“Low hanging fruit”: How Nutrient Management Can Improve Organic Tomato Production In High Tunnels

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NEVFC

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The University of Vermont

VERMONT VEGETABLE & BERRY GROWERS ASSOC.

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Today's talk:

- There is not a lot of great guidance on tunnel fertility -- not greenhouses, not field. Important to understand defining characteristics.
- Big nutrient demand in tunnel crops; align nutrient management with crop needs and target yields.
- Organic amendments work well. Pay special attention to N and K.
- Track yields to learn what works!

Tunnels have high yield and revenue potential

- 8-12 times yield per square foot in tunnel vs. field
- Ripen ~1 month earlier than field
- Lower risk of climate related losses

There are many different tunnel shapes, sizes, and systems.
There is no one size fits all approach for tunnel recommendations.

Growth potential in tunnels should guide nutrient recommendations plan for optimal yield, then identify limiting factors

- Size of tunnel?
- Heat? Ventilation?
- Market / harvest window?
- What type/variety of tomato?
- Duration of plants in the soil?

Plant density and biomass accumulation drive tomato nutrient uptake

- Tunnels have high plant density
  - tunnel: **5,000-10,000 plants per acre**
  - field: **2,400-3,200 plants per acre**
- High yielding varieties (often grafted onto vigorous rootstocks)
- A lot of high nutrient biomass is pruned off
- Extended season—plants are growing for 30-90% more time (& absorbing more nutrients)

Greenhouse tomato recommendations provide adequate benchmarks for tunnel systems

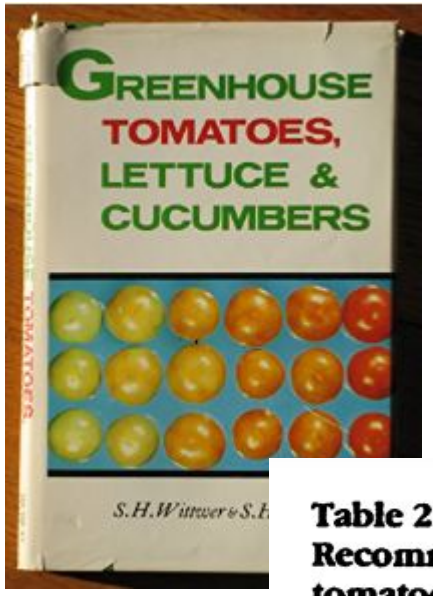


Table 2.
Recommended fertilizer rates (part per million) for tomatoes cropped in peat-lite and rockwool systems.

	Peat-lite Bags (ppm)						
Stage of Development	***N***	***P***	***K***	***Ca***	***Mg***	***Fe***	***B***
Planting to 1st cluster	150-200	50	225-300	80	30	3	0.5
1st to 4th cluster	200-225	50	300-340	80	30	3-5	0.5
4th to finish	225-300	50	340-500	80	30	3-10	0.5

*

*Richard McAvoy, , Connecticut Greenhouse Newsletter

But controlled growing environments and hydroponic systems do not have the same soil - nutrient dynamics

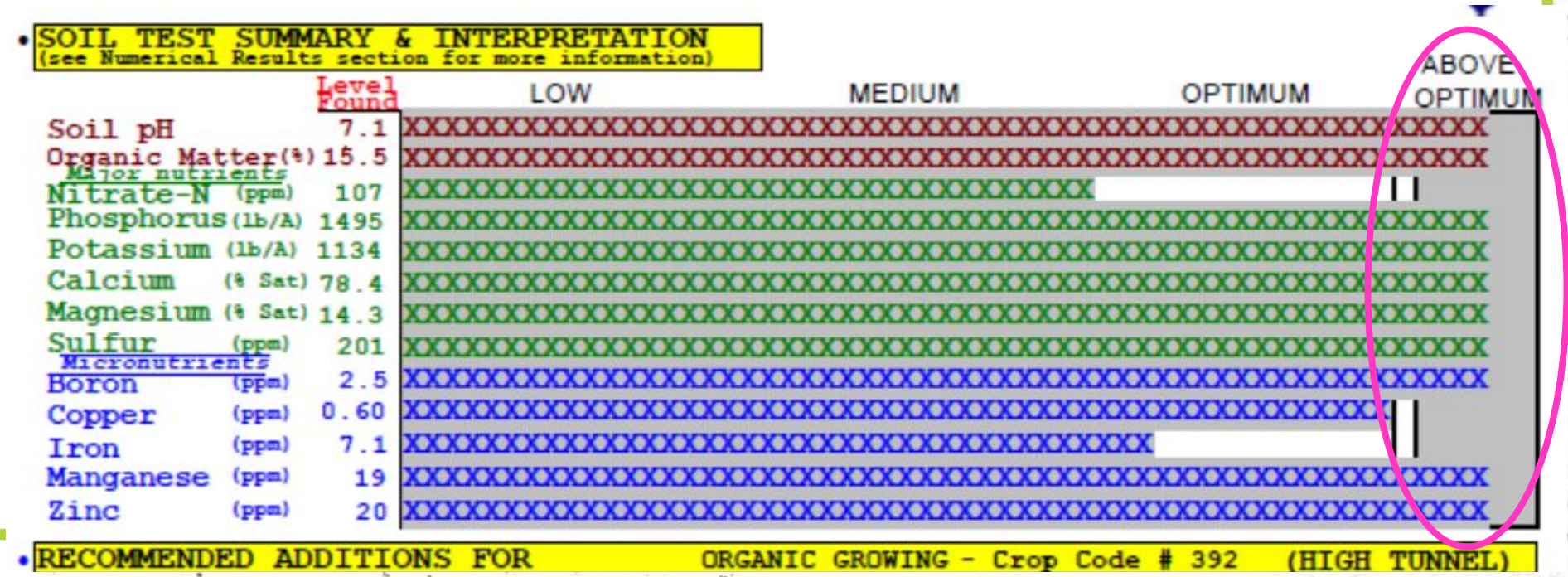
Photo credits: Cheryl Frank Sullivan, UVM

Tunnel soils develop different properties than field soils

- No rain + high nutrient inputs => salt buildup
- Warmer drier soils => accelerated mineralization
- Lots of compost =>highly buffered soil
- Limited cover cropping or crop rotation

Without informed nutrient management, some tunnel soil trends become difficult to reverse

- High inputs of compost, sometimes without soil testing.
  - High/ imbalanced nutrients, especially P
- Dry soil, altered microbe activity
- Soil pH increases



SOIL TEST SUMMARY & INTERPRETATION
(see Numerical Results section for more information)

		Level Found	LOW	MEDIUM	OPTIMUM	ABOVE OPTIMUM
Soil pH		7.1				
Organic Matter	(%)	15.5				
Major nutrients						
Nitrate-N	(ppm)	107				
Phosphorus	(lb/A)	1495				
Potassium	(lb/A)	1134				
Calcium	(% Sat)	78.4				
Magnesium	(% Sat)	14.3				
Sulfur	(ppm)	201				
Micronutrients						
Boron	(ppm)	2.5				
Copper	(ppm)	0.60				
Iron	(ppm)	7.1				
Manganese	(ppm)	19				
Zinc	(ppm)	20				

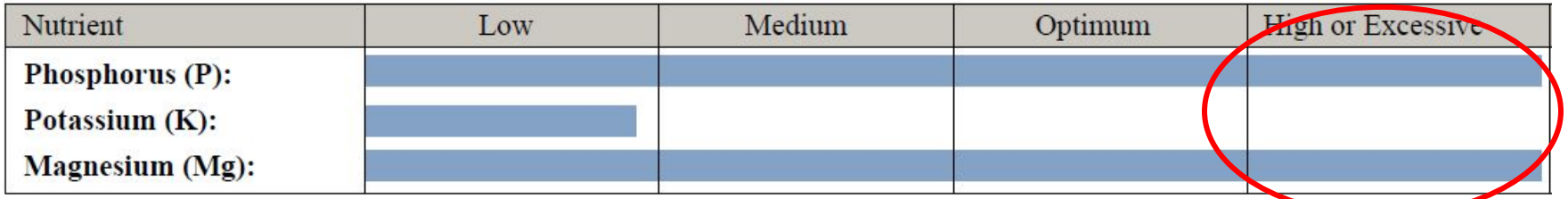
RECOMMENDED ADDITIONS FOR ORGANIC GROWING - Crop Code # 392 (HIGH TUNNEL)

Tunnel tomatoes have heavy nutrient demands to achieve yield potential

In organic systems, compost alone can't meet crop needs. Bagged amendments are critical to optimal yield.

‘Field’ soil tests alone do not provide good guidance for tunnels

- Some nutrient levels appear off the charts; recommendations are low.
- Field soil tests do not typically include soluble salts, nitrate-N, ammonium-N.



Phosphorus is excessive!!!

Analysis	*Value Found*	*Optimum Range ** (or Average *)*
Soil pH (2:1, water)	7.7	
Modified Morgan extractable, ppm		
Macronutrients		
Phosphorus (P)	220.4	4-7
Potassium (K)	46	100-130
Calcium (Ca)	5185	**
Magnesium (Mg)	473	50-100
Sulfur (S)	807.0	11*
Micronutrients		
Iron (Fe)	3.1	7.0*
Manganese (Mn)	9.2	8.0*

Analysis	*Value Found*	*Optimum Range ** (or Average *)*
Boron (B)	1.0	0.3*
Copper (Cu)	0.6	0.3*
Zinc (Zn)	2.5	2.0*
Sodium (Na)	528.0	20*
Aluminum (Al)	8	35*
Soil Organic Matter %	6.2	**
Effective CEC, meq/100g	30.0	**
Base Saturation, %		
Calcium Saturation	86.5	40-80
Potassium Saturation	0.4	2.0-7.0
Magnesium Saturation	13.1	10-30

Use different tests for different information

- **Field soil test** for reserve nutrients (modified Morgan, Brays, Melich-3)
- **Potting soil test** for soluble nutrients (Saturated Media Extract)
- **Tissue analysis** for nutrient levels in plants (concentration of elements in dry leaves)

Together, these tests guide tunnel nutrient management

Tunnel tomatoes need nutrients *now* (soluble) and nutrients *later* (reserve).

It is hard to *guess* what plants need.

Combination of saturated media tests, field soil test, and tissue tests can provide answers

UMaine offers combined soil tests for high tunnels:

field soil tests (reserve nutrients) + saturated media (soluble nutrients)

Field soil test (reserve nutrients)

•SOIL TEST REPORT FOR: [redacted] ERS

MAINE SOIL TESTING SERVICE
UNIVERSITY OF MAINE 1865
5722 DEERING HALL
ORONO,MAINE 04469-5722

•SOIL TEST SUMMARY & INTERPRETATION
(see Numerical Results section for more information)

	Level Found	LOW	MEDIUM	OPTIMUM	ABOVE OPTIMUM
Soil pH	6.1				
Organic Matter(%)	7.9				
Major nutrients					
Nitrate-N (ppm)	37				
Phosphorus (lb/A)	64.2				
Potassium (lb/A)	169				
Calcium (% Sat)	70.5				
Magnesium (% Sat)	15.1				
Sulfur (ppm)	792				
Micronutrients					
Boron (ppm)	2.2				
Copper (ppm)	0.15				
Iron (ppm)	5.3				
Manganese (ppm)	7.0				
Zinc (ppm)	2.5				

•RECOMMENDED ADDITIONS FOR ORGANIC GROWING - Crop Code # 392 (HIGH TUNNEL)

To raise soil pH to 6.5, apply 30 pounds of lime per 1000 sq. ft.

Magnesium level is sufficient. Use a calcitic (low magnesium) lime.
To meet major nutrient requirements, Apply on every 1000 sq. ft.:
Nitrogen(5.8 lb) - from 48 lb bloodmeal or 83 lb soybean meal
Phosphorus(1.6 lb) - from 10 lb bonemeal/bonechar or 53 lb rock phosphate.
Potassium(19.2 lb) - from 37 lb potassium sulfate

N-P-K recommendations are for heavier feeding crops, such as Tomatoes, Peppers, & Vines.
1/2 the recommended rates should be sufficient for Greens, Cut Flowers, and Fruit crops.
Tomatoes: Recommendations are based on 60 ton/A (3 lb/sq ft) yield goal.
15 bushel cow, pig, or horse manure or 7-8 bushel poultry, sheep, goat, or rabbit manure/1000 sq. ft. can substitute for 1/4 recommended nutrients (apply in fall).
Broadcast lime uniformly, in spring or fall, and till in 6-7 in.

Till in manure or compost to improve soil organic matter content.
If you use manure or compost, reduce any additional phosphate application by 50%.

For information on micronutrient management and recommendations, see enclosed form.

•NUMERICAL RESULTS (Test methodology: pH in water and Mehlich buffer, available nutrients by modified Morgan extract) (Organic matter measured by LOI, P determined colorimetrically, all others measured by ICP-OES)

CEC and nutrient balance calculations assume the pH will be raised to 6.5

	Soil pH	Lime Index 2	Phosphorus (lb/A)	Potassium (lb/A)	Magnesium (lb/A)	Calcium (lb/A)	CEC (me/100 g)	K	Mg (% Saturation)	Ca (% Saturation)	Acidity
Level Found	6.1	6.23	64	169	877	6785	11.1(A)	2.0	15.1	70.5	12.5
Optimum Range	6.0-7.0	N/A	40-80	600-800			> 5		10-20	60-80	< 10

	Organic Matter(%)	Sulfur (ppm)	Copper (ppm)	Iron (ppm)	Manganese (ppm)	Zinc (ppm)
Level Found	7.9	792	0.15	5.3	7.0	2.5
Normal Range	5 - 8	> 15	.25-.60	6 - 10	4 - 8	1 - 2

(Extras)	Boron (ppm)	Sodium (ppm)	Soluble Salts (mmhos/cm)	Nitrate-N (ppm)	Ammonium-N (ppm)
Level Found	2.2	274	2.44	37	1
Normal Range	0.5-1.2	< 200	< 4.0	100-200	< 10

Additional Results or Comments:
Metals scan: NORMAL BACKGROUND LEVEL - no health risk.

Full payment received for this sample. Thank you.

Saturated media (soluble nutrients)

MAINE SOIL TESTING SERVICE
High Tunnel Saturated Media Analysis For: [redacted]

MAINE

Analysis date: 03/20/2020 **Job #** 379
Sample Name: HHT
Crop Grown: Tomato
Comments: 1027

Analytical Results

Determination	Optimum Range	Level Measured		Relative Level
pH	6.0 - 7.0	6.1		OPTIMUM
Soluble Salts	2.0 - 4.0 mmhos/cm	2.44	mmhos/cm	OK
Organic Matter	8 - 12 %	7.9	%	LOW
Nitrate-N	100 - 200 ppm	31.7	ppm	LOW
Ammonium-N	< 10 ppm	0.5	ppm	OK
Phosphorus	1 - 5 ppm	0.3	ppm	LOW
Potassium	150 - 275 ppm	8	ppm	LOW
Magnesium	> 60 ppm	107	ppm	OPTIMUM
Calcium	> 250 ppm	444	ppm	OPTIMUM
Aluminum	< 10 ppm	0.2	ppm	OK
Boron	0.05 - 0.50 ppm	0.62	ppm	HIGH
Copper	0.01 - 0.5 ppm	0.013	ppm	OPTIMUM
Iron	0.3 - 5.0 ppm	0.04	ppm	LOW
Manganese	0.1 - 3.0 ppm	0.24	ppm	OPTIMUM
Sodium	< 100 ppm	163	ppm	HIGH
Sulfur	25 - 100 ppm	491	ppm	HIGH
Zinc	0.3 - 3.0 ppm	0.08	ppm	LOW

Note: Results are expressed as concentration in saturated media water extract, measuring the short-term intensity of nutrient availability in your soil.

2018 New England High Tunnel Tomato Survey

Revised nitrogen recommendations are based on yield potential

N application rate based on yield goal						
	Yield goal lb/acre	=Yield lb/ft²	=Yield lb/stem = lb/4 ft²	Approx. plant height	N need lb/acre @ 90% recovery	N need* lb/1,000 ft²
Low yield	40,000	1	4	8'	100	2.3
Medium yield	80,000	2	8	12'	200	4.6
Good yield	120,000	3	12	16'	300	6.9
High yield	160,000	4	16	20'	400	9.2

* Subtract N credit for each 1% soil organic matter of .25 lb/1,000 ft², up to 1 lb.

We have been collecting data on these recommendations since 2020, finding that most tunnel growers fall in the "medium" to "good" category.

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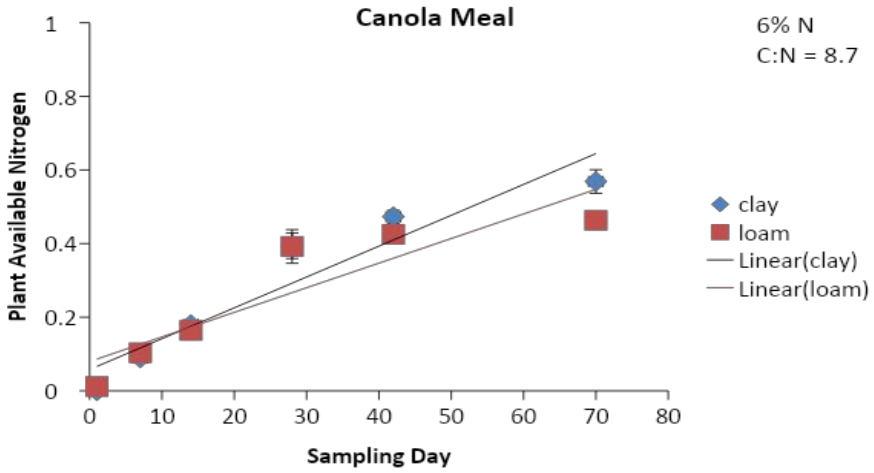
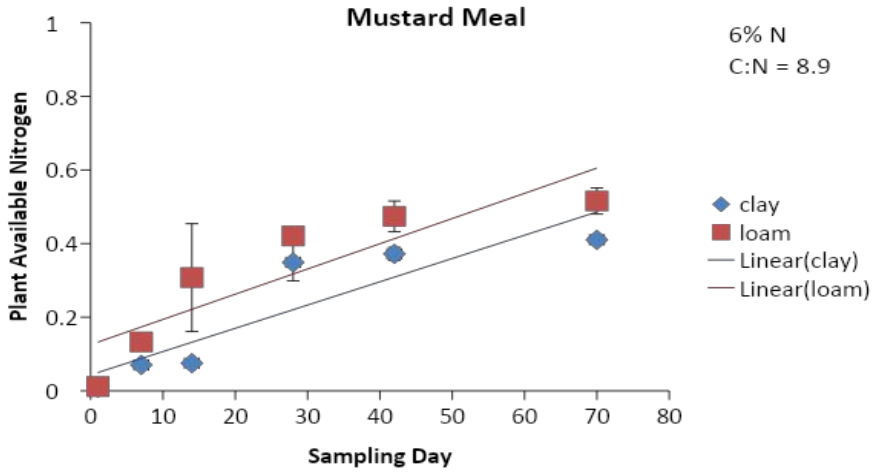
Split applications of N balance vegetative growth with sustained plant needs

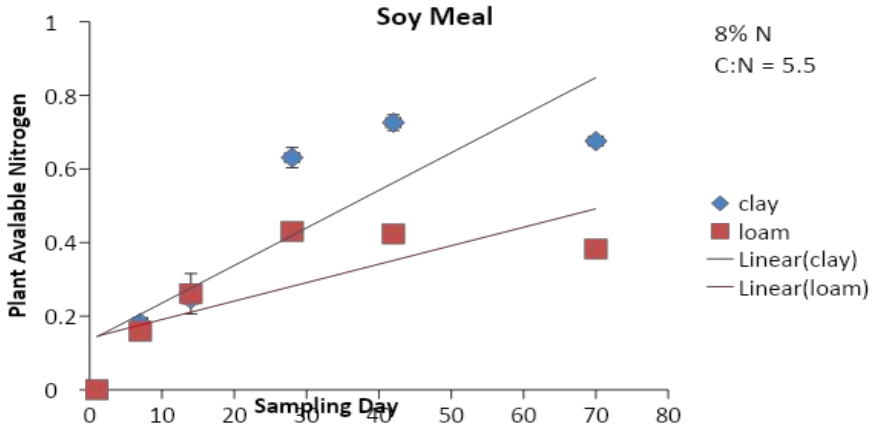
- 1/2 to 2/3 N before planting
  - Amend 2 weeks before planting, mix well in warm, moist soil
- Follow soil test recommendation rates
- Amend full rates of P, K, Mg, Ca, and other nutrients

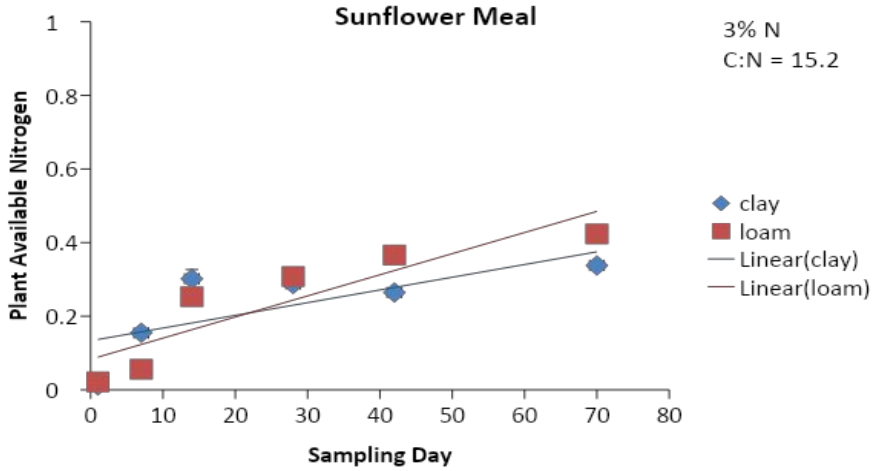
Most organic N sources– slow steady release over growing season, with only 60-75% of total N available year 1

Expect quicker mineralization rates in tunnel soils than in field









Potassium rates for tunnel tomatoes are 2-3 times field recommendations

K_2O application rate based on Modified Morgan's soil test								
Yield goal	Low <400 lb./A = <200 ppm K		Medium 400-800 lb./A = 200-400 ppm K		High/optimum 800-1200 lb./A = 400-600 ppm K		Excessive > 1200 lb./A = > 600 ppm K	
	lbs/acre	lbs/ 1000 ft²	lbs/acre	lbs/ 1000 ft²	lbs/acre	lbs/ 1000 ft²	lbs/acre	lbs/ 1000 ft²
Low yield	300	6.9	200	4.6	100	2.2	0	0
Med yield	450	10.3	300	6.9	150	3.4	0	0
Good yield	600	13.8	400	9.2	200	4.6	0	0
High yield	750	17.2	600	13.8	300	6.9	0	0

Nutrients affect quality not just yield

Potassium is very important for fruit marketability

Spread “front loaded” soil amendments evenly!

Many tunnels have lower yields in areas by sidewalls
due to lower fertility, colder soil, other…?

Compost cannot meet the nutrient needs of tunnel tomatoes: know your organic fertilizer options

N: soy, peanut, feather meal; Chilean (sidedress), "meat" meals (e.g. Naturesafe 13-0-0)

P: bone meal, bone char, rock phosphate

K: potassium sulfate, sul-po-mag, greensand

Ca: lime, gypsum

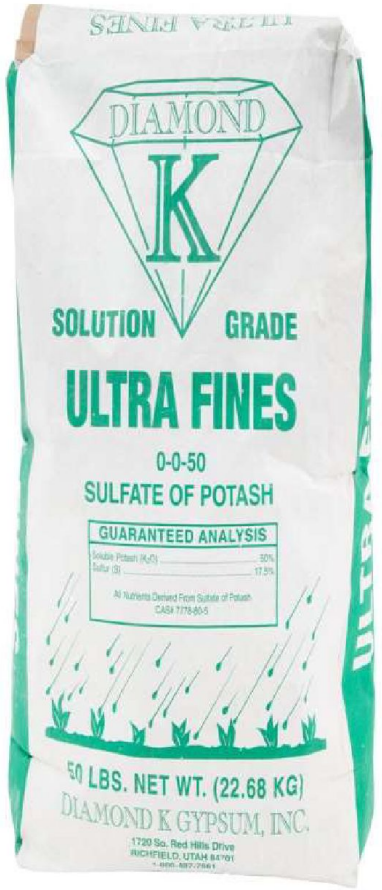
Mg: dolomitic lime, sul-po-mag, epsom salts

Blends: ProGro, Cheep-Cheep, Kreher's, etc.

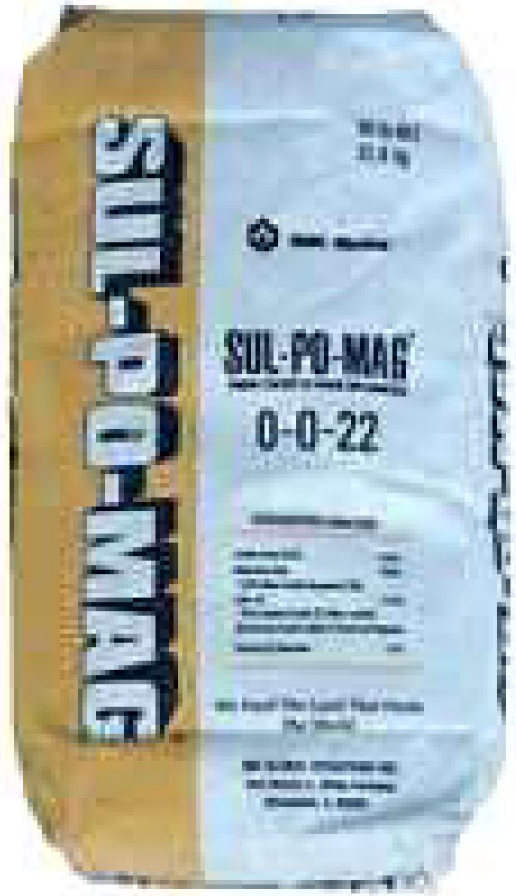
Micros: compost, borax, Azomite, chelates

Organic matter: compost, peat moss, leaves, wood chips, etc.

To add potassium, soluble “fines” (0-0-50) dissolve in water and are quickly available to plants



If soil test calls for magnesium, sul-po-mag (0-0-22 11 Mg) is a good choice



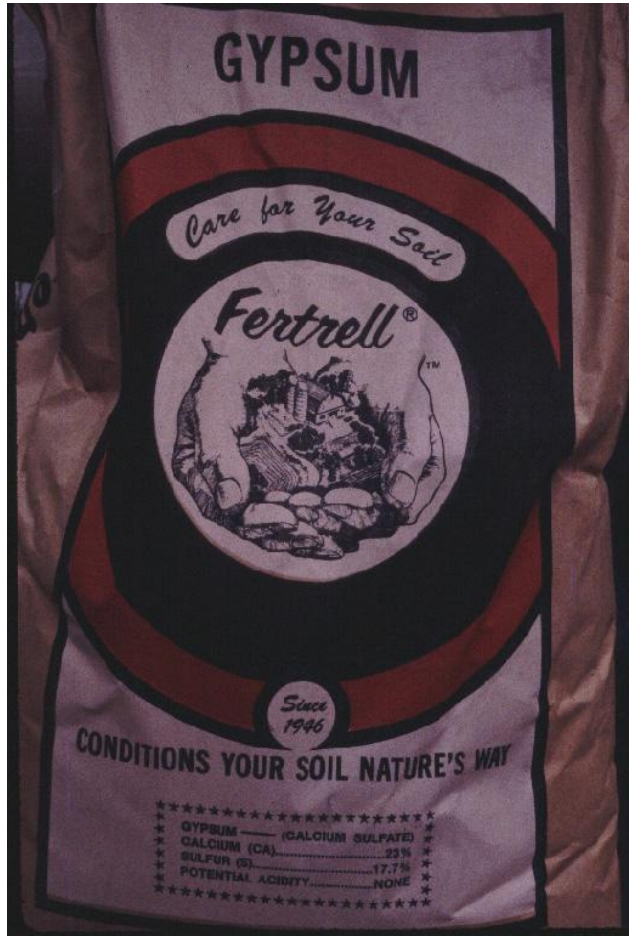
If soil test calls for phosphorus, bone char is a quickly available organic option.

Compost builds up P reserves

Photo courtesy of Vern Grubinger

Epsom Salts for Mg

Gypsum adds calcium, doesn't change soil pH



Nutrient deficiencies appear in mature plants, indicating insufficient levels of uptake

Leaf tissue analysis measures what the plants took up

Begin 1 month after transplant, sample monthly.

- *Tissue analysis can alert you to deficiencies before they are visually apparent.*
- *It is important to correct deficiencies before fruit forms!*

Using tissue sample results to adjust mid season fertility

	Low	Normal	High	Excessive
Nitrogen (% DW)	2.50	3.75	4.25	5.50
Phosphorus (% DW)	0.20	0.30	0.52	0.60
Potassium (% DW)	1.50	2.30	4.10	5.00
Calcium (% DW)	0.20	1.00	4.75	6.50
Magnesium (% DW)	0.20	0.55	1.00	1.25
Sulfur (% DW)	0.20	0.30	1.21	3.00
Manganese (ppm DW)	20	30	100	500
Iron (ppm DW)	25	40	100	450
Copper (ppm DW)	6	10	20	35
Boron (ppm DW)	15	25	45	90
Zinc (ppm DW)	20	25	71	72

More N and K during vegetative growth; less when fruiting

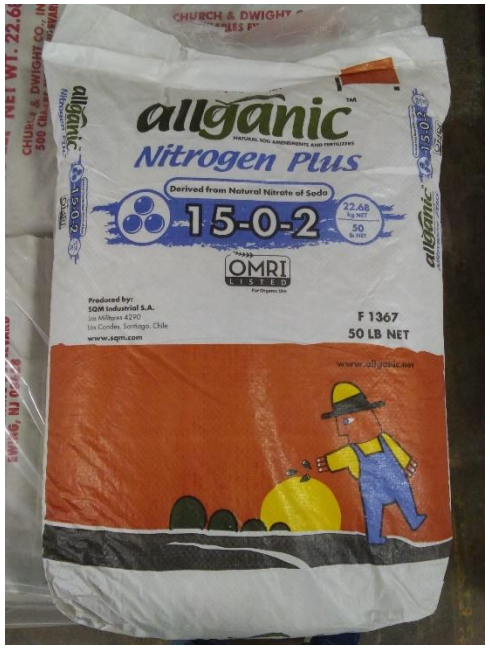
Source: https://agsci.psu.edu/aasl/plant-analysis/plant-tissue-total-analysis/interpretive-nutrient-levels

‘Fertigation’ can quickly correct for deficiencies

- Mazzei Venturi injectors simple and inexpensive
- Dosatron more precise; good for high volumes
- Begin N and K weekly 4-6 weeks after planting
- 0.25 lb/ 1000 sq feet/ week of both N and K20

Not many options available for organic fertigation

Fish emulsion 2-4-1



Sodium nitrate 15-0-2 dissolves and can go through drip

Potassium sulfate 0-0-50 "fines" dissolve and are more available

OMRI LISTED
For Organic Use

NutriAg's Enviro Products

Any other suggestions?

Without adequate water, plants can't take up nutrients

Salts build up can take time to remediate

- Mix soil regularly with tillage
- Use transplants in high salt soils
- When possible, use overhead irrigation
- When changing plastic, let rain flush the soil

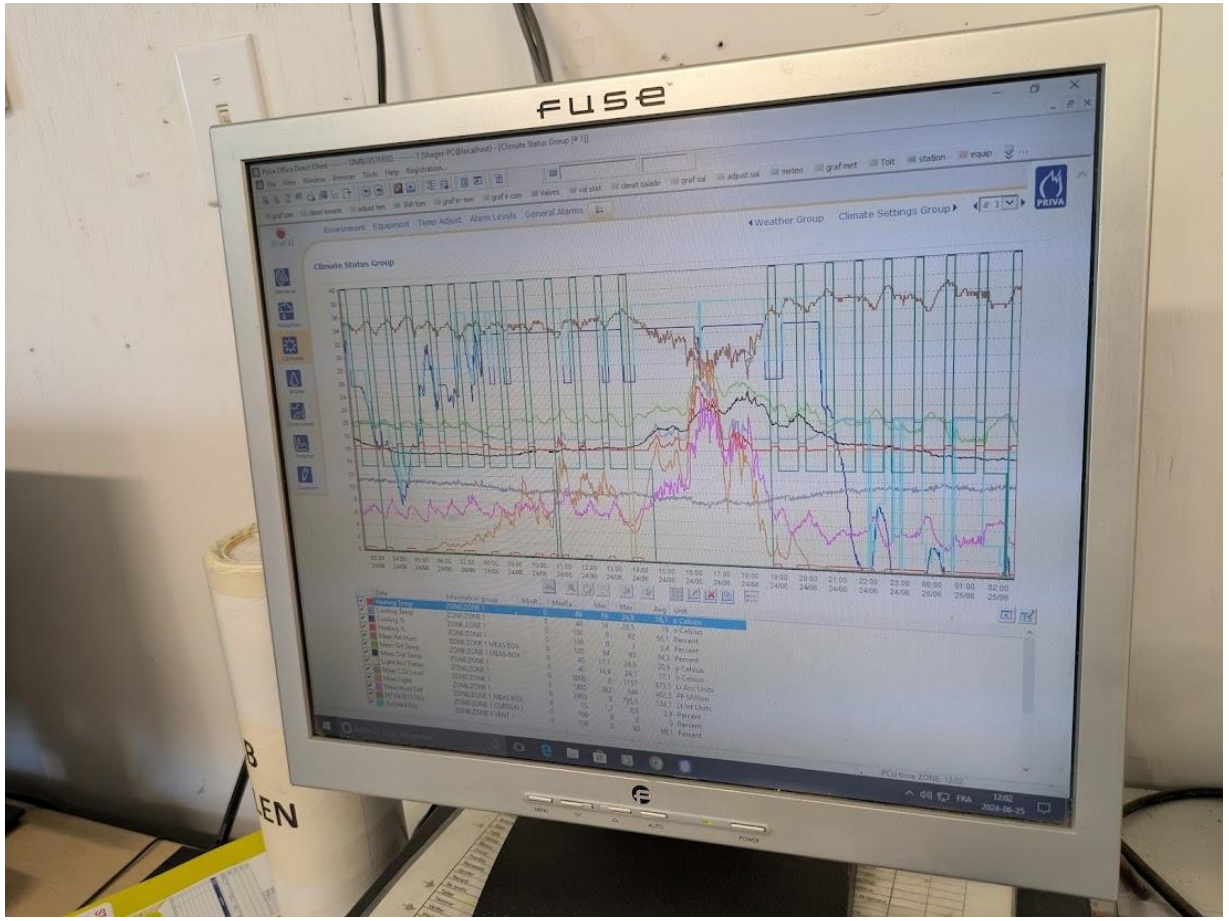
Setting yield goals is important to guide nutrient management

- Use previous yield data to set goals
- Set realistic expectations based on variety, planting date, labor, and infrastructure
- Track yield weekly
- Record pruning practices and environmental factors that affect yield

Reducing abiotic stresses is also critical to good production

- Many factors besides nutrients can be a limitation on fruit quality
- What factors do tunnel growers have control over?

There is a lot of automation available to improve greenhouse management, but most of it is out of reach for tunnel growers



Conclusion: focusing on nutrient management improves tunnel yields

- Growers report increased yield and quality following recommendations.
- Low cost steps big improvements
- Be proactive with tissue testing and fertigation
- Many factors drive tomato yields—levelling up nutrients is an easy path to quick results
- What are the other limitations on yield?? Next up!

Thank you!

Rebecca.maden@uvm.edu

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