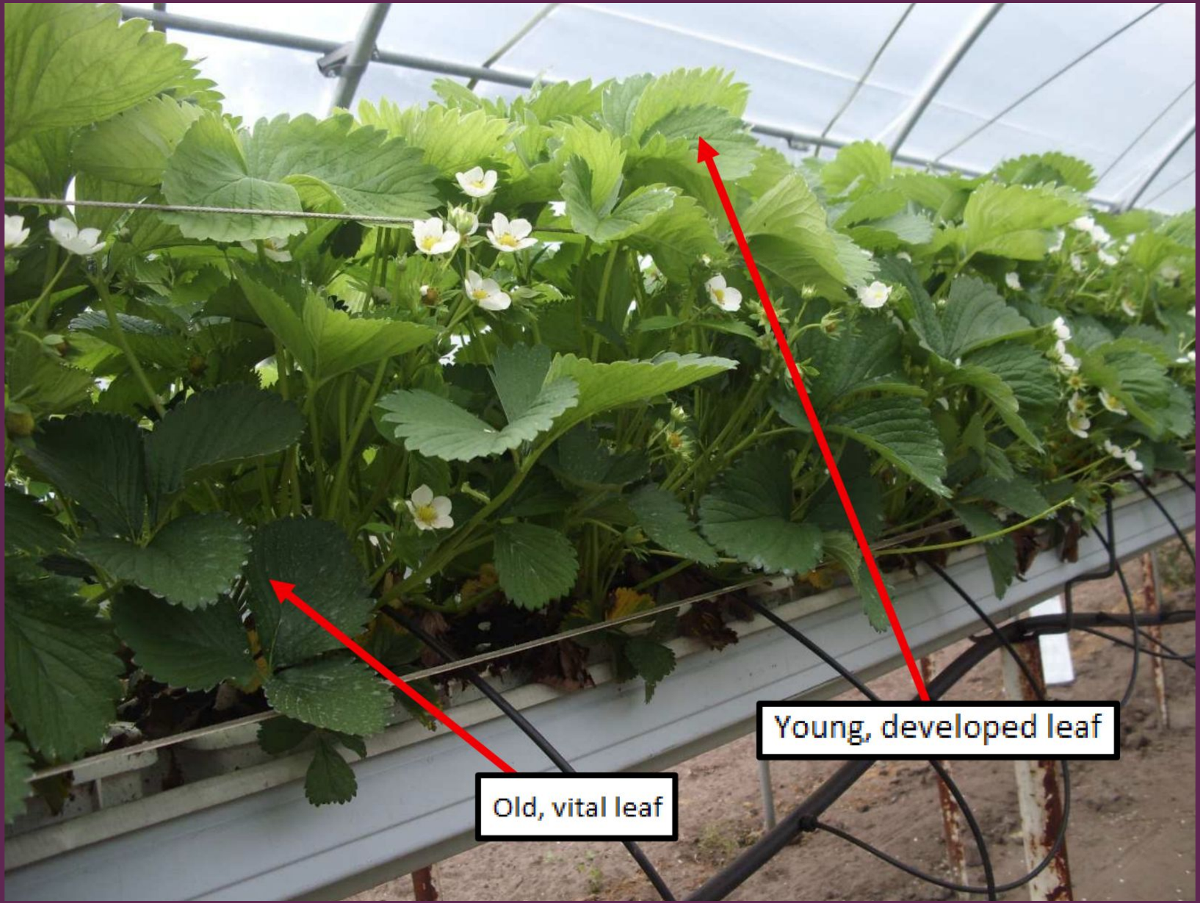
<u>Example Fruiting Crops:</u>

After pollination Ca demand rises

After fruit set K demand rises

These are critical points of influence

Young vs. old leaves



Sample leaves separately (100 g wet weight)

Only sample healthy leaves

Crop Specific Manuals

Young and old leaves measured separately

Good plants > poor plants

Leaves without petioles

Avoid collection after rain or if dew is on the samples

Avoid evaporation of sample

Parameters in Plant Sap Analysis

Non-Plant Mineral	Macro	Micro	Beneficial
pH	Nitrogen(NH4, NO3, Total Nitrates)	Iron	Selenium
Sugars Total	Potassium	Molybdenum	Silicon
Brix	Calcium	Manganese	Nickel
Conductivity	Magnesium	Boron	Aluminium
	Sodium	Copper	
	Chloride	Zinc	
		Cobolt	

Interpreting A Plant Sap Analysis

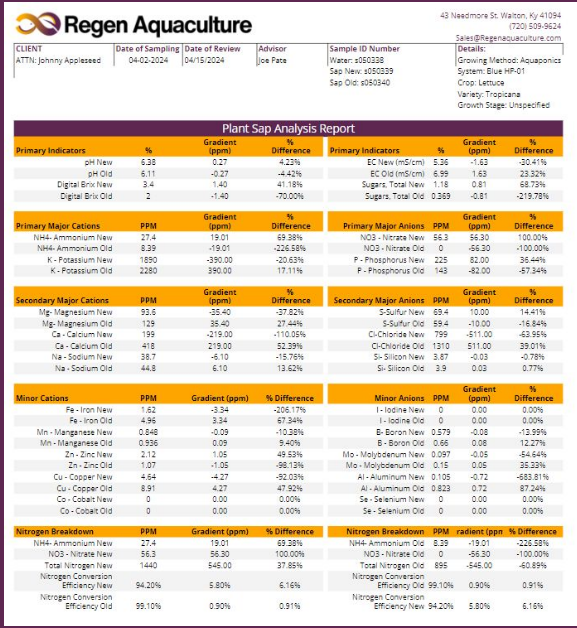
Example report

Primary Major Cations	PPM	Gradient (ppm)	% Difference
NH4- Ammonium New	27.4	19.01	69.38%
NH4- Ammonium Old	8.39	-19.01	-226.58%
K - Potassium New	1890	-390.00	-20.63%
K - Potassium Old	2280	390.00	17.11%

Primary Major Anions	PPM	Gradient (ppm)	% Difference
NO3 - Nitrate New	56.3	56.30	100.00%
NO3 - Nitrate Old	0	-56.30	-100.00%
P - Phosphorus New	225	82.00	36.44%
P - Phosphorus Old	143	-82.00	-57.34%

Secondary Major Cations	PPM	Gradient (ppm)	% Difference
Mg- Magnesium New	93.6	-35.40	-37.82%
Mg- Magnesium Old	129	35.40	27.44%
Ca - Calcium New	199	-219.00	-110.05%
Ca - Calcium Old	418	219.00	52.39%
Na - Sodium New	38.7	-6.10	-15.76%
Na - Sodium Old	44.8	6.10	13.62%

Secondary Major Anions	PPM	Gradient (ppm)	% Difference
S-Sulfur New	69.4	10.00	14.41%
S-Sulfur Old	59.4	-10.00	-16.84%
Cl-Chloride New	799	-511.00	-63.95%
Cl-Chloride Old	1310	511.00	39.01%
Si- Silicon New	3.87	-0.03	-0.78%
Si- Silicon Old	3.9	0.03	0.77%



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CLIENT	Date of Sampling	Date of Review	Advisor	Sample ID Number	Details:
ATTN: Johnny Appleseed	04-02-2024	04/15/2024	Joe Pate	Water: s050338 Sap New: s050339 Sap Old: s050340	Growing Method: Aquaponics System: Blue HP-01 Crop: Lettuce Variety: Tropicana Growth Stage: Unspecified

Plant Sap Analysis Report

Primary Indicators	%	Gradient (ppm)	% Difference
pH New	6.38	0.27	4.23%
pH Old	6.11	-0.27	-4.42%
Digital Brix New	3.4	1.40	41.18%
Digital Brix Old	2	-1.40	-70.00%

Primary Indicators	%	Gradient (ppm)	% Difference
EC New (mS/cm)	5.36	-1.63	-30.41%
EC Old (mS/cm)	6.99	1.63	23.32%
Sugars, Total New	1.18	0.81	68.73%
Sugars, Total Old	0.369	-0.81	-219.78%

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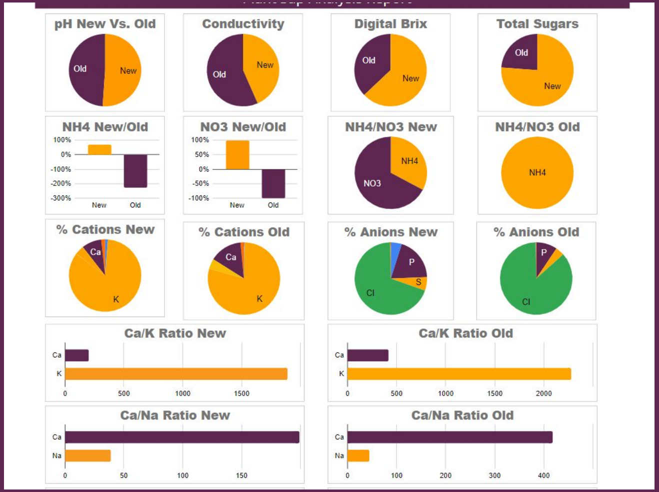
Secondary Major Anions	PPM	Gradient (ppm)	% Difference
S-Sulfur New	69.4	10.00	14.41%
S-Sulfur Old	59.4	-10.00	-16.84%
Cl-Chloride New	799	-511.00	-63.95%
Cl-Chloride Old	1310	511.00	39.01%
Si- Silicon New	3.87	-0.03	-0.78%
Si- Silicon Old	3.9	0.03	0.77%

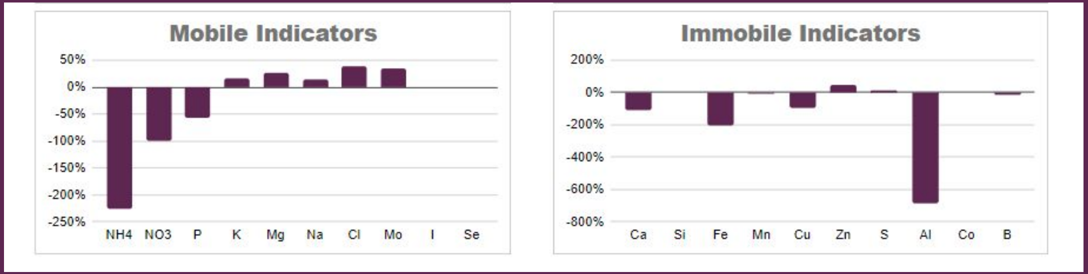
Minor Cations	PPM	Gradient (ppm)	% Difference
Fe - Iron New	1.62	-3.34	-206.17%
Fe - Iron Old	4.96	3.34	67.34%
Mn - Manganese New	0.848	-0.09	-10.38%
Mn - Manganese Old	0.936	0.09	9.40%
Zn - Zinc New	2.12	1.05	49.53%
Zn - Zinc Old	1.07	-1.05	-98.13%
Cu - Copper New	4.64	-4.27	-92.03%
Cu - Copper Old	8.91	4.27	47.92%
Co - Cobalt New	0	0.00	0.00%
Co - Cobalt Old	0	0.00	0.00%

Minor Anions	PPM	Gradient (ppm)	% Difference
I - Iodine New	0	0.00	0.00%
I - Iodine Old	0	0.00	0.00%
B- Boron New	0.579	-0.08	-13.99%
B - Boron Old	0.66	0.08	12.27%
Mo - Molybdenum New	0.097	-0.05	-54.64%
Mo - Molybdenum Old	0.15	0.05	35.33%
Al - Aluminum New	0.105	-0.72	-683.81%
Al - Aluminum Old	0.823	0.72	87.24%
Se - Selenium New	0	0.00	0.00%
Se - Selenium Old	0	0.00	0.00%

Nitrogen Breakdown	PPM	Gradient (ppm)	% Difference
NH4- Ammonium New	27.4	19.01	69.38%
NO3 - Nitrate New	56.3	56.30	100.00%
Total Nitrogen New	1440	545.00	37.85%
Nitrogen Conversion Efficiency New	94.20%	5.80%	6.16%
Nitrogen Conversion Efficiency Old	99.10%	0.90%	0.91%

Nitrogen Breakdown	PPM	radient (ppn	% Difference
NH4- Ammonium Old	8.39	-19.01	-226.58%
NO3 - Nitrate Old	0	-56.30	-100.00%
Total Nitrogen Old	895	-545.00	-60.89%
Nitrogen Conversion Efficiency Old	99.10%	0.90%	0.91%
Nitrogen Conversion Efficiency New	94.20%	5.80%	6.16%





Primary Indicators - Total Sugars

- Total Sugars (TS) is a general indicator of plant health and vigor.
- Higher TS is usually indicative of good Calcium uptake and crops with desirable qualities (health, yield, flavor, shelf life, etc.).
- Generally, as TS increases, insect and disease pressure decrease.

Primary Indicators	%	Gradiant (ppm)	% Difference
Qualitative Brix New	15.4	0.20	1.30%
Qualitative Brix Old	15.2	-0.20	-1.32%

Primary Indicators	%	Gradiant (ppm)	% Difference
Digital Brix New	15.5	0.10	0.65%
Digital Brix Old	15.4	-0.10	-0.65%

Primary Indicators - Leaf Extract pH

Primary Indicators	%	Gradiant (ppm)	% Difference
pH New	5.5	-0.10	-1.82%
pH Old	5.6	0.10	1.79%

- Lower pH readings usually indicate low levels of light, low microbial activity, a low concentration of cations, an excess of anions, or too much water.
- High pH often indicates excessive heat, an excess of cations, low total anions, or insufficient water.

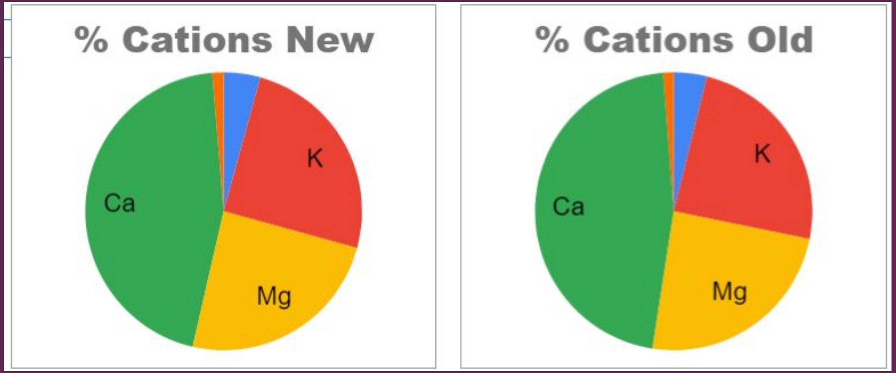
Primary Indicators - Leaf Extract EC

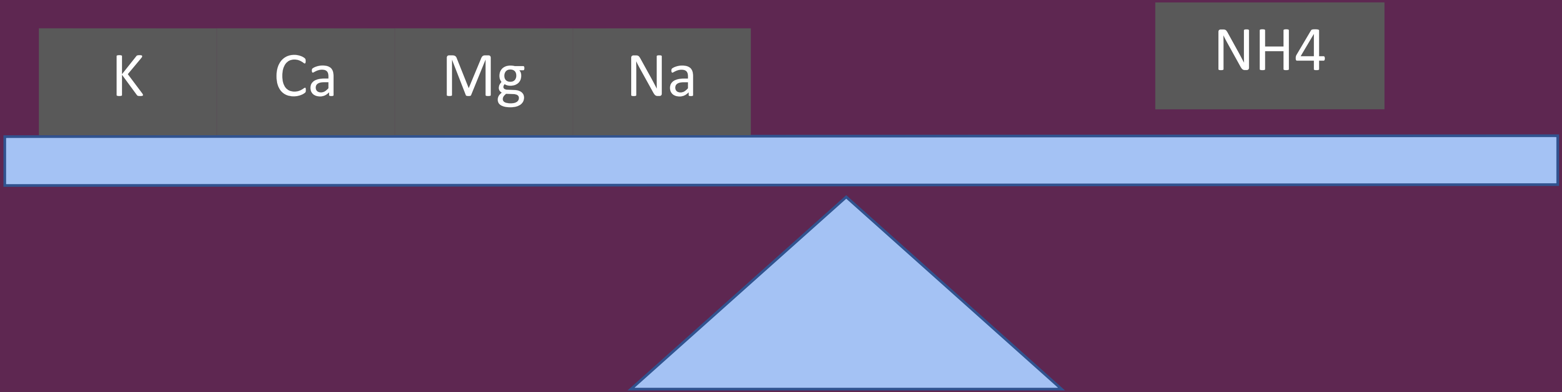
- Electrical Conductivity (EC) should gradually rise through the crop cycle.
- Low EC (< 5 mS/cm) can be caused by excess Phosphorus, Sulfur, compacted soils, or low soil pH.
- High EC (> 18 mS/cm) is often caused by excess Nitrate, Potassium, loose soils, or high soil pH.

Primary Indicators	%	Gradiant (ppm)	% Difference
EC New (mS/cm)	8.94	0.09	1.01%
EC Old (mS/cm)	8.85	-0.09	-1.02%

Cations

- All about balance
- Sufficient numbers in the soil/water is no guarantee for a balanced uptake
- One cation increases another decreases
- One cation decreases another increases





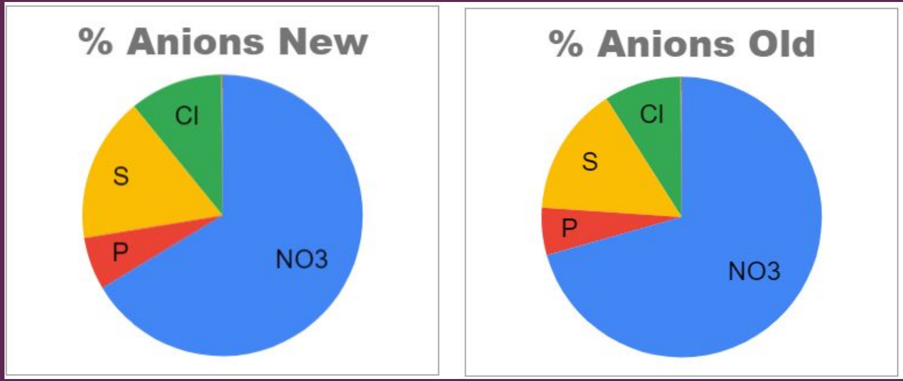
Anions

Same as Cations all about balance

For Ex.

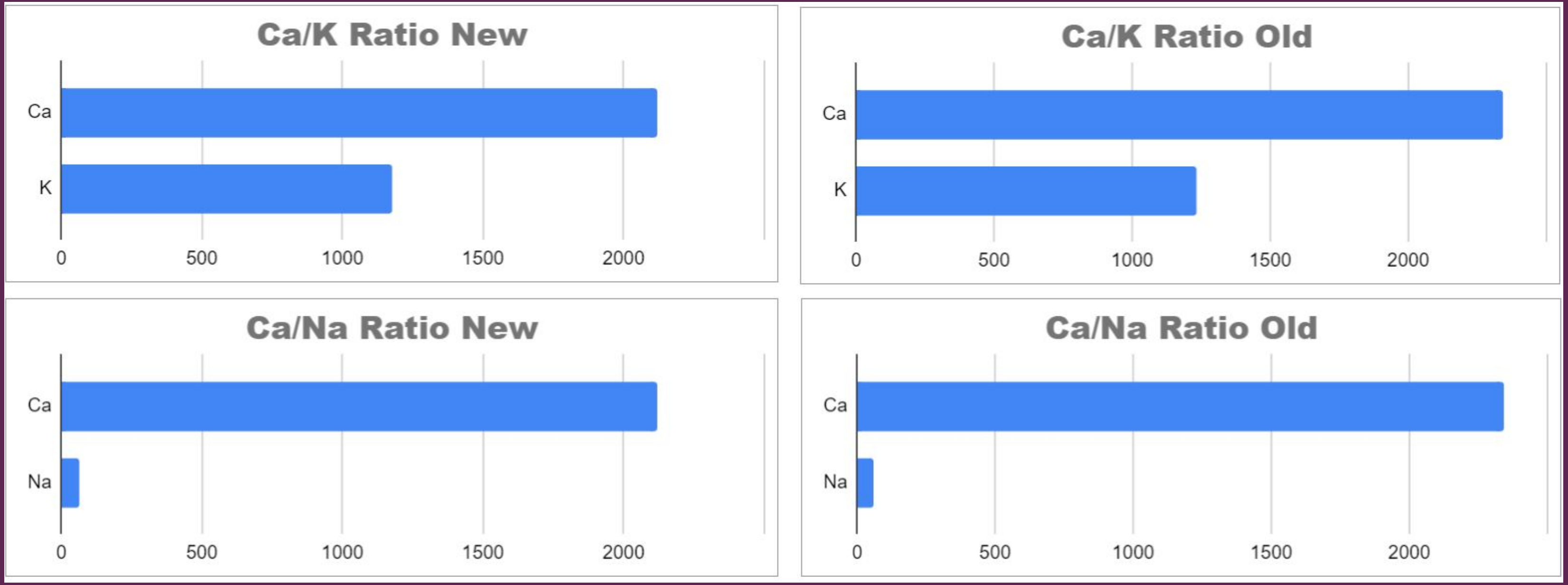
Reduction of NO3 improves P uptake.

Too much Cl will reduce uptake of P, NO3, S.



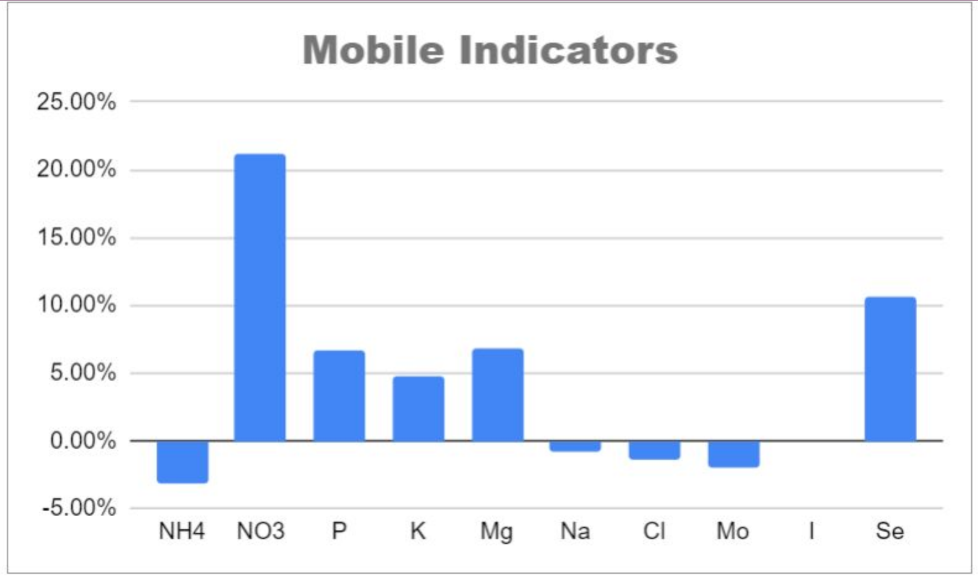
Nutrient Ratios

Nutrient Ratios Help with Antagonistic and Synergistic Relations, graphs indicate visual representation



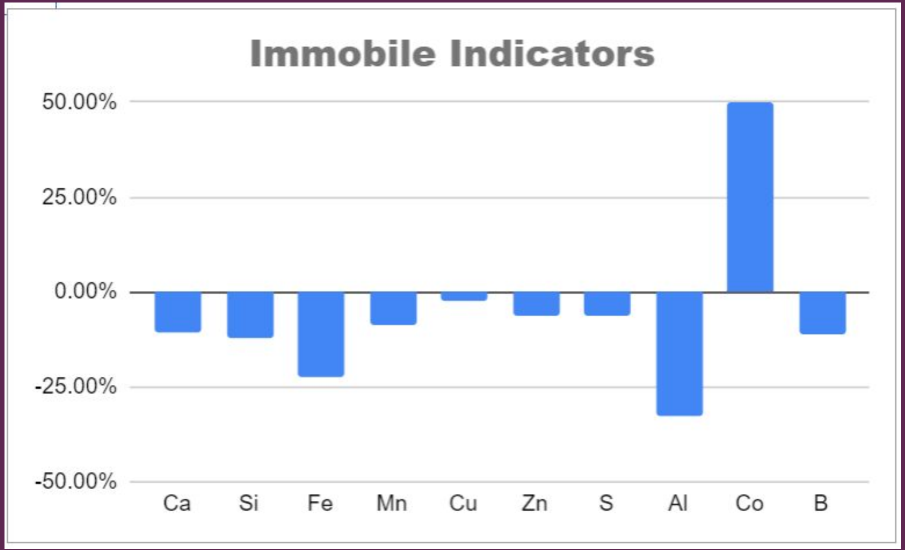
Mobile Nutrients (Phloem)

- Deficiencies of mobile nutrients are indicated by lower ppm readings in old leaves compared to new leaves due to nutrient translocation to new growth as compensation.
- These deficiencies can be caused by excessive levels of competing nutrients (antagonism), relative soil deficiencies, or low microbial activity in soil.
- An excess of mobile nutrients is indicated by higher ppm readings in old leaves compared to new leaves.
- Excesses are often caused by over-fertilization, loose soil, soil type, or plant bioaccumulation.

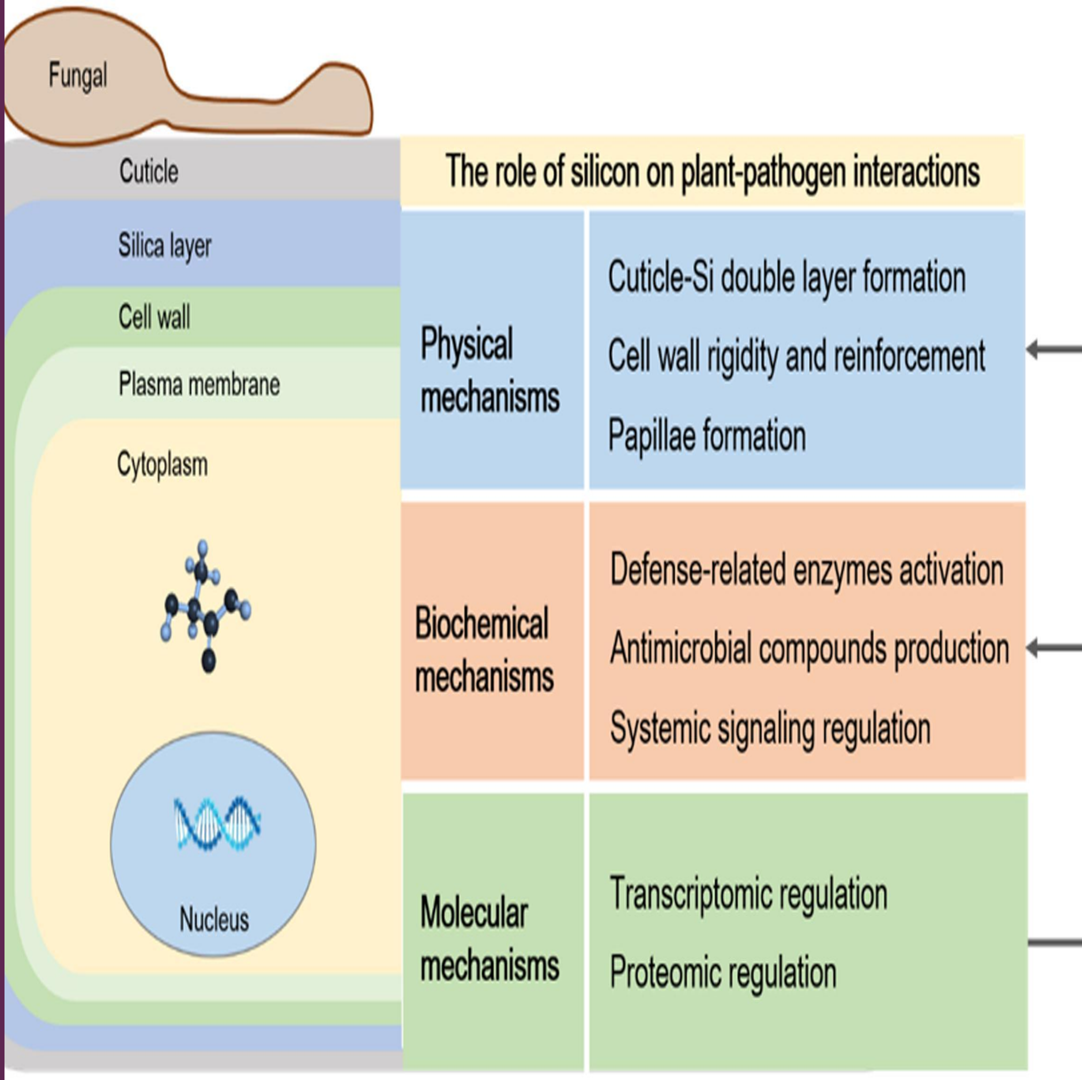


Immobile Nutrients (Xylem)

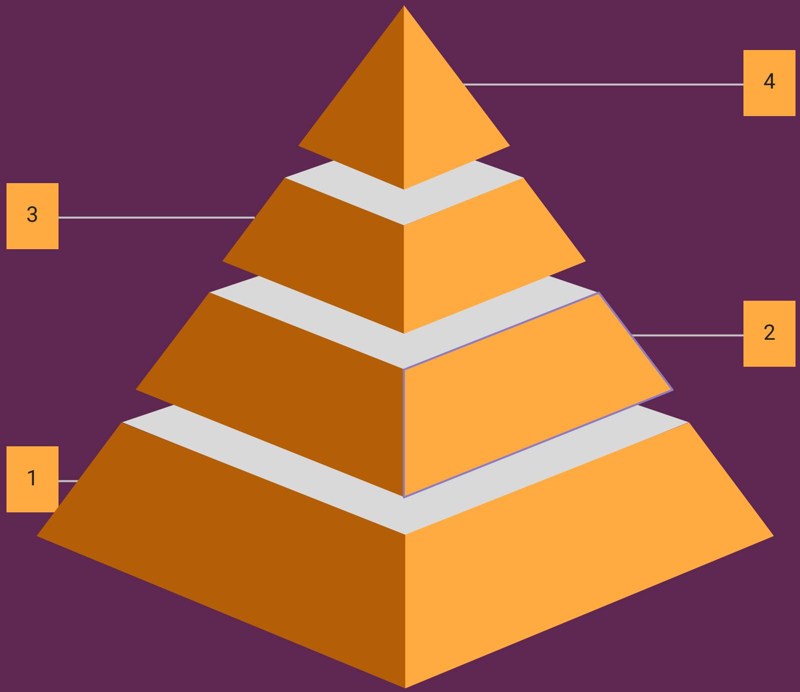
- Deficiencies of immobile nutrients are indicated by lower ppm readings in new leaves compared to old leaves, as the plant is unable to transport immobile nutrients to new growth.
- Deficiencies are often caused by improper pH, temperature, ORP, soil-compaction, or antagonism.
- Deficiencies often occur during periods of rapid growth, low micronutrient soil levels, and low microbial activity.
- An excess of immobile nutrients is indicated by higher ppm readings in new leaves compared to old leaves.
- Excesses are often caused by soil type and/or low pH.



Increasing Pest and Disease Resistance With Plant Sap



The Plant Health Pyramid



Increased Lipid Synthesis

Increasing microbial metabolites leads to increasing lipid production and stored in the form of waxes and oils

Complete Carbohydrate Synthesis

Shifting the carbohydrate profile to more complex carbohydrates and fewer non-reducing sugars

Increased Plant Secondary Metabolite Synthesis

Increases in lipids allows for greater production of PSM which enhance plant immune pathways (SAR and ISR)

Complete Protein Synthesis

Conversion of free nitrogen compounds into amino acids peptides, polypeptides, and proteins.

Complete Photosynthesis

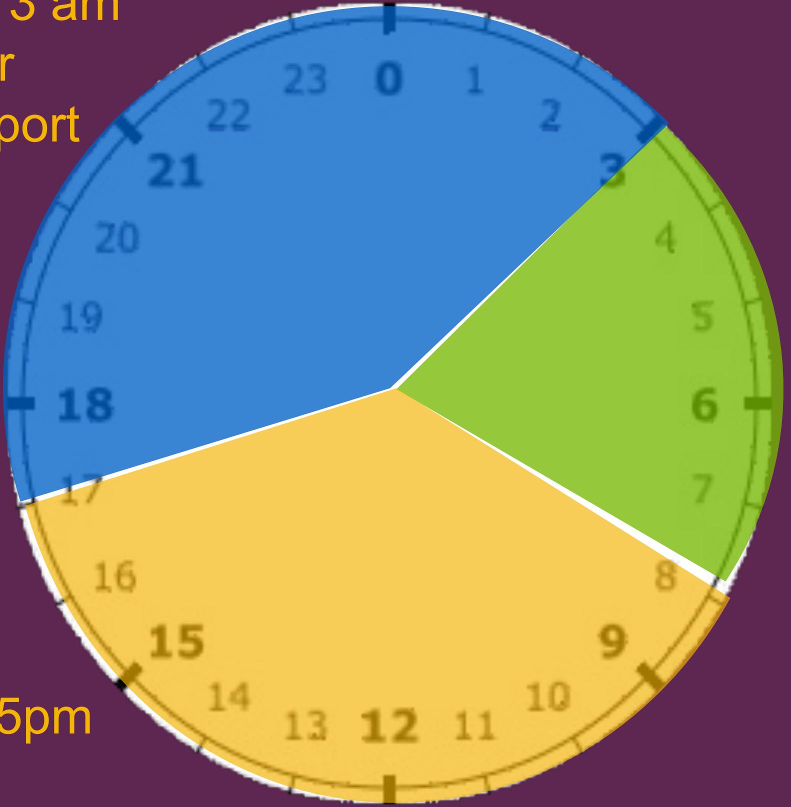
AKA: Complete Carbohydrate Synthesis

Refers to the shifting the carbohydrate profile of the plants from simple sugars (monosaccharides, disaccharides) into complex sugar carbohydrates (oligosaccharides, polysaccharides)

Carbohydrate Synthesis

24 Hour Cycle
C3 Plants

5pm - 3 am
Sugar
Transport



3am - 8 am
Cell
Division and
Sugar
Utilization

8am- 5pm
Peak
Photosynthesis

Three forms of Carbohydrate Metabolism- C3, C4, and Crassulacean acid metabolism (CAM)

C3- MAJORITY OF ALL PLANTS; REQUIRE A NIGHT TIME PERIOD FOR CARBON METABOLISM

C4- ~3% OF ALL PLANTS; ABLE TO WITHSTAND SHORTER DARK PHOTOPERIODS AT THE EXPENSE OF EXTRA ENERGY.
THIS IS A NET POSITIVE GAIN

CAM- SUCCULENTS AND PLANTS THAT DEVELOPED IN ARID REGIONS. PHOTOSYNTHESIS ONLY OCCURS AT NIGHT; CAN BE STIMULATED BY WATER

Factors Affecting Photosynthesis

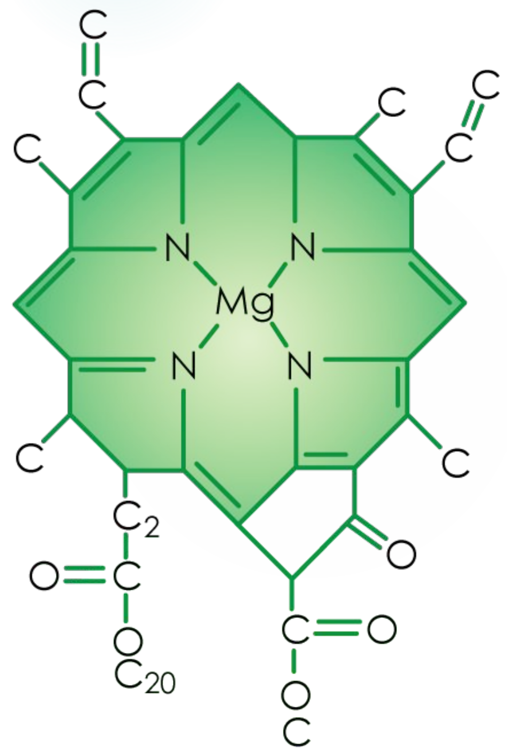
- Light availability
- Water availability
- Vapor pressure deficit
- Available carbohydrate sources in the soil or growing media
- Air Temperature
- Water Temperature
- Relative Humidity
- Available nutrients
- Stress

Factors Affecting Photosynthetic Capacity

- Leaf thickness; creates more storage area inside the leaf
- Width: length ratio of the leaves
- Concentration of chloroplasts
- Quantity of chlorophyll within each chloroplast

Key Minerals for Complete Carbohydrate Synthesis

- Magnesium- Center ion for chlorophyll
- Nitrogen- Surrounds Mg ion
- Iron- Required for chloroplast synthesis
- Manganese- Required for hydrolysis
- Phosphorus- Required for energy transfer (ATP)
- Trace minerals: Cobalt, Selenium, Zinc, Copper, Boron, Molybdenum, etc. act as a enzyme cofactors



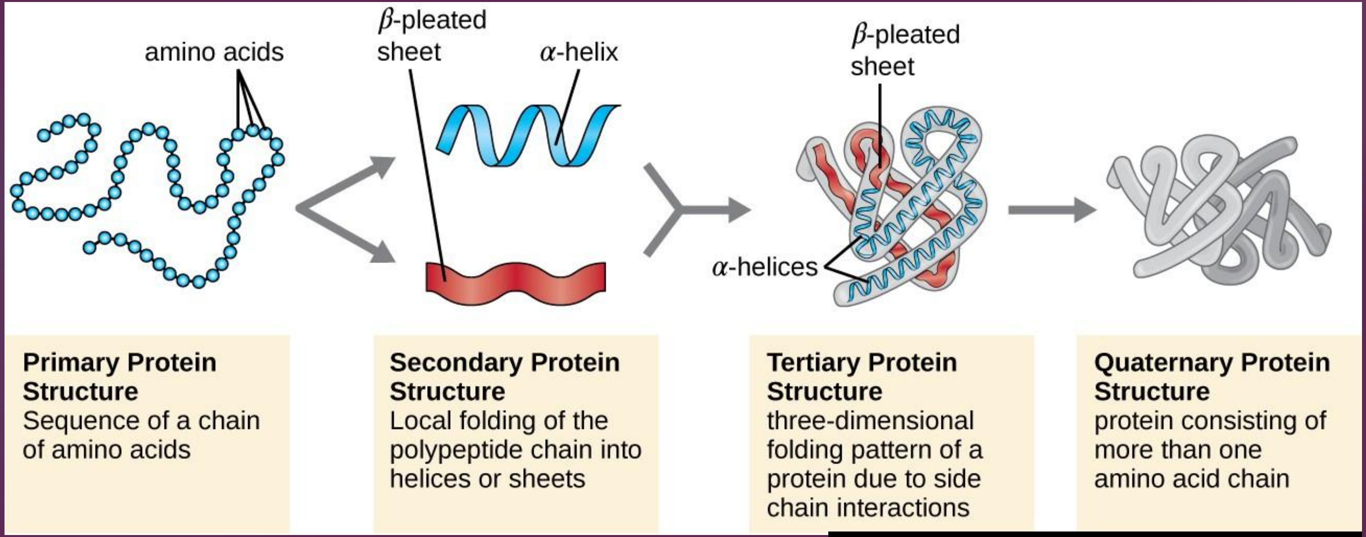
Plant Chlorophyll

Results of Complete Carbohydrate Synthesis

- Carbohydrate Profile = Polysaccharides > monosaccharides
- Increased Brix Levels in early morning just before or after dawn
- Increased amount of sugars sent to roots for storage and to be released as exudates
- Increased Biomass production (Roots and Shoots)
- Increased beneficial microbial populations
- Promotes almost complete resistance to fungal borne soil/root pathogens

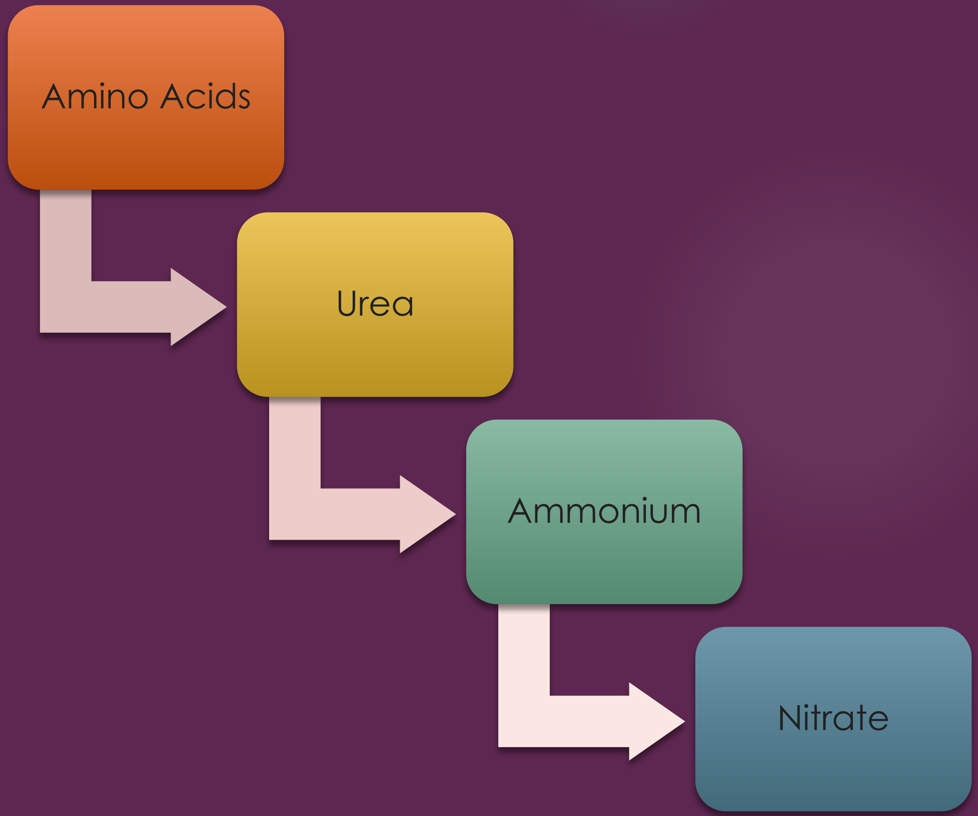
Complete Protein Synthesis

- The complete conversion of basic nitrogen compounds into complex proteins over a 24 hour period



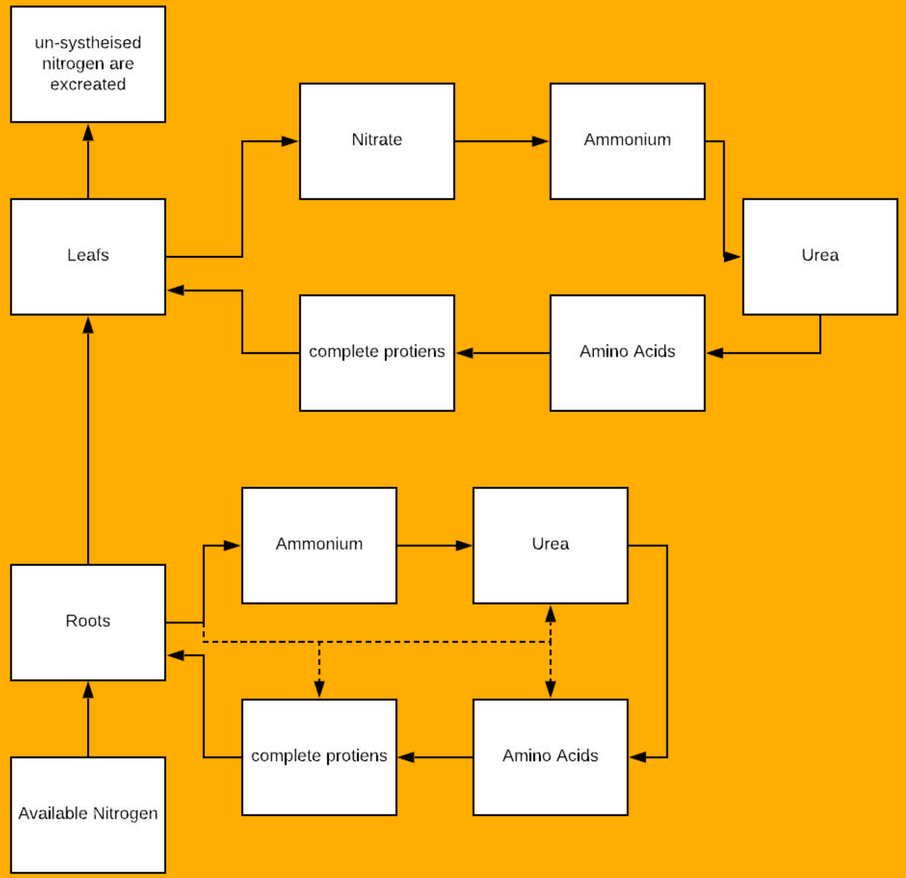
Plant Available Nitrogen

- Preferred sources in most to least preferred



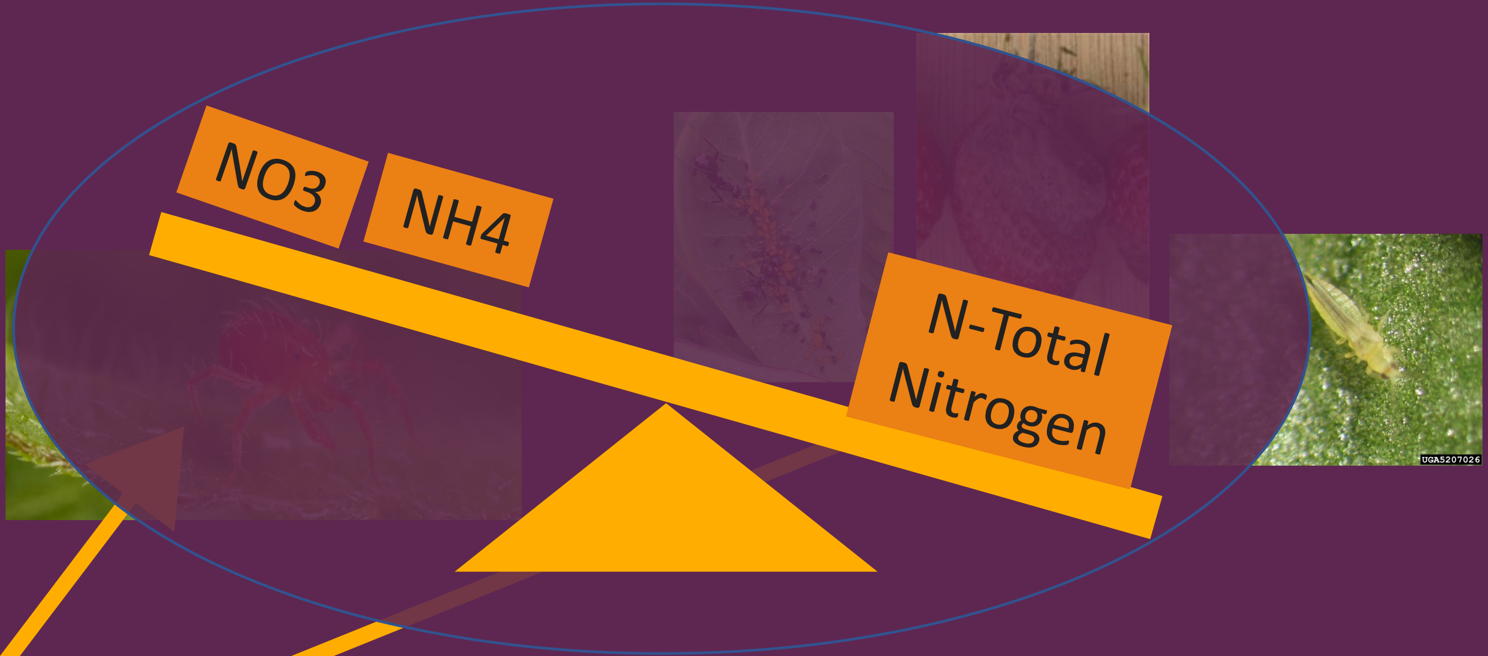
Nitrogen Conversion Efficiency

- The complete conversion of basic nitrogen compounds into complex proteins over a 24 hour period
- Ammonium can be processed directly in the root system; Require Some Energy
- Nitrate must be transported to the leaves via the xylem for processing; Requires Extra Energy
- Amino acids, polypeptides, and complete proteins can be absorbed directly into roots and processed; Energy Positive
- Each step requires enzymes and coenzyme factors



Nitrogen Conversion Efficiency and pest

NH4 - Ammonium	ppm	59	1
	ppm	47	2
NO3 - Nitrate	ppm	418	1
	ppm	2517	2
N in Nitrate	ppm	94	1
	ppm	568	2
N - Total Nitrogen	ppm	691	1
	ppm	1053	2



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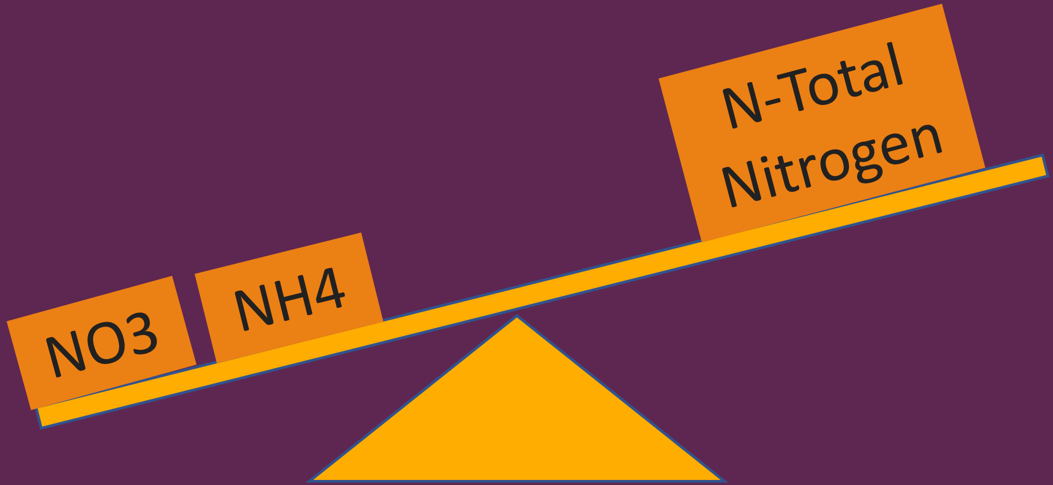


NH4 - Ammonium	ppm	5	1
	ppm	7	2
NO3 - Nitrate	ppm	185	1
	ppm	220	2
N in Nitrate	ppm	45	1
	ppm	65	2
N - Total Nitrogen	ppm	1120	1
	ppm	1250	2

Factors affecting Protein Synthesis

ENVIRONMENTAL STRESS

CARBOHYDRATE SUPPLY

AVAILABLE NUTRIENTS

Key Minerals for Complete Protein Synthesis

- Molybdenum- Coenzyme factor required for Nitrate Reductase
- Magnesium- Coenzyme factor required for multiple protein synthesis pathways
- Sulfur- Required for sulfur bearing amino acids (Methionine, cystine, and taurine)
- Boron- Increases resistance against soft-shelled insects

*When stressed additional carbohydrates may be required for protein synthesis

Results of Complete Protein Synthesis

- Plant Sap Analysis will show ZERO Ammonium and Nitrate at the end of a 24-cycle
- Free-nitrogen are converted into indigestible peptides and complete proteins
- Plants will develop resistance to soft bodied insects including all insects with a larval stage, spider mites, aphids, whiteflies, fungus gnats, cabbage loopers etc.
- Plants develop resistance to nematodes

Complete Lipid Synthesis

- Refers to increasing energy surplus for plants; allows for greater energy storage in the form lipids (Fats and oils)

Understanding Lipid Synthesis

- Inorganic minerals taken up require energy to process into usable forms
- Organic nutrients, chelating compounds, and other microbial metabolites are excreted from bacteria and fungi these require no energy to process and often provide surplus energy to the plant
- 100% Dependent on the microbiome of the system

Increasing Lipid Synthesis

Synbiotics- A mix of both!

Probiotics- Predominantly Plant Growth Promoting Microorganisms (PGPMO)

- Bacteria
- Fungi
- Protozoa

Prebiotics- food sources for microorganisms

- Fermented Goods
- Simple and Complex Sugars
- Amino acids, natural chelating compounds, hormones, etc

Lipid Storage

Increased levels of fats and oils in leaves, and seeds

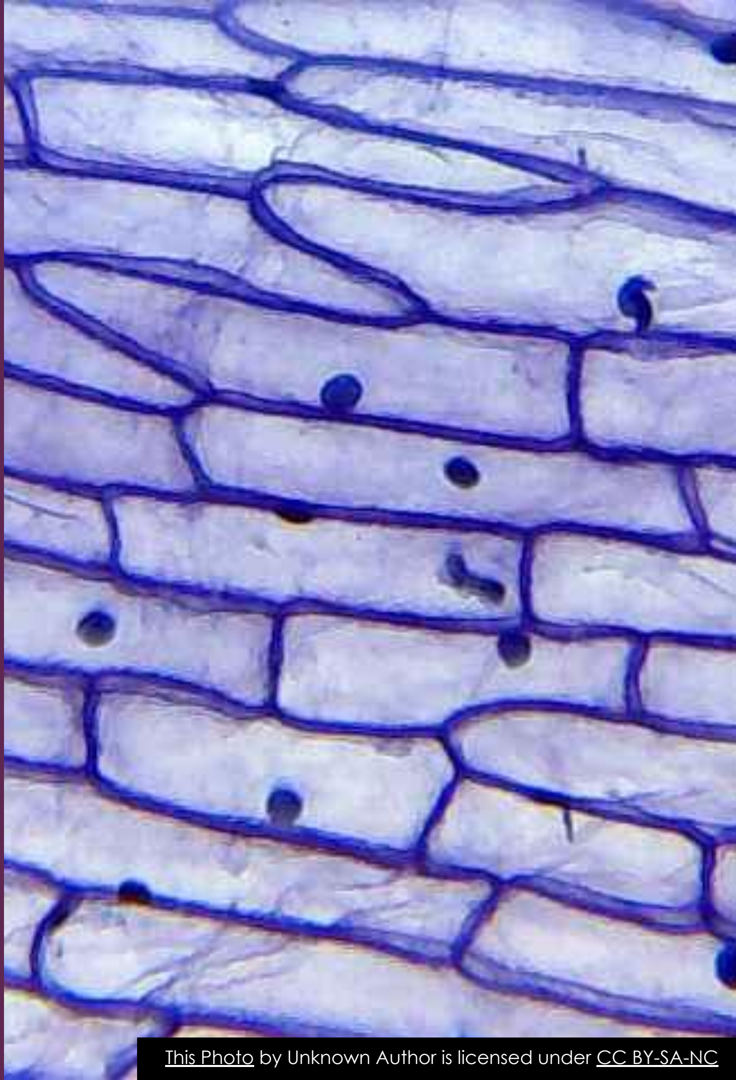
Increased levels in root and in root exudates exudates

Results of Complete Lipid Synthesis

- Thicker wax layer on leaves
- A shift from higher amounts of violate Omega-3 to more stable Omega-6 and Omega-9 Fatty acids
- Increased seed longevity
- Increased shelf-life
- Rapidly improves soil biology
- Rapidly improves organic matter growth in soil (up to 0.5% per year)
- Increased levels of fats and oils in leaves, and seeds
- Increased levels of Boron, Silicon, and Calcium
- Increased levels in root and in root exudates

Results of Complete Lipid Synthesis (Cont.)

- Health wax layer on leaves makes it less likely to hold moisture
- Fungi and bacteria can't penetrate the waxy layer
- Creates a barrier between plants and bacteria and fungi without hurting either
- Increase beneficial bacteria and fungal populations on leaves creating an undesirable home for pathogens
- Near complete resistance to airborne-fungal, and bacterial pathogens

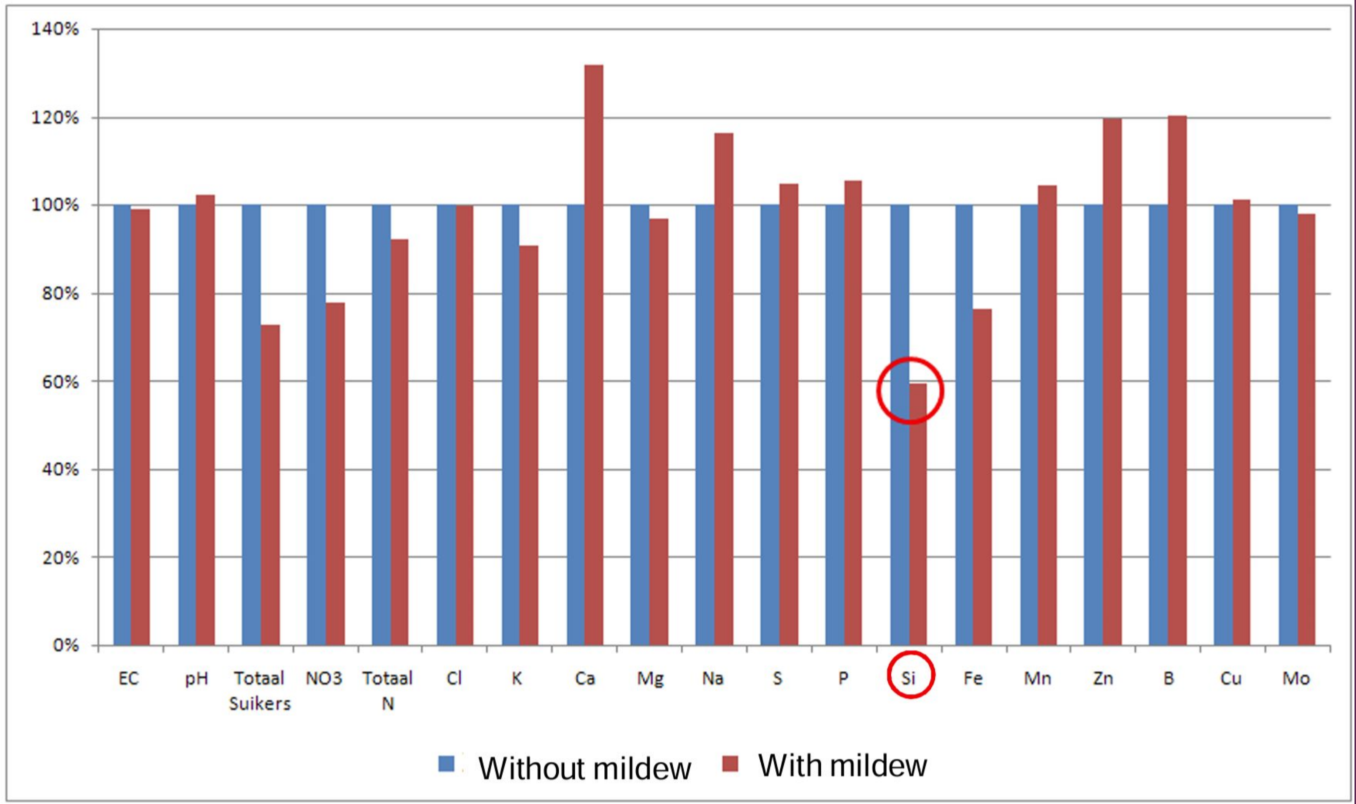


Mildew and Nutrition

Strawberry Production

- 1 field
- Same soil
- Same fertilization
- Two different species

Improving Resistance to powdery mildew



Plant Secondary Metabolite (PSM) Synthesis

Increased nutrition allows of higher productions of secondary metabolites; these are the foundation of ISR

↓

100% Dependent on the microbiome of the system

Group	Compounds present	Main Features	Pharmaceutical properties
Alkaloids	Hormones, carotenoid pigments, sterols, latex and essential oils	Group of major importance with more than 40,000 molecules, they are considered of importance for the survival of plants. They are insoluble in water and are derived from the union of isoprene units	Anticarcinogenic, antiulcerous, antimalarial, antimicrobial, etc.
Phenolic compounds	Coumarins, flavonoids, lignin and tannins.	They are derived from a phenol group	Antidiarrheals, antitumorals, antibacterials, antivirals and enzyme inhibitors (Isaza, 2007)
Glycosides	Saponins, cardiac glycosides, cyanogenic glycosides and glucosinolates.	They arise from the condensation of a sugar molecule with another containing a hydroxyl group, thus forming a glycosidic bond	Antimicrobials, fungicides, insecticides, anticancer, anti-inflammatory and allelopathic (Agustín *et al.*, 2011)
Terpenes	Quinoline, isoquinoline, indole, tropane, quinolizidine, piperidine, purine, pyrrolizidene.	Group with about 15000 secondary metabolites. They are soluble in water, contain at least one nitrogen atom and exhibit biological activity. Most	At high doses, most are very toxic, however, at low doses they work as muscle relaxants, tranquillizers, antitussives

(Hernández-Alvarado, Jerelly 2018)

Results of Secondary Metabolite Synthesis

Total Volume of PSM can be increased 3-4 x or more

Enhance the immune system of the plants and the animals that consume them

Increased flavor, color, and aroma development

Promotes growth of truly nutritious Bio-fortified food

Promotes Beneficial bacteria, fungia, protozoa, and nematodes, etc; Suppresses pathogenic ones

Promotes hormone stability and strong cytokinin production

Results of Secondary Metabolite Synthesis (Cont.)

Suppresses adult beetles and mites (Colorado potato beetle, Japanese beetles, cucumber beetle, corn rootworm beetle, etc)

Increased resistance to bacterial and Viral infections (sudden death syndrome, citrus greening,etc)

Managing Plant Nutrition

Knowing Your Nutrients

Xylem tissue: facilitates movement of water and nutrients upward to photosynthetic sites.

Phloem tissue: facilitates movement of photosynthates from sites of photosynthesis to the rest of the plant.

Deficient – when the concentration of an essential element is low enough to severely limit yield

Critical range – that range of nutrient concentration above which we are reasonably confident the crop is amply supplied and below which we are reasonably confident the crop is deficient.

Sufficient (optimal) – nutrient concentration range when the yield will not increase when more of the essential nutrient is added, but plant tissue concentration can increase

Excessive (toxic) – when the concentration of an essential, or non-essential, element is high enough to reduce plant growth and yield

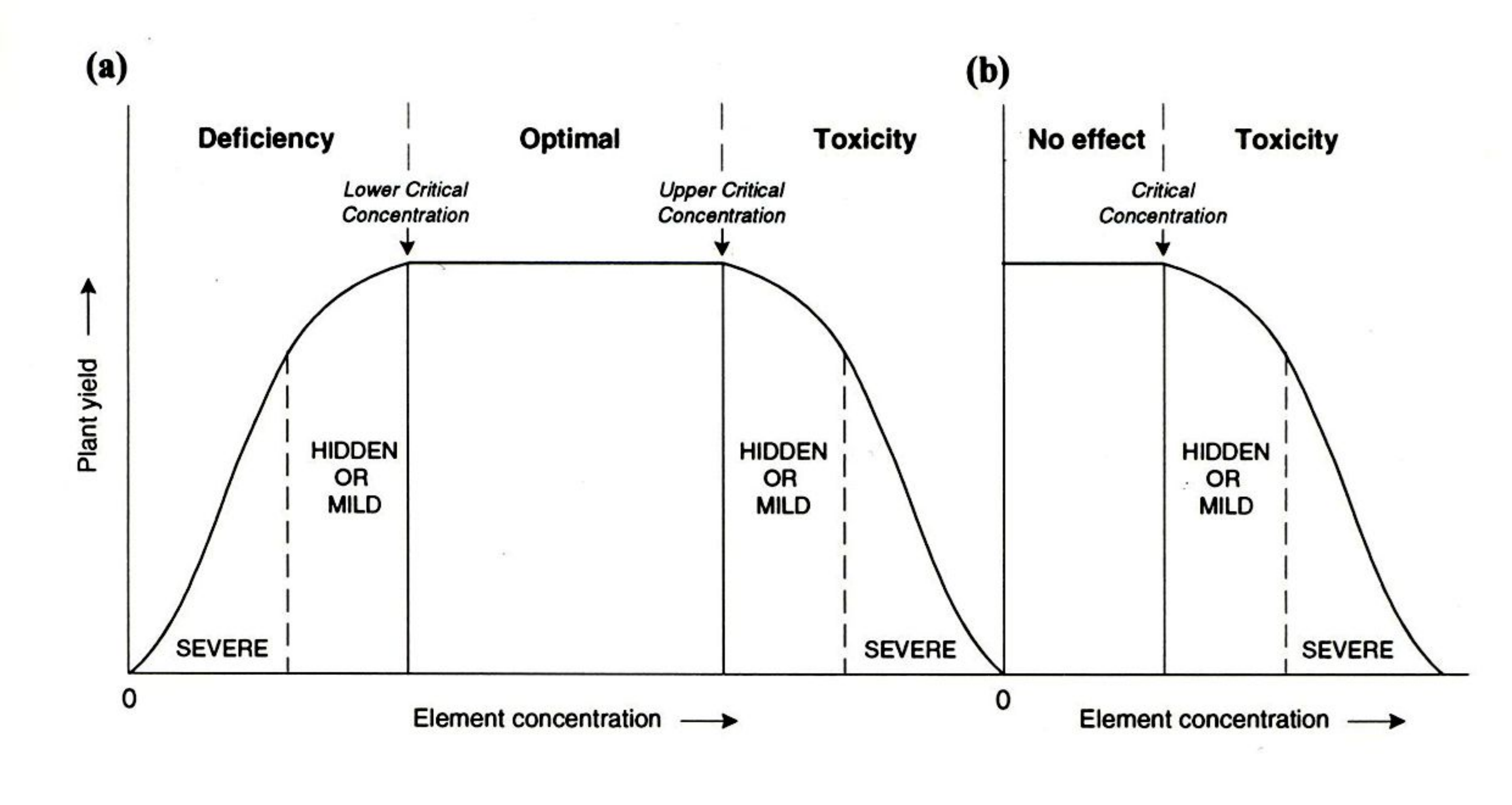


Figure 2.5. Typical dose-response curves for (a) essential elements (macronutrients & micronutrients) and (b) non-essential elements. (Alloway,1995, p. 31)

Terms used to describe nutrient levels in plants

Macroelements

- Carbon (C)
- Hydrogen (H)
- Oxygen (O)
- Nitrogen (N)
- Phosphorous (P)
- Potassium (K)
- Calcium (Ca)
- Sulfur (S)
- Magnesium (Mg)

Microelements

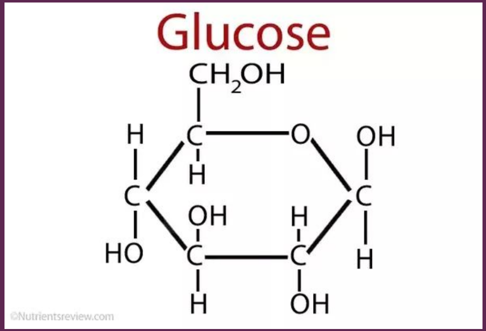
- Iron (Fe)
- Chlorine (Cl)
- Manganese (Mn)
- Boron (B)
- Zinc (Zn)
- Copper (Cu)
- Molybdenum (Mo)

The 16 essential minerals marco/micro elements as of 1954

Carbon (C)

- Comes from the air
- Critical for photosynthesis
- Plants use CO_2 to create sugars

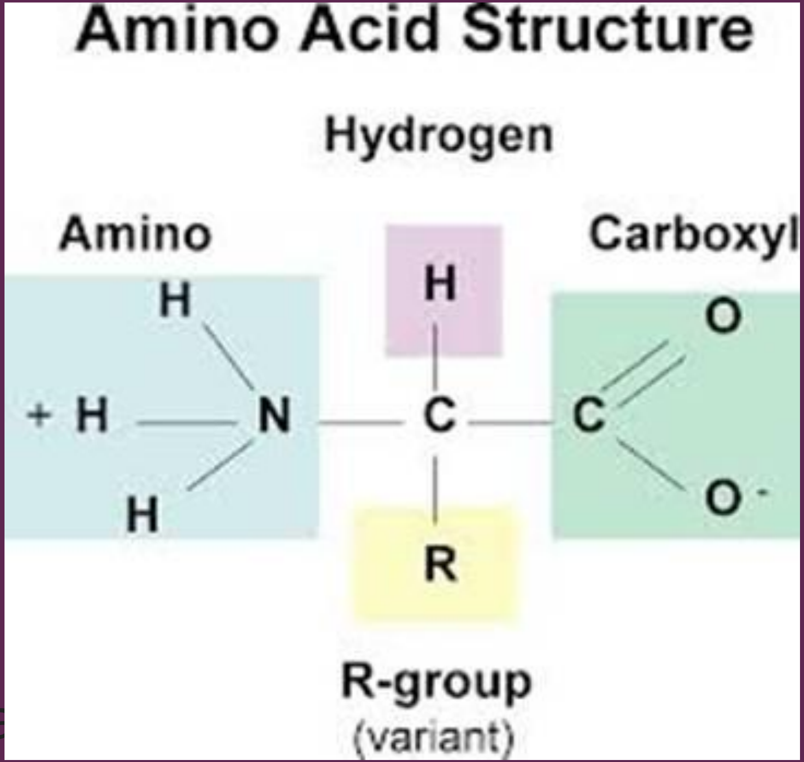
$6\ CO_2 + 6\ H_20 + \text{light}$ □ $C_6H_{12}O_6 + 6\ O_2$



Hydrogen (H_2)

- Comes from water (H_2O) & mineral nutrients (Ex. KH_2PO_4)
- is a constituent of carbohydrates, proteins, amino acids, fats, etc.

Hea



Oxygen (O)

- **Comes from air (O_2), water (H_2O) & mineral A**(Ex. $MgSO_4$, KH_2PO_4, KNO_3)
- **Critical for respiration**
- **Plants use O_2 to break down sugars to create energy.**

$C_6H_{12}O_6 + \underline{O}_2$ □ $CO_2 + H_2O$ + Energy

Healthy roots

Nitrogen (N)

- Elemental nitrogen from the air cannot be used by plants. It must be "fixed" into nitrate or ammonium first.

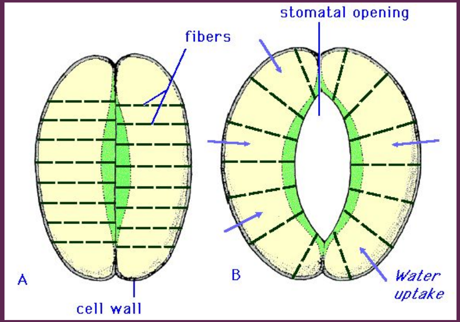
- Comes from minerals (Ex. KNO_3, $Ca(NO_3)_2$, NO_3^-, NH_4^+)
- Critical to photosynthesis, part of chlorophyll molecule, stimulates stem and leafy growth
- Part of every amino acid, protein, RNA, DNA molecule
- Helps in the utilization of other nutrients (P, K)

Phosphorus (P)

- Comes from KH_2PO_4
- Critical for "energy", cell development
- Encourages root growth, rapid and strong shoot growth, and resistance to disease
- Stimulates blooming, promotes maturing of plant
- Part of many important organic compounds including sugar phosphates, ATP, nucleic acids, phospholipids, and certain co-enzymes.

Potassium (K)

- Comes from KH_2PO_4, KNO_3, K_2SO_4
- Catalyst/activator for enzymes
- Encourages root development, strong stems, vigor/health, protein development
- Regulates plant metabolism and water pressure
- Controls stomates, triggers open/close

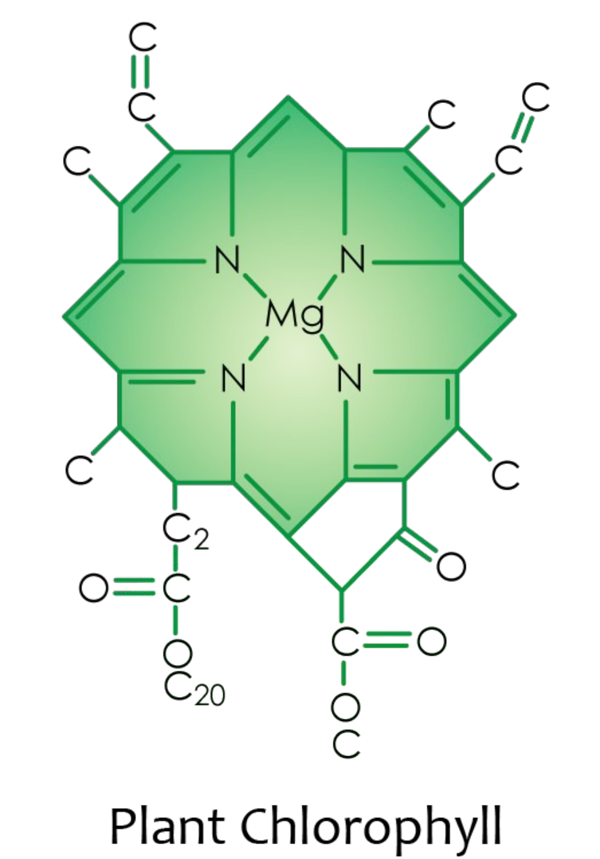


Calcium (Ca)

- Comes from $Ca(NO_3)_2$, source water
- Important part of cell walls: "Cements", cross-links between cells to enhance vigor and strength
- Needed in large amounts for fruit development (or blossom end rot occurs)
- Enzyme activator; Membrane integrity

Magnesium (Mg)

- Comes from $MgSO_4$
- Critical for photosynthesis
- Mg is the heart of the chlorophyll molecule
- Enzyme activator
- ATP bond breakage.
- Essential to maintaining ribosomal structure



Sulfur (S)

- **Comes from** K_2SO_4 ,$MgSO_4$, $ZnSO_4$
- **Integral part of 2 amino acids, which are building blocks for proteins.**
- **These proteins are critical to all metabolic processes of the plant cell.**

Iron (Fe)

- **Comes from** ferrous sulfate, ferric chloride, iron chelate, foliar application
- **Critical for photosynthesis, chlorophyll synthesis**
- **Critical for respiration and protein synthesis**
- **Enzyme activator**

Manganese (Mn)

- **Comes from** $MnCl_2$, $MnSO_4$, foliar spray, chelate
- **Critical for photosynthesis, important for energy storage and production of oxygen**
- **Enzyme activator**
- **Oxidizes excess iron**
- **Fatty Acid synthesis, DNA/RNA formation**

Boron (B)

- Comes from Boric acid: H_3BO_3
- Related to metabolism of Ca, K
- Regulates carbohydrate metabolism
- Involved in RNA synthesis
- Flower and Fruit formation

Zinc (Zn)

- Comes from $ZnSO_4$
- Enzyme activator
- Involved in protein, hormone (indoleacetic acid), and RNA/DNA synthesis
- Involved in ribosome complex stability
- Required for the formation of the hormone indoleacetic acid.

Copper (Cu)

- Comes from $CuSO_4$, $CuCl_2$
- Critical to photosynthesis
- 70% of copper is in chloroplasts
- Part of several oxydases
- Electron carrier

Molybdenum (Mo)

- **Comes from** $NaMoO_4$, MoO_3 (abs. as MoO_4)
- **Involved in nitrogen metabolism**
- **Part of nitrogenase**
- **Electron carrier for nitrogen reductase**
- **Involved in carbohydrate metabolism**

Chloride (Cl)

- **Comes from** $MnCl_2$, $CuCl_2$, $CaCl_2$, Source water
- **Enzyme activator to help in release of oxygen from water during photosynthesis**
- **Also involved in respiration**
- **Negatively charged chloride acts as a counter ion to positively charged ions.**
- **Promotes healthy growth**
- **Helps regulate turgor pressure and growth of cells, important in drought resistance**
- **“Macro” levels of $CaCl_2$, or NaCl stresses plant to concentrate salts and sugars for enhanced flavor.**

Genetic Potential

Epigenetics

the study of how your behaviors and environment can cause changes that affect the way your genes work.

Unlike genetic changes, epigenetic changes are reversible and do not change your DNA sequence, but they can change how your body reads a DNA sequence.

What determines genetic expression?

Environment determines genetic expressions

What determines genetic expression?

Environment is climate <u>mediated by nutrition</u>

What determines genetic expression?

“Heredity is nothing more than stored environment”

—Luther Burbank

Was that me or you?

When we get a yield response from something we have done, we have not increased yields. We have kept those yields from being lost.

The foundation of BMP for Fertilizer Application

Right Rate
Right Time
Right Product
Right Place

Interventions Via Nutrient Management

- % Adjustment is inverse of % Gradient
- Always deal with Excess BEFORE Deficiencies
- Calculate fertilization additions same as hydroponics
- Direct Additions Use fish safe fertilizers, avoid high chloride and sodium fertilizers as these accumulate in closed systems

Element	WQ at Time of Sampling	% Gradiant	% Adjustment	New Target Concentration (ppm)
NH4	1	-3.08%	3.08%	1.03
NO3	200	21.12%	-21.12%	157.76
P	40	6.64%	-6.64%	37.35
K	200	4.71%	-4.71%	190.58
Mg	50	6.76%	-6.76%	46.62
Na	65	-0.86%	0.86%	65.56
Cl	50	-1.42%	1.42%	50.71
Mo	0.05	-1.96%	1.96%	0.05
I	0.001	0.00%	0.00%	0.00
Se	0.001	10.59%	-10.59%	0.00
Ca	150	-10.67%	10.67%	166.01
Si	16	-11.89%	11.89%	17.90
Fe	2	-22.52%	22.52%	2.45
Mn	0.5	-8.54%	8.54%	0.54
Cu	0.5	-2.38%	2.38%	0.51
Zn	0.5	-6.01%	6.01%	0.53
S	100	-6.43%	6.43%	106.43
Al	0.0001	-32.64%	32.64%	0.00
Co	0.003	50.00%	-50.00%	0.00
B	0.5	-11.09%	11.09%	0.56

Creating Bounds

- For macros
  - If >40%, 25%
  - If >25%, 12.5%,
  - If <25%, 0
- For Micros
  - If >=40%, 50%
  - If >=30%, 25%
  - If <30%, 0

Comparison of Water Quality vs. Plant Sap

Element	WQ at Time of Sampling (ppm)	Gradient (%)	Adjustment (%)	Predicted Target Concentration (ppm)
NO3-N	48.2	-46.83%	25.00%	60.25
NH4-N	0	-122.64%	25.00%	0.00
Ca	116	-120.61%	25.00%	145.00
K	51	20.76%	0.00%	51.00
Mg	16.2	13.56%	0.00%	16.20
Na	24.9	13.97%	0.00%	24.90
S	56	22.05%	0.00%	56.00
P	19.1	-34.88%	12.50%	21.49
Cl	60.2	25.46%	-12.50%	52.68
Si	0.816	-10.22%	0.00%	0.82
Fe	0.771	-34.21%	25.00%	0.96
Mn	0	-133.29%	50.00%	0.00
Zn	0.483	22.29%	0.00%	0.48
B	0.086	28.71%	0.00%	0.09
Cu	0.00	50.47%	-50.00%	0.00
Mo	0.00	15.21%	0.00%	0.00
Al	0.00	-6.34%	0.00%	0.00
I		0.00%	0.00%	0.00

Knowing The Right Time

Critical Points of Influence

CPI’s

Critical Points of Influence

Growth occurs in cycles of alternating dominance

Male	|	Female
Expansion	|	Contraction
Vegetative	|	Reproductive

Critical Points of Influence occur when the hormone/nutrient balance shift back and forth from reproductive dominance to vegetative dominance.

Peak: Lack of nutritional integrity or stress at the peak moment of each cycle sabotages yield potential.

Transition: Lack of nutritional integrity at the transition **FROM** vegetative **TO** reproductive triggers proteolysis and creates disease/insect susceptibility.

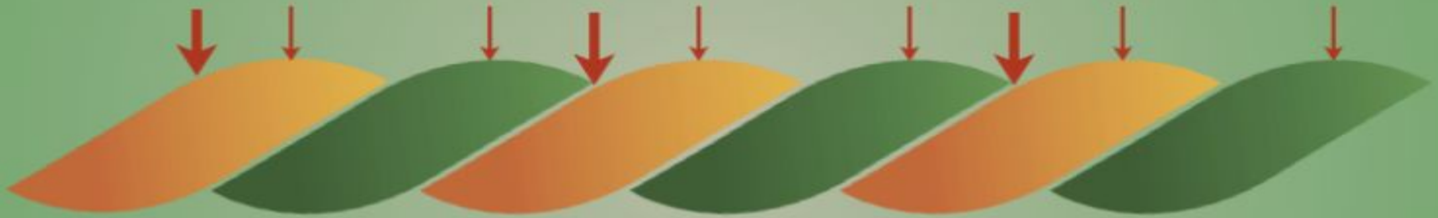
Growth cycles —

Lack of nutritional integrity or stress at the peak moment of each cycle sabotages yield potential

Lack of nutritional integrity at the transition <u>FROM vegetative TO reproductive</u> triggers proteolysis and creates disease/insect susceptibility

Critical Points of Influence

Major points, and minor points



Major points correlate to peak pest susceptibility

Minor points correlate to peak yield loss

Align CPI's with phenological growth stages

Most influential CPI’s

Vegetative Growth

Reproductive bud

Determination/initiation

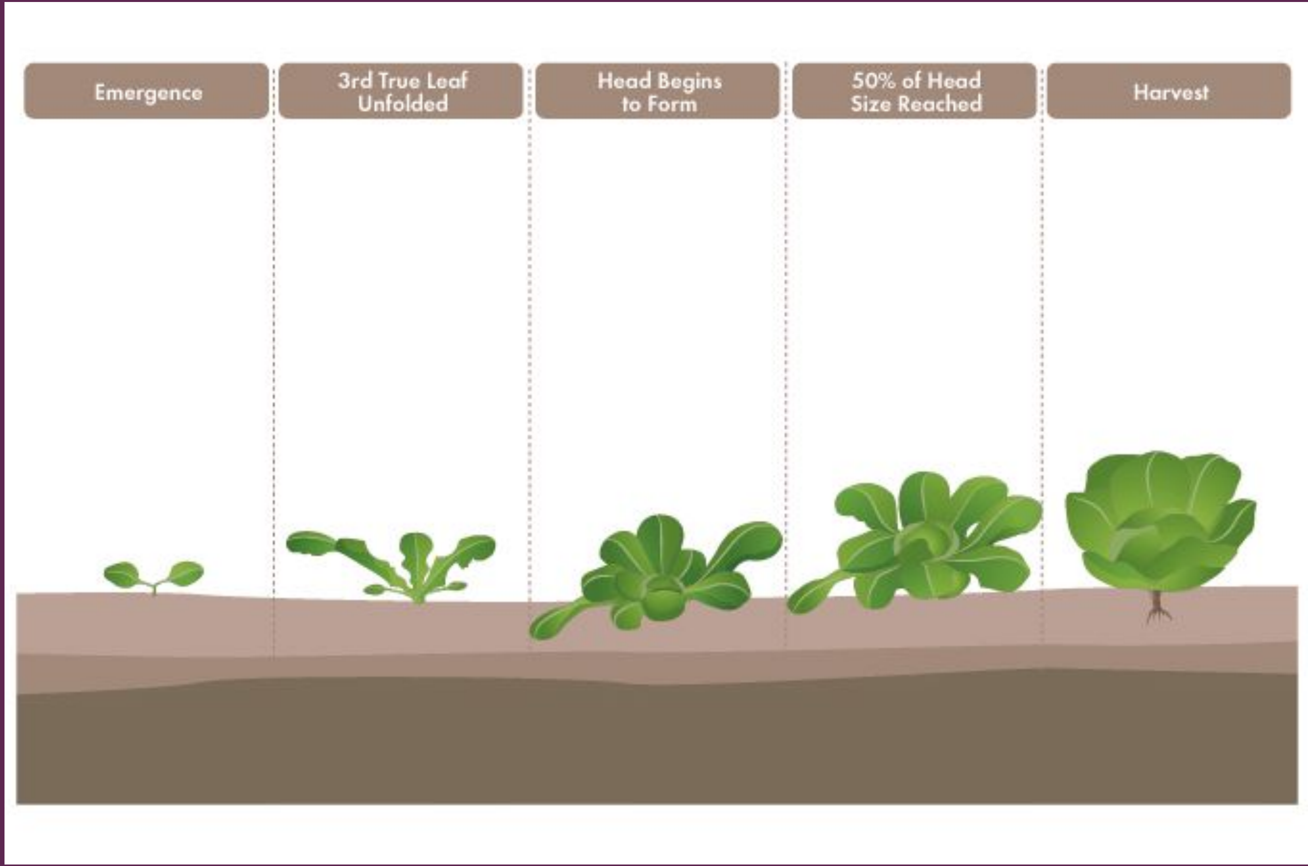
Flowing/Pollination

Fruit Cell Division

Fruit Cell Expansion

Ripening

Phenological growth stages in life cycle of Lettuce



Phenological Reproductive stages in life cycle of Strawberries

Vegetative growth— What can we impact during this CPI?

1. Rapid vegetative growth with tightly spaced internodes, many reproductive buds
2. Speed and mass of vegetative growth without the presence of excess nitrates
3. Disease and insect resistance

Critical Nutrients for Vegetative growth

1. Calcium
2. Boron

Reproductive Bud Initiation— What can we impact during this CPI?

1. Number of buds
2. Bud Uniformity
3. Bud Size and Energy
4. Blossom Size
5. Bloom Timing

Critical Nutrients for Reproductive Bud Initiation

1. Calcium
2. Manganese
3. Boron
4. Zinc
5. Copper
6. Urea
7. Seaweed

Bloom/Pollination— What can we impact during this CPI?

1. Number of blossoms pollinated
2. Earliness/speed of pollination
3. Condensed pollination window
4. Pollen count
5. Pollen tube strength

Critical Nutrients for Bloom and Pollination

1. Calcium
2. Manganese
3. Boron
4. Zinc
5. Copper
6. Seaweed

Embryo cell division— What can we impact during this CPI?

The development of as many high integrity cells in a fruit or grain as possible

Cell Division

Lasts 10-14 days

Determines potential fruit size

Number of cells is limited by calcium availability

Critical Nutrients for Bloom and Pollination

1. Manganese
2. Potassium
3. Calcium
4. Boron

Cell Expansion/ Fruit/grain fill

Remainder of season

Determines actual fruit size

Fruit fill is limited by potassium availability

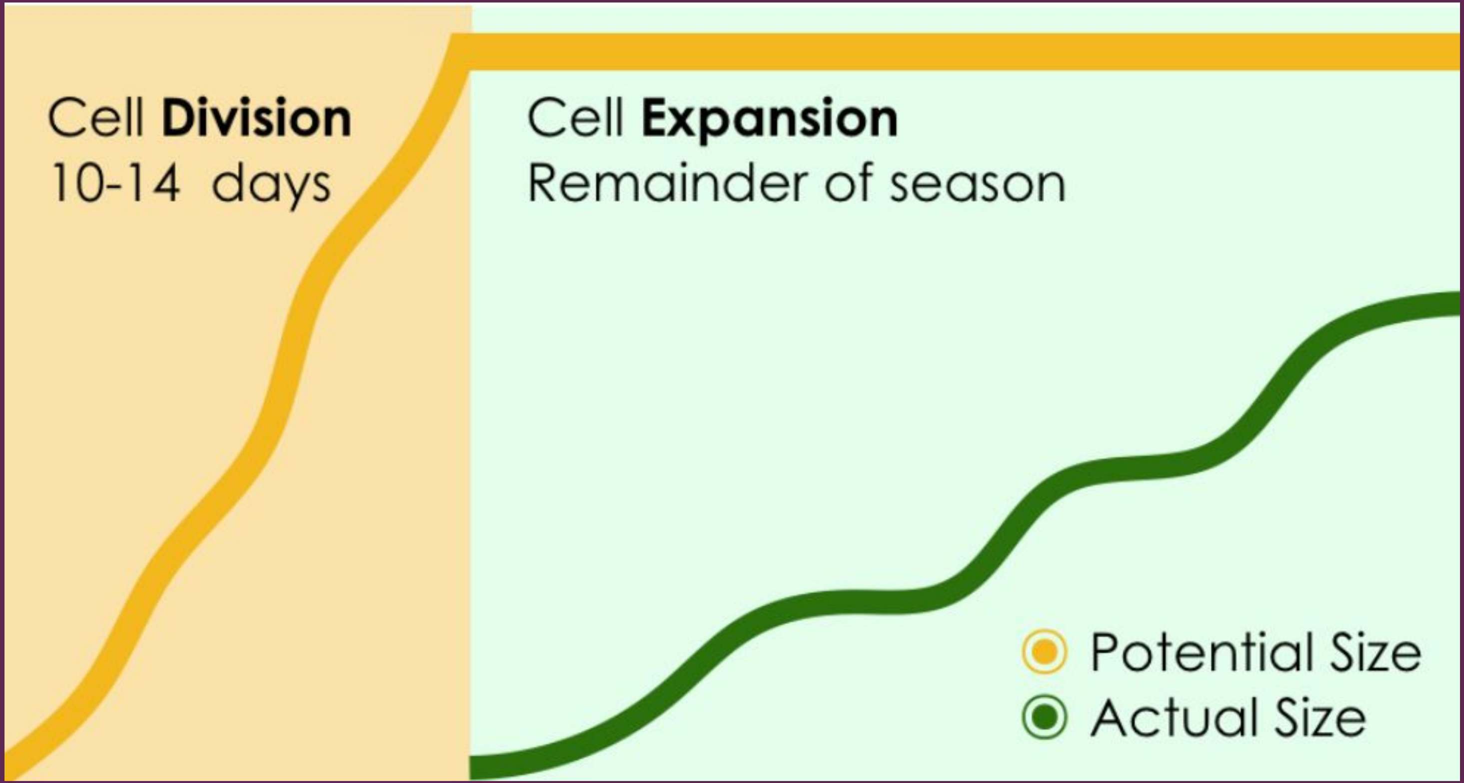
Fruit/Grain Fill — What factors can we affect?

1. Quantity of sugar transported to fruit/grain
2. Quantity of sugar produced in leaves
3. Fruit/Grain quality parameter

Critical Nutrients for Fruit/grain fill

1. Potassium
2. Nitrogen
3. Manganase
4. Zinc
5. Boron
6. Calcium
7. Copper

Impact of nutrition on fruit yield



Ripening— What can we impact during this CPI?

1. The production of a ripe crop on green plants with proper senescence
2. Test weight, protein content, and related quality characteristics
3. Earlier or delayed senescence

Critical Nutrients for Ripening period

1. Boron
2. Cobalt
3. Magnesium
4. Sulfur
5. Molybdenum

Nutrient	Product	Place
pH and Alkalinity, bicarbonates	phosphoric acid, sulfuric acid, lactic acid. acetic acid,nitric acid, hydrochloric acid	water
	Potassium Carbonate, Bicarbonate, or hydroxide	Water
	Calcium Carbonate. or hydroxide	

Macro Minerals		
Calcium (Ca) ppm	Calcium sulfate	Water, Foliar
	Calcium Acetate	Foliar
Magnesium (Mg) ppm	Magnesium Sulfate	Water, Foliar
Potassium (K) ppm	Potassium Sulfate	Water, Foliar
	Potassium Acetate	Foliar
Sodium (Na) ppm	Fish feed, sea-90 (Sodium)	Water
Ammonium-Nitrogen (NH4-N) ppm	Fish feed	Water
Nitrate-Nitrogen (NO3-N) ppm	Fish feed	Water
Chloride (Cl) ppm	Fish feed, sea-90 (chloride)	Water
Sulphate-Sulphur (SO4-S) ppm	Fish feed, anything with sulfate	Water
Phosphate-Phosphorus (PO4-P) ppm	Monopotassium Phosphate, phosphoric Acid	

Micro Minerals		
Iron (Fe) ppm	Fish feed, chelated iron (Fe DTPA)	Water
	Ferrous Sulfate	Foliar, Water
Manganese (Mn) ppm	Manganese sulfate	Water, Foliar
Zinc (Zn) ppm	Zinc Sulfate (Monohydrate)	Water, Foliar
Copper (Cu) ppm	Copper Sulfate (Pentahydrate)	Water, Foliar
Boron (B) ppm	Solubor (Disodium octaborate)	Water, Foliar
Molybdenum (Mo) ppm	Sodium Molybdate	Water, Foliar
Trace Minerals		
Silicon (Si) ppm	Potassium silicate, Fermented Plants, Stinging Nettle, Horsetail Mono-silicic acid,	Foliar
Others	sea-90	Foliar, Water

Assessing Yield Improvements

% change in Yield

Changes in yield results directly with impacts on income

(Current Yield - Previous yield) / Current yield

% Change in Grow Out time

(Current Days - Previous Days) / Current Days

Benchmarking Production

Benchmark your production to see where you compare to other growers

Yield (kg/m2)

Water Use Efficiency (kg/l)

Nutrient Use Efficiency (kg/kg)

Profit or Income per yield ($/kg)

Profit or Income per area ($/m2)

Assessing Quality Improvements

% change in plant nutritional content
Changes in plant nutritional content results directly with impacts on income
(Current concentration - Previous concentration) / Current concentration

*Look at things like protein, lipids, carbohydrates, and brix Where a forage analysis comes in

Relating Management to Farm Economics

Simple Method ROI = Return on investment of inputs and outputs

ROI = Net Income / Cost Investment * 100

Treatment	Revenue	Cost of Investment	ROI
A - No Supplements	45000	1200	3650.00%
B - Supplements	60000	1500	3900.00%
C - Supplements+	65000	3000	2066.67%

Treatment B provides the Best ROI

*A more complete method would be to do a Cost Benefit Analysis

Case study for Lettuce on 6,000 sq.ft facility

	Control	YR 1	%change
Days cycle	48	35	-27%
harvest per year	8	10	37%
lbs per harvest	455	495	9%
waste per harvest	45	5	-89%
$/lbs	$4.00	$4.00	0%
$/year	$13,839.58	$20,648.57	49%
Change in cost	0	6,000	
Profit	13,840	14,649	6%

27% decrease in grow time

37% increase in harvest per year

89% decreased in crop waste

49% increase in revenue

6% increase in profit Year 1

Year 2 -> 49% increase in profit

Case study for Cannabis in 640 sq.ft DWC

	Control	YR 1	%change
Days cycle	104	90	-14%
harvest per year	3.5	4.1	16%
Dry Flower weight/ lbs per havest	1.5	4.0	167%
$/lbs	$1,000.00	$1,000.00	0%
$/year	$5,250.00	$16,222.22	209%
Change in cost	0	6,000	
Profit	5,250	10,222	95%

14% decrease in grow time

16% increase in harvests per year

167% increase in salable weight

117% increase in revenue

93% increase in profit Year 1

209% increase in profit Year 2

Nutrition is the foundation of Life. Don’t guess, test.

Accessing Your Course Benefits

1. Make sure you’re logged in.
2. Class resources can be found in the Plant Sap Analysis Short Course @ Regen Aquaculture.
    a. Recorded Materials
    b. 60+ Crop Sampling Guides
    c. Logs Sheets for data collection
    d. Your Course Certification Test

THANK YOU

Linko.page/joepate

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