# Improving Nutrient Management in High Tunnels

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*NEVFC*

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VERMONT
AGENCY OF AGRICULTURE, FOOD & MARKETS

The University of Vermont

VERMONT VEGETABLE & BERRY GROWERS ASSOC.

NEW ENGLAND VEGETABLE & BERRY GROWER'S ASSOC.

**High tunnels /hoophouses /greenhouses have proliferated on vegetable farms in the Northeast**

Most production is “in the ground”

# High tunnels extend the season and protect crops from increasingly severe weather

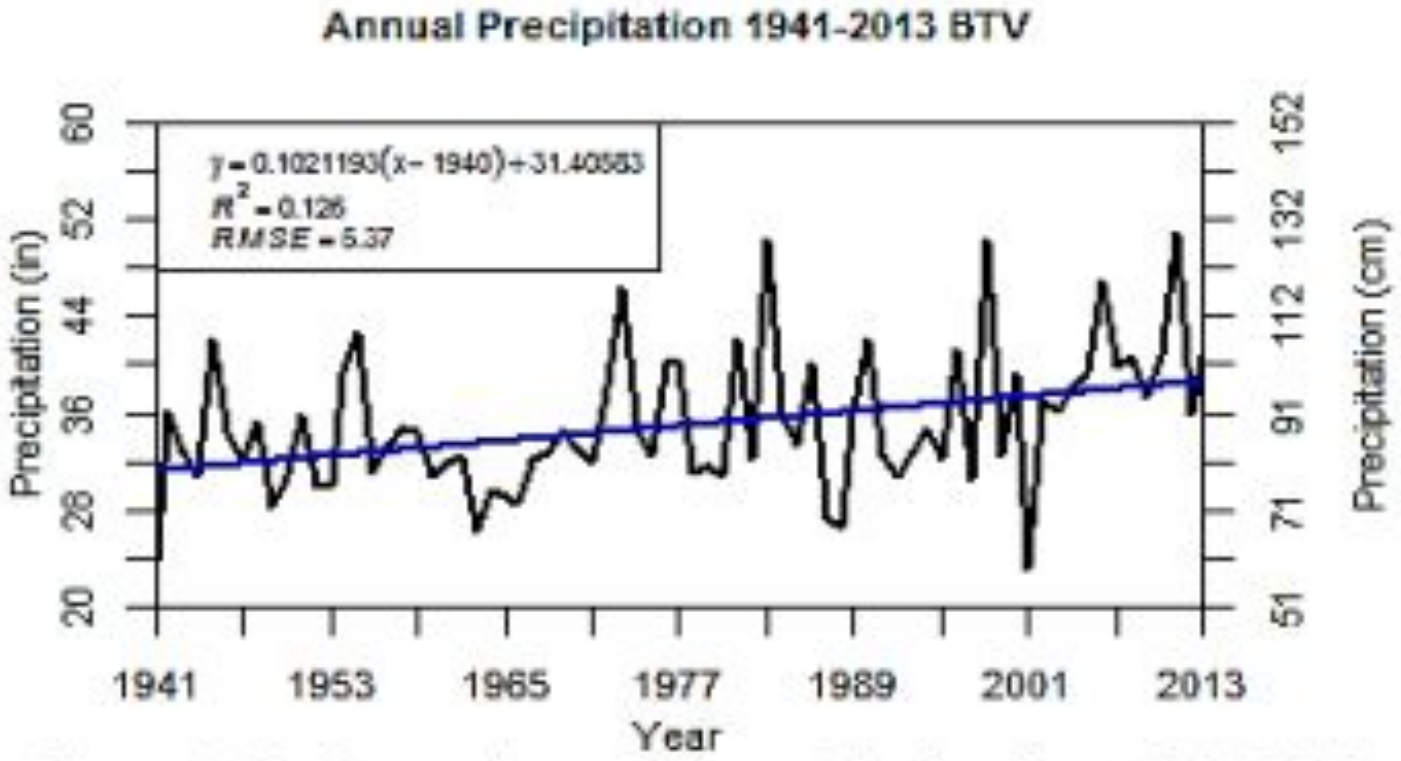
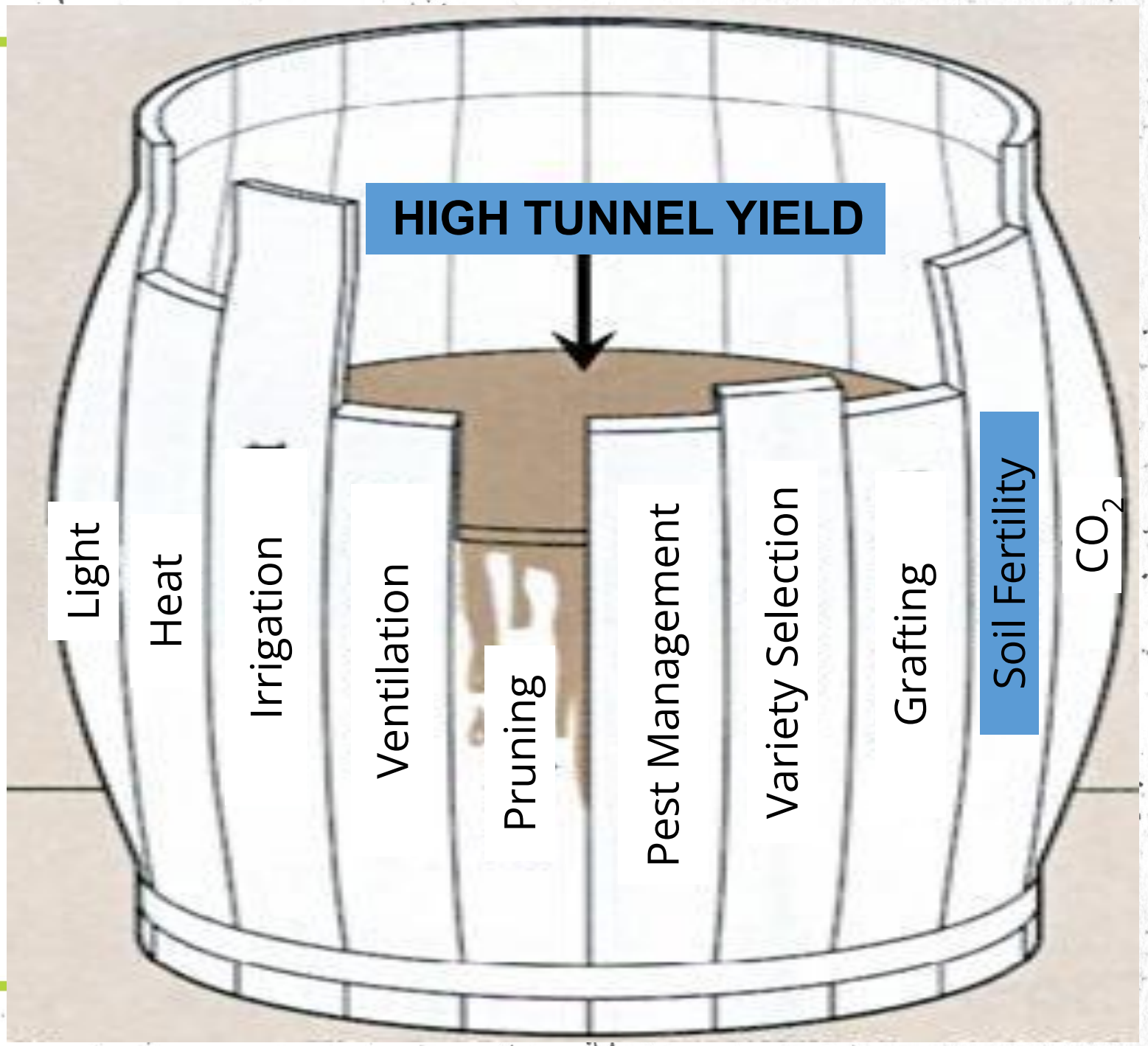



**Figure 1.14**. *Change in annual precipitation from 1941-2013 (BTV station).*

Source: https://www.uvm.edu/femc/products/long_term_update/2017/vermont/climate

**Soil fertility is important, but a whole-tunnel approach is needed**



**Many different tunnel systems**
**…so guidance varies**

# Many different production contexts, too


raised beds


trays and containers


winter greens


summer crops

# In-ground growing is highly buffered, due to soil volume

The ground is typically amended with lots of compost and nutrients so it is somewhere between a field soil and a potting soil

**Tunnel tomatoes have heavy nutrient demands--**

**Yields can be much greater than in the field**

# Nutrients affect quality not just yield

**Nutrient deficiencies also occur in mature plants**

## Tunnel soil looks good and feels good, but what is in it?

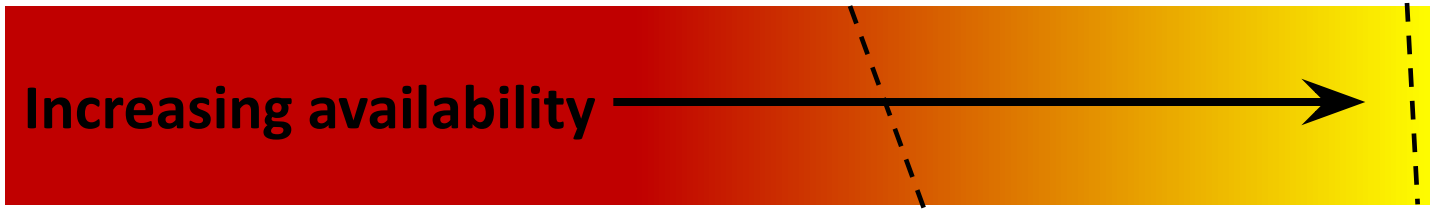
## Soil tests can help you understand what is going on.

Soil testing provides data about nutrient content, pH, salt level

**‘Field’ soil test alone for established tunnel soil is not so helpful: nutrients are usually ‘off the chart’ but that is for field yields. Also does not include soluble salts, nitrate-N, ammonium-N**

Best option is Saturated Media Extract (water soluble nutrients) + field soil test

**Soil tests: Measure reserve and available nutrients**




Modified Morgan Saturated Media

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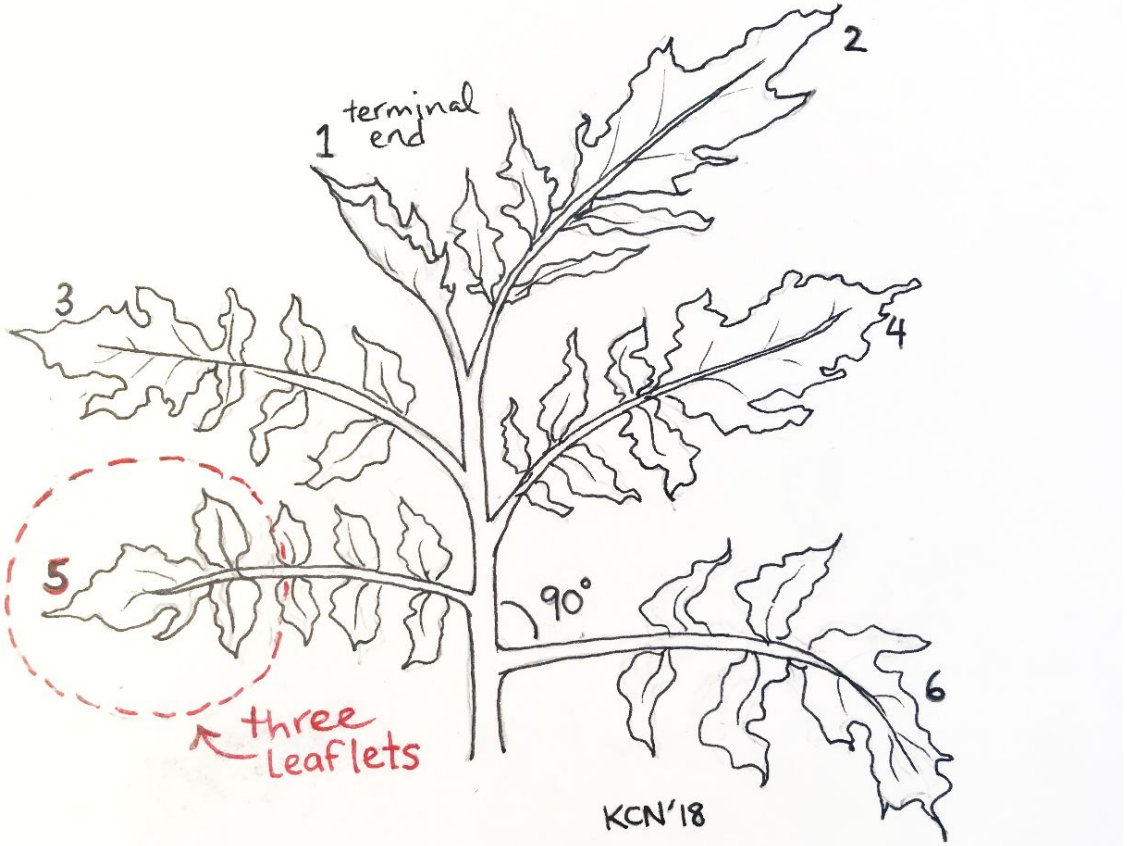
**Leaf tissue tests tell you what the plant actually took up**



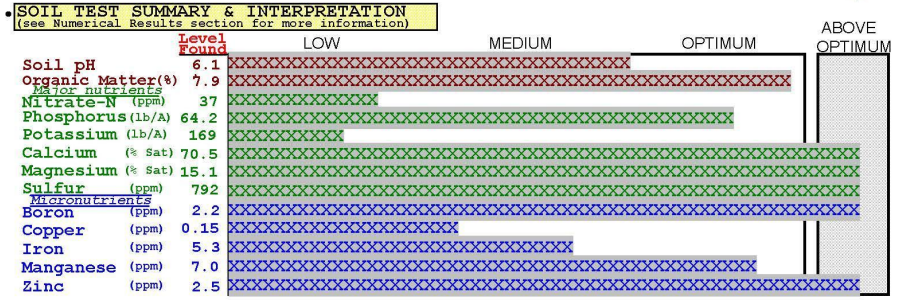
| 03/20/2020 | 1027 | HHT | ---- | 7840 sq. ft |
|---|---|---|---|---|
| PRINT DATE | LAB NO. | SAMPLE IDENTIFICATION | COUNTY | ACRES OR SQ. FT. |

•SOIL TEST REPORT FOR:

[redacted]

**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)




•**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 |

| | Boron (ppm) | Sodium (ppm) | Soluble Salts (mmhos/cm) | Nitrate-N (ppm) | Ammonium-N (ppm) |
|---|---|---|---|---|---|
| Level Found | 2.2 | 274 | 2.44 | 37 | 1 |
| (Extras) | | | | | |
| 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.

Field soil test (reserve nutrients)

## MAINE SOIL TESTING SERVICE

**High Tunnel Saturated Media Analysis For:**

THE UNIVERSITY OF MAINE 1865

[redacted]

**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.

Saturated media (soluble nutrients)

# Use soil test results to plan ahead for nutrient demands…

# But also consider your production goals and context

*Factors include planting date, grafting, tomato type and variety, tunnel style, markets, heat, etc.*

# 2018 New England High Tunnel Tomato Survey

Landscape 'scan' of 20 farms in New England

## Nitrogen applications should be 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.

# 2020-2021 High Tunnel Tomato Research

Applied newly revised recommendations & tracked outcomes

Developed “intake” form to document practices and inform recommendations

Farms reported yield and quality

*51 farms participated*

*5 farms closely studied with monthly soil and tissue samples*

# What did we learn?

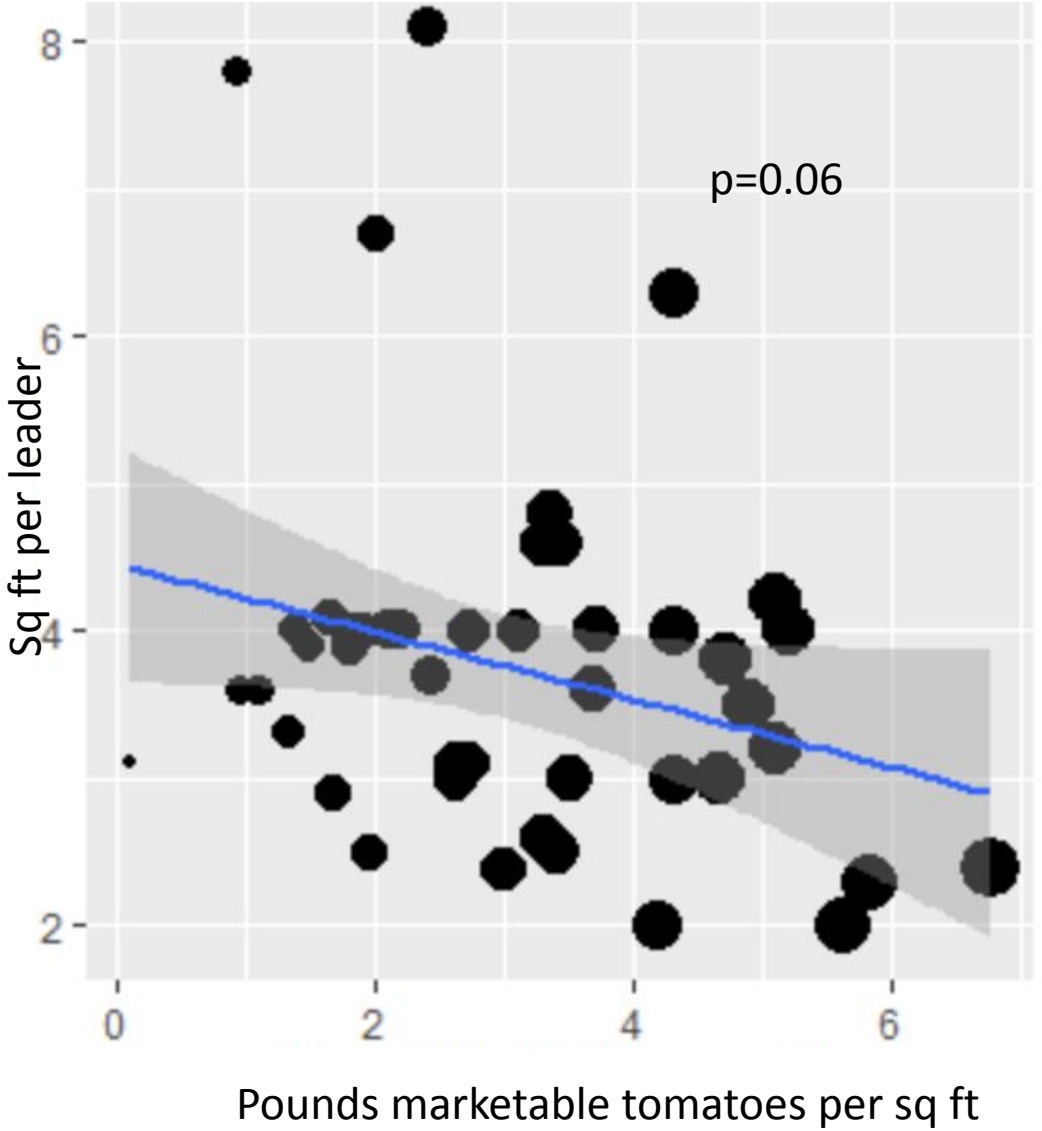
High tunnel tomatoes **yield 14 times more marketable fruit** than field tomatoes

*Average yield in this study's tunnels (n=51) = 71 tons/ acre*

*Average yield in Vermont field = 5 tons/ acre**

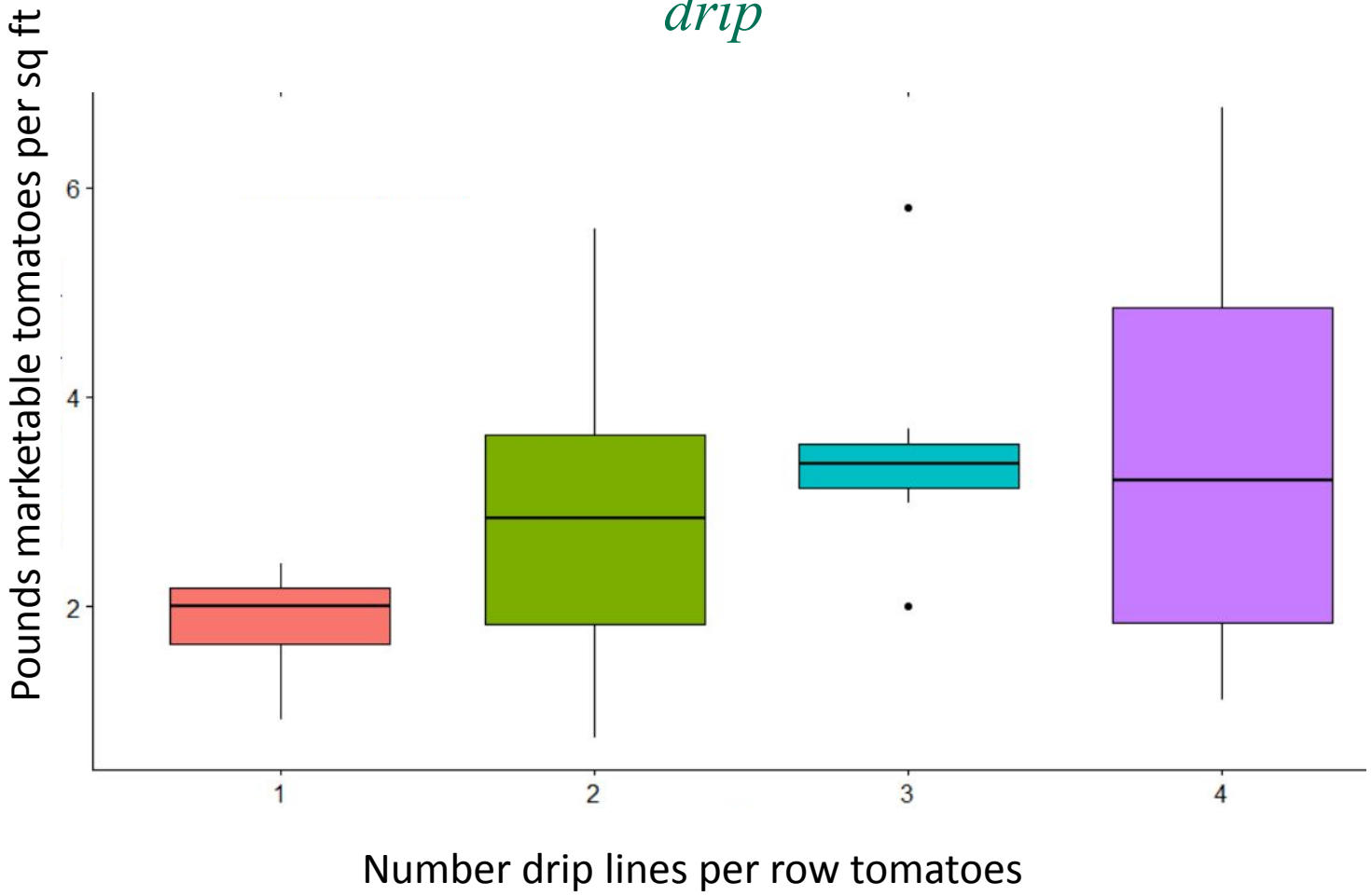
*NASS, 2017.

# Tighter stem density increases yield



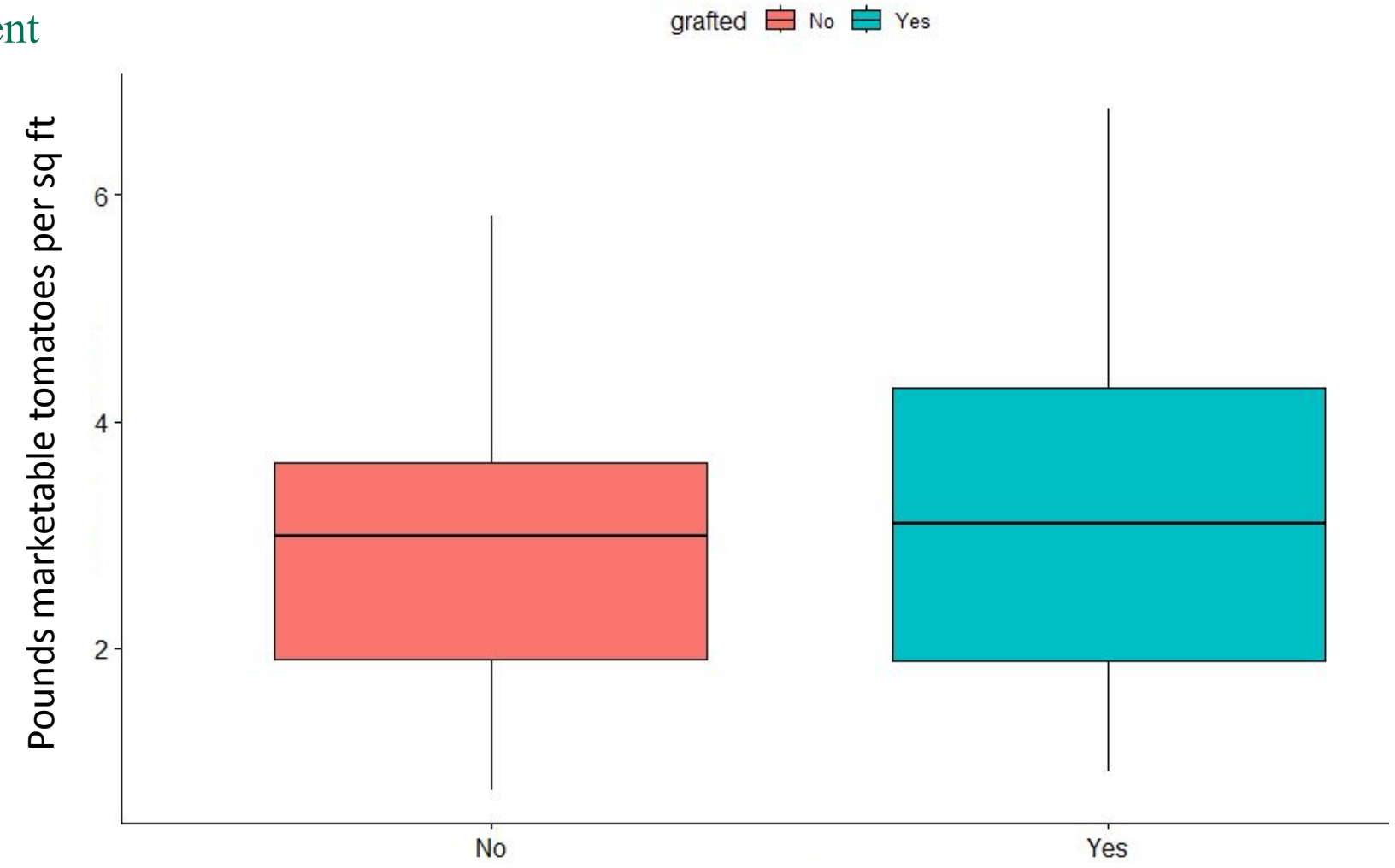
# Irrigation is important!

*Marketable tomato yield increases w/ up to 4 lines of drip*

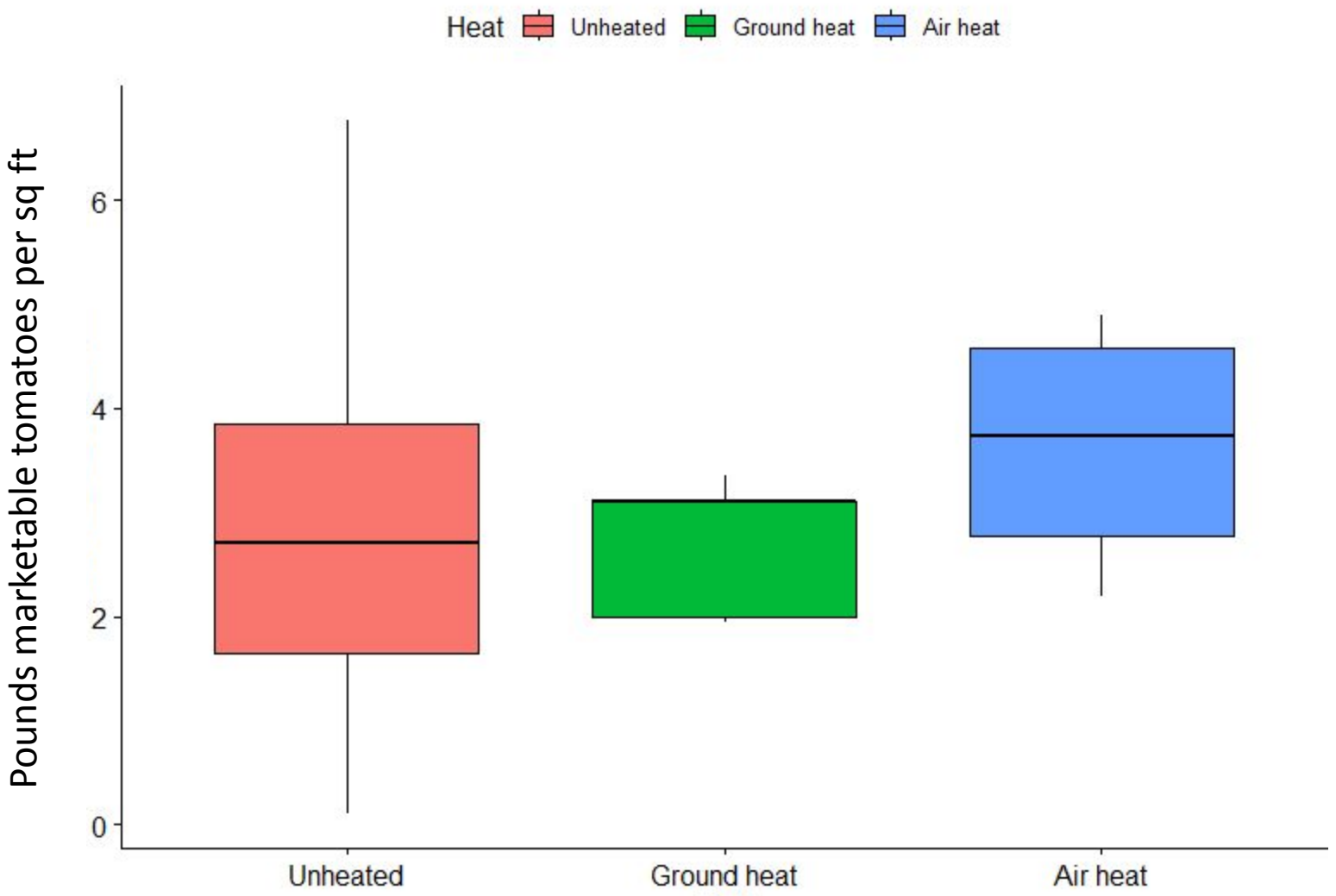



# Does grafting pay off?

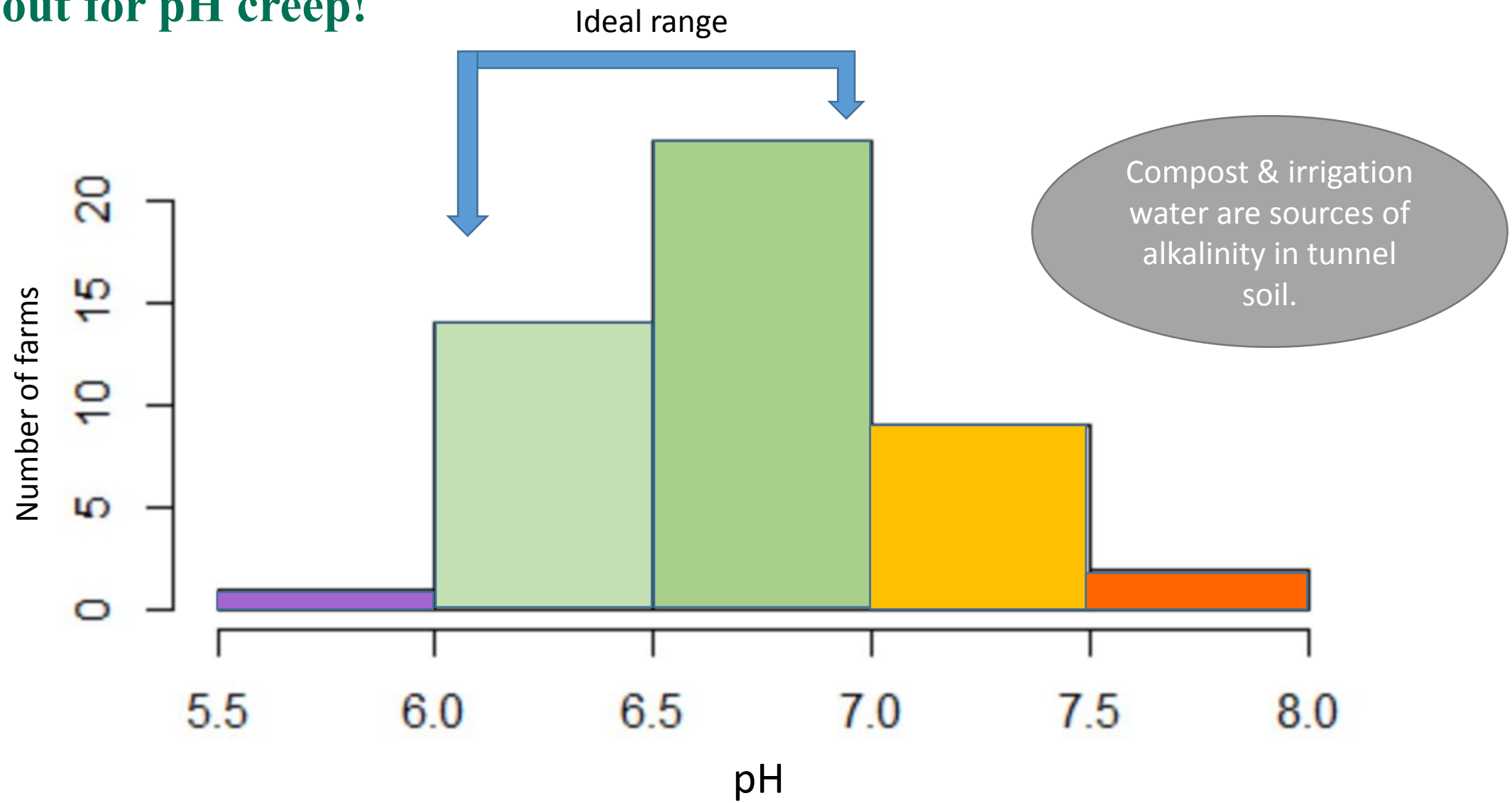
No significant yield improvement



## Air heat helps
*but does it pay off?*



# Look out for pH creep!




Compost & irrigation water are sources of alkalinity in tunnel soil.

**Sulfur lowers soil pH in tunnel.**

**Takes time to change pH**

(rate ~apx, 15 lbs/ 1000 sq feet)

# Basic high tunnel soil amending

**Follow soil test recommendation rates**

Amend full rates of P, Mg, Ca, and other nutrients but only **2/3 N and K up front**

Sidedress remaining N and K 3 to 4 weeks after planting and/or begin fertigating weekly 4-6 weeks after planting

**Spread “front loaded” soil amendments evenly!**

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

# Common organic soil amendments

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

**P**: bone meal, bone char

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

**Ca**: lime, gypsum

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

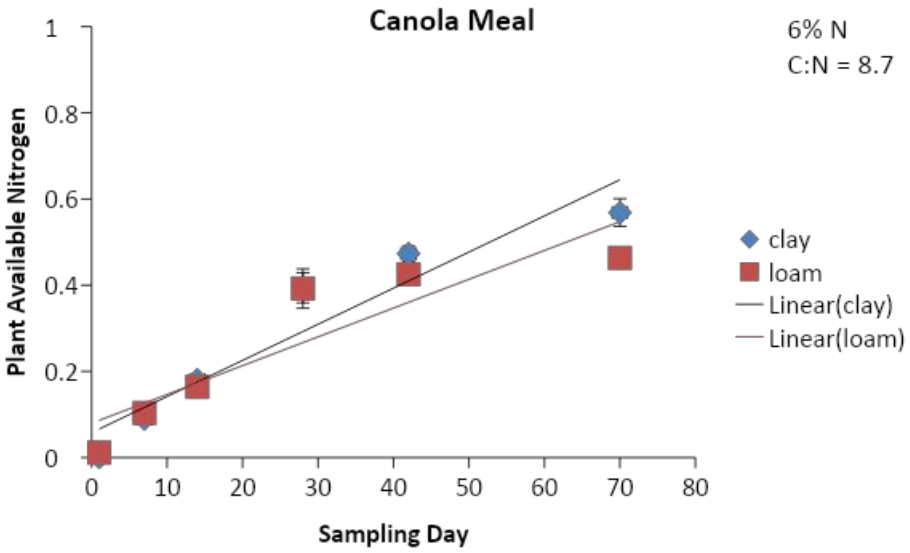
**Blends**: ProGro, Cheep-Cheep, alfalfa meal etc.

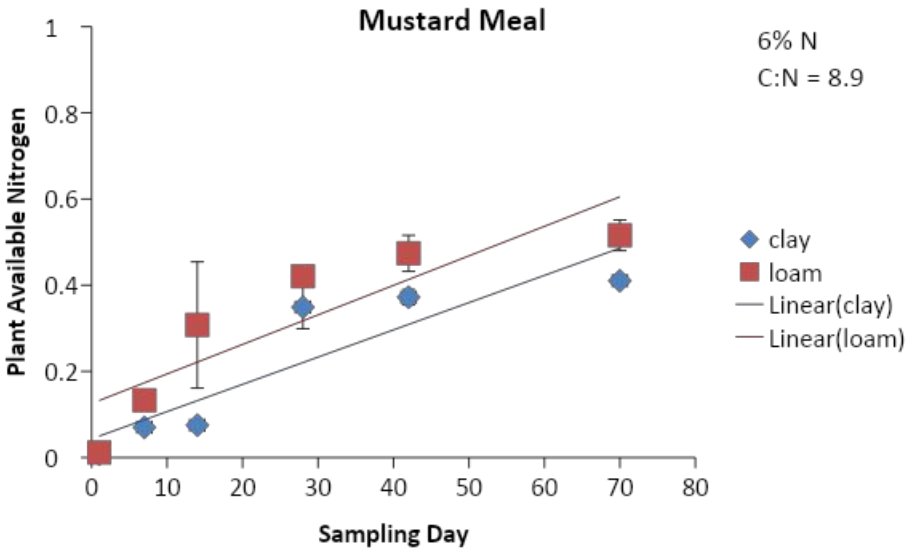
**Micros**: compost, borax, Azomite, chelates

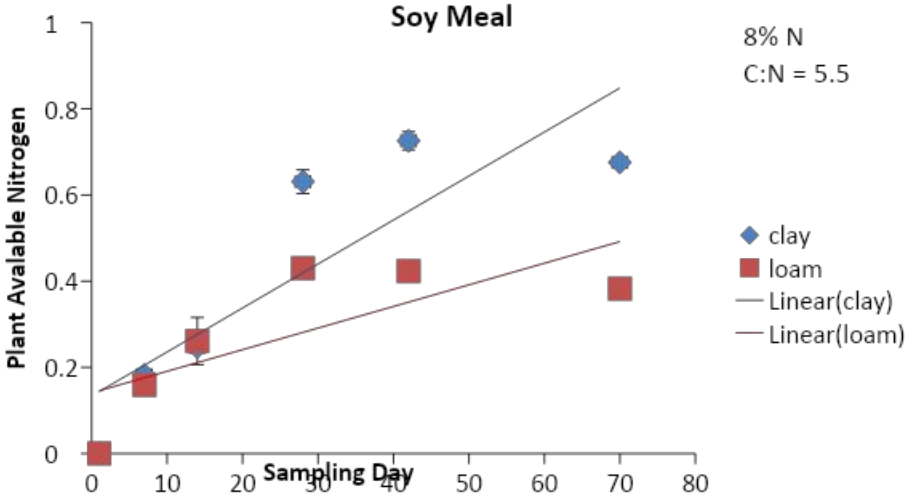
**Organic matter**: compost, peat moss, leaves, carbon, etc.

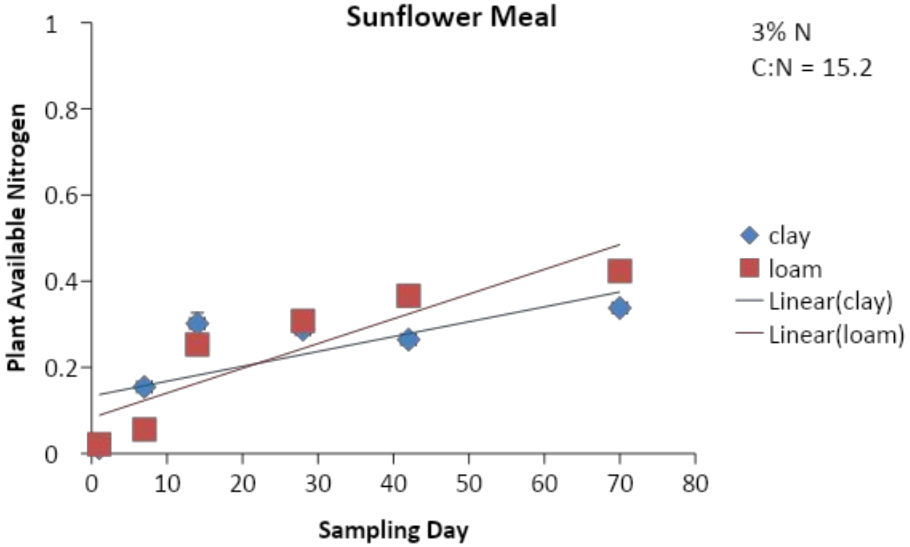
*Slide courtesy of Vern Grubinger*

# Seed meals – slow steady N release over growing season



# If pH and nutrients are high, consider materials besides compost to add organic matter

**Peat moss (3-4 bales compressed per 1000 sq feet) works well, but not sustainably sourced**

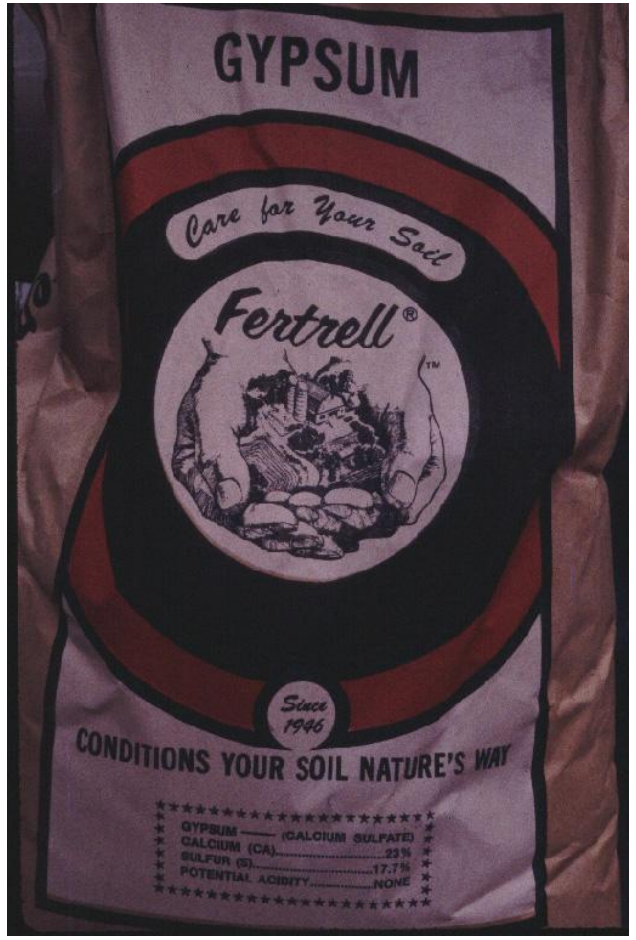
***Shredded cover crops, grass clippings, coir, shredded straw leaves, other organic materials?***

**If soil test calls for phosphorus, compost is a good long term source, but for immediate availability, bone char is an organic option**


*Photo courtesy of Vern Grubinger*

## Epsom Salts for Mg


## Gypsum adds calcium, doesn't change soil pH



**Salts can build up in tunnel soils, especially near the surface**

**Leaf tissue analysis measure what the plants took up**

Begin 1 month after transplant, sample monthly.

*'Reading the plants' is a good idea, but it's not precise, and by the time you see a symptom it's harder to recover*

# Understanding Tissue Samples

| UMaine Lab | Sample results | Optimal Range |
|---|---|---|
| Nitrogen (%) | 1.54 | 3.5-5 |
| Potassium (%) | 0.96 | 3.5-4.5 |
| Phosphorus (%) | 0.206 | 0.3-0.65 |
| Calcium (ppm) | 2.7 | 1-3 |
| Magnesium (ppm) | 0.218 | .35-1 |
| Manganese (ppm) | 42 | 25-200 |
| Iron (ppm) | 119.4 | 50-300 |
| Copper (ppm) | 5.42 | 5-35 |
| Boron (ppm) | 45 | 30-75 |
| Zinc (ppm) | 85.8 | 18-80 |

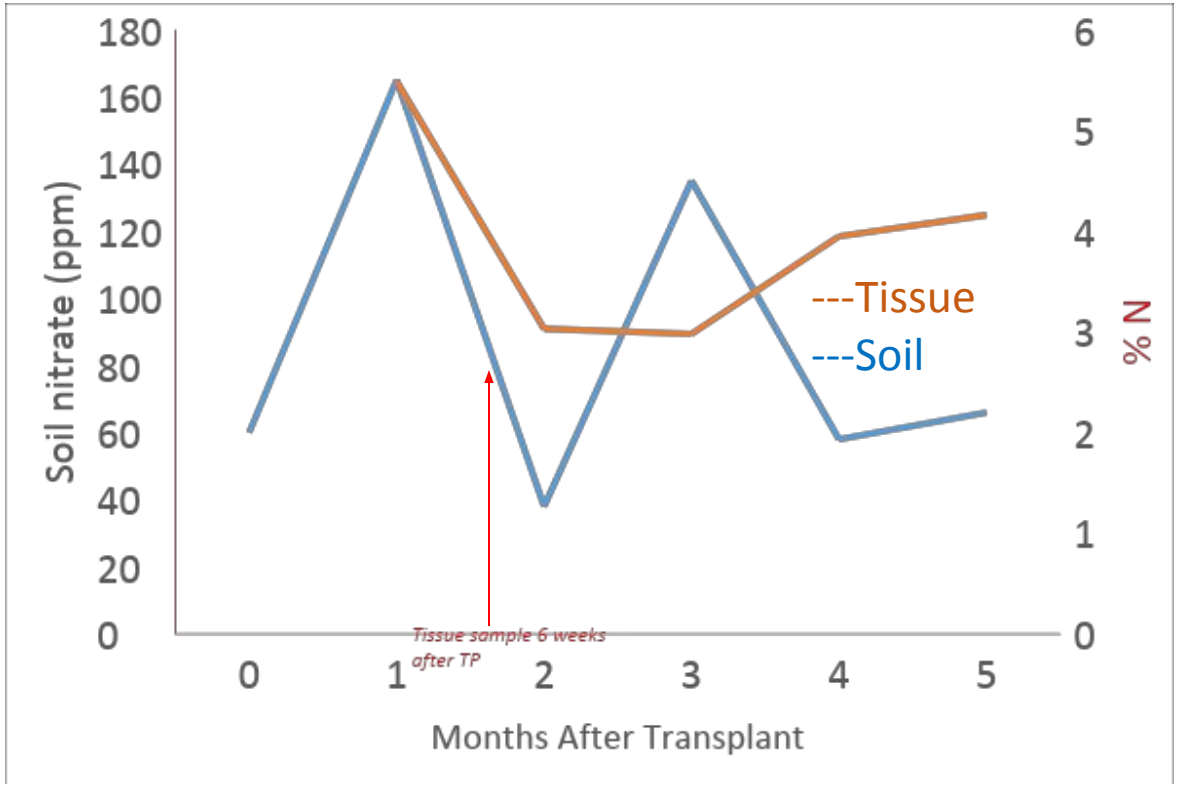
*

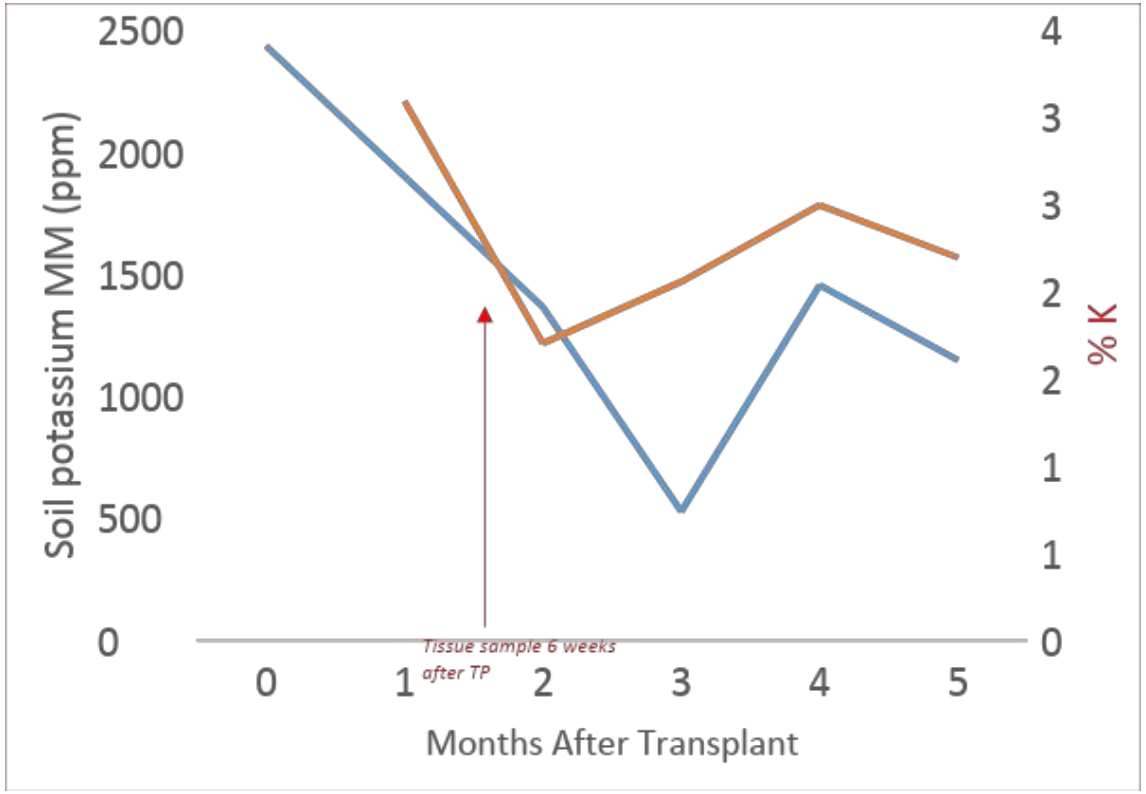
| Nutrient | Conc. in leaves (%) | |
|---|---|---|
| | Before fruiting | During fruiting |
| N | 4.0-5.0 | 3.5-4.0 |
| P | 0.5-0.8 | 0.4-0.6 |
| K | 3.5-4.5 | 2.8-4.0 |
| Ca | 0.9-1.8 | 1.0-2.0 |
| Mg | 0.5-0.8 | 0.4-1.0 |
| S | 0.4-0.8 | 0.4-0.8 |

*More N and K during vegetative growth; less when fruiting*

*Source: https://www.haifa-group.com/

# Tissue tests help guide fertigation; plants respond quickly.




**Both soil nitrate and potassium quickly respond to soluble applications of N (left) and K (right)**

# Simple organic fertigation

**0.25 lb/ 1000 sq feet N and K** = 1.5 lbs sodium nitrate and 0.5 lbs

potassium sulfate fines dissolved


Potassium sulfate 0-0-50 “fines” dissolve and are more available


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

**Best to add at end of irrigation cycle**

**Flush drip lines**

## So what does a “good” crop look like???

May

June

July

August

September

November

**Marketable Yield = 6.76 lb per sq ft** *(294,000 lb / acre)*

May

June

July

August

**Marketable Yield = 1.3 lb per sq ft** *(56,602 lb/acre)*

# What about leafy greens, winter growing?

A lot less nutrients are needed, but data are lacking.

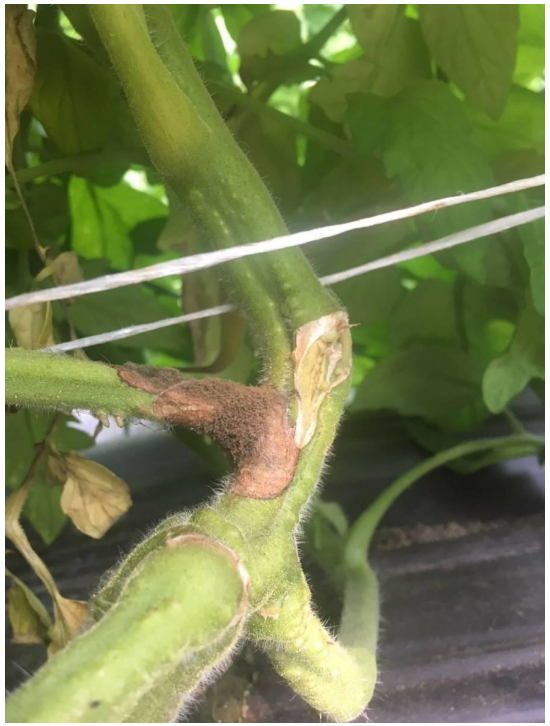
Soil testing before planting still makes sense

**How important is cover cropping to tunnel soil fertility?**

*There are pros and cons.*

# A bare tunnel between crops is less likely to host pests

# Other factors that affect yield



# Cultural practices

Maintain good airflow and low humidity


Pruning and lower leaf removal

## Recommendations:

- Set yield goal (3-5 lbs/$ft^2$).
- Transplant at higher density 3-5$ft^2$ per leader.
- Soil test for available AND reserve soil nutrients.
- Provide sufficient available N for biomass production through the entire growing season
- Make sure adequate K is available, especially as fruits form.

## More recommendations:

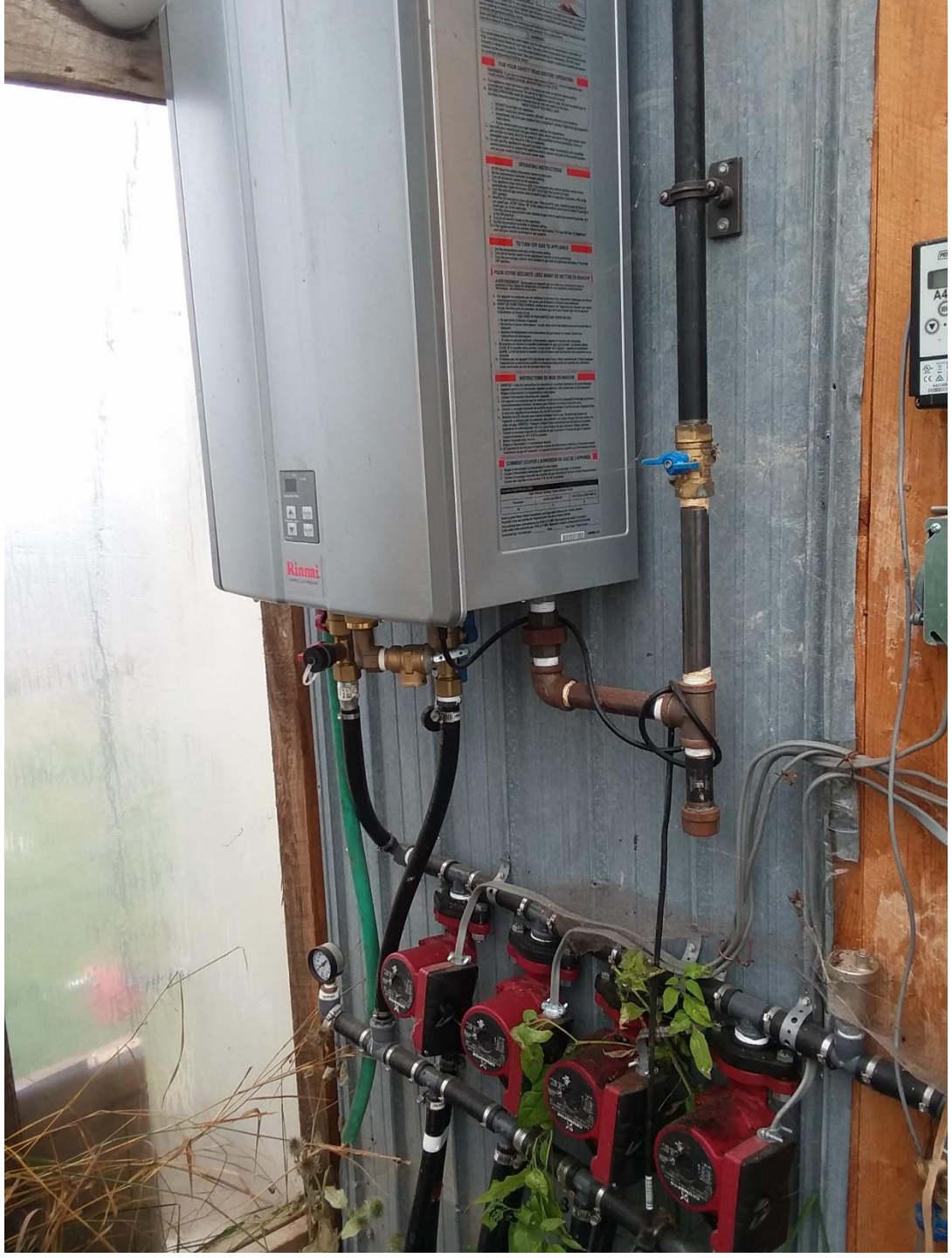
- Front-load slow-release amendments.
- Take tissue samples one month after transplanting.
- Be prepared to fertigate N and K.
- Have at least 2 drip lines per plant row; sandier soils 4 lines.
- Track performance.

# Efficiencies—pruning and clipping


# Efficiencies—harvest carts

Photos: Intervale Community Farm

# Efficiencies—radiant heat system



# Ventilation—ridge vent

# Ventilation—gable end vent

# Ventilation—Vertical Air Flow Fans

# Ventilation: socket roll ups

# Troubleshooting

# Troubleshooting

# Troubleshooting

# Troubleshooting

# Troubleshooting

# Troubleshooting

# Thank you!

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