# High Tunnel Tomato Production for Organic Soil-Based Systems

**Kootenay and Boundary Farm Advisors**

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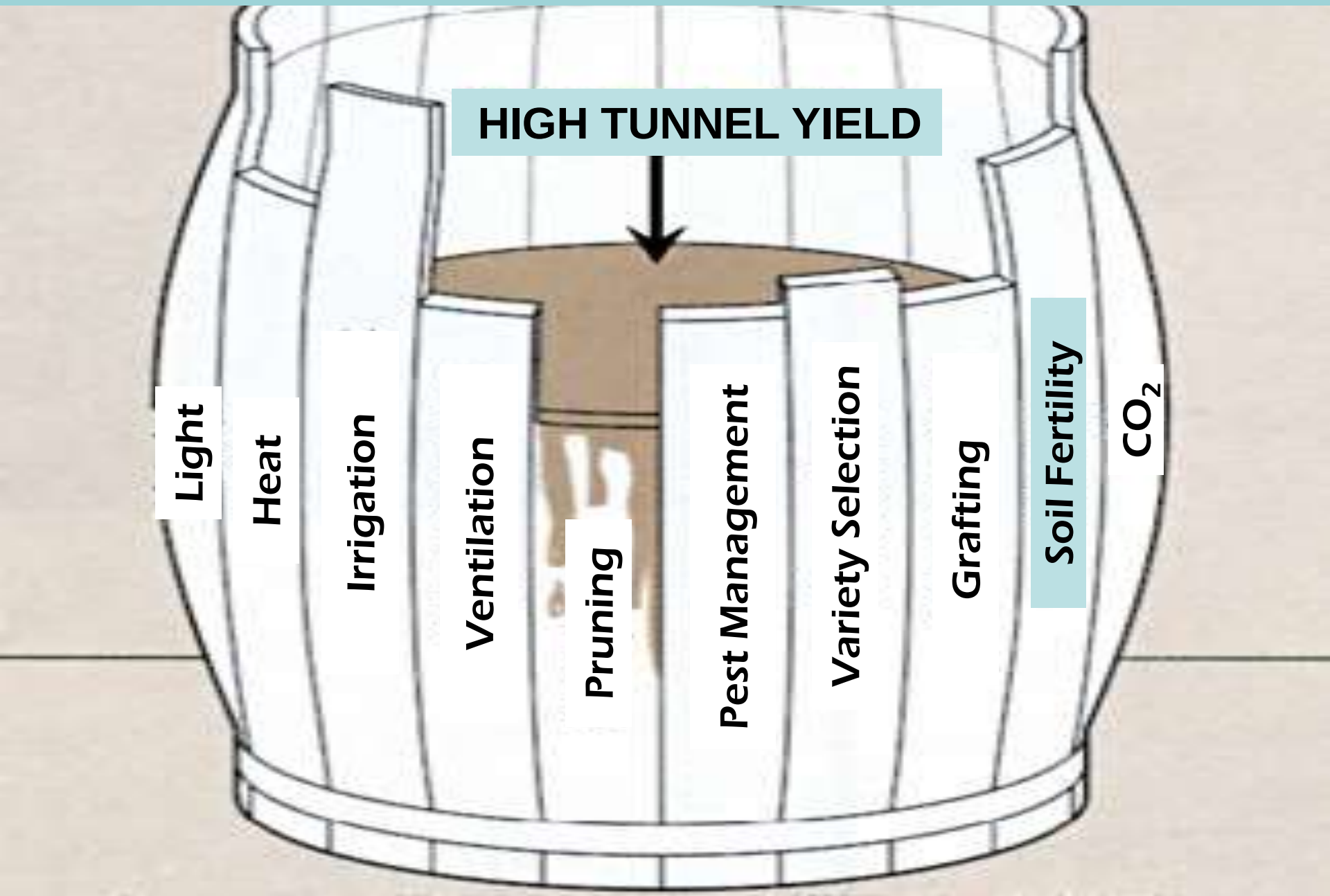
https://www.uvm.edu/extension/horticulture/commercial

THE UNIVERSITY OF VERMONT EXTENSION

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

**Most production is “in the ground”**

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



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

# Many different types of production often as sequences of crops in the same tunnel


raised beds


trays and containers


winter greens


summer crops

# Rooting volume matters: small=less buffered

**Need to "dial it in" for small root volumes.**

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

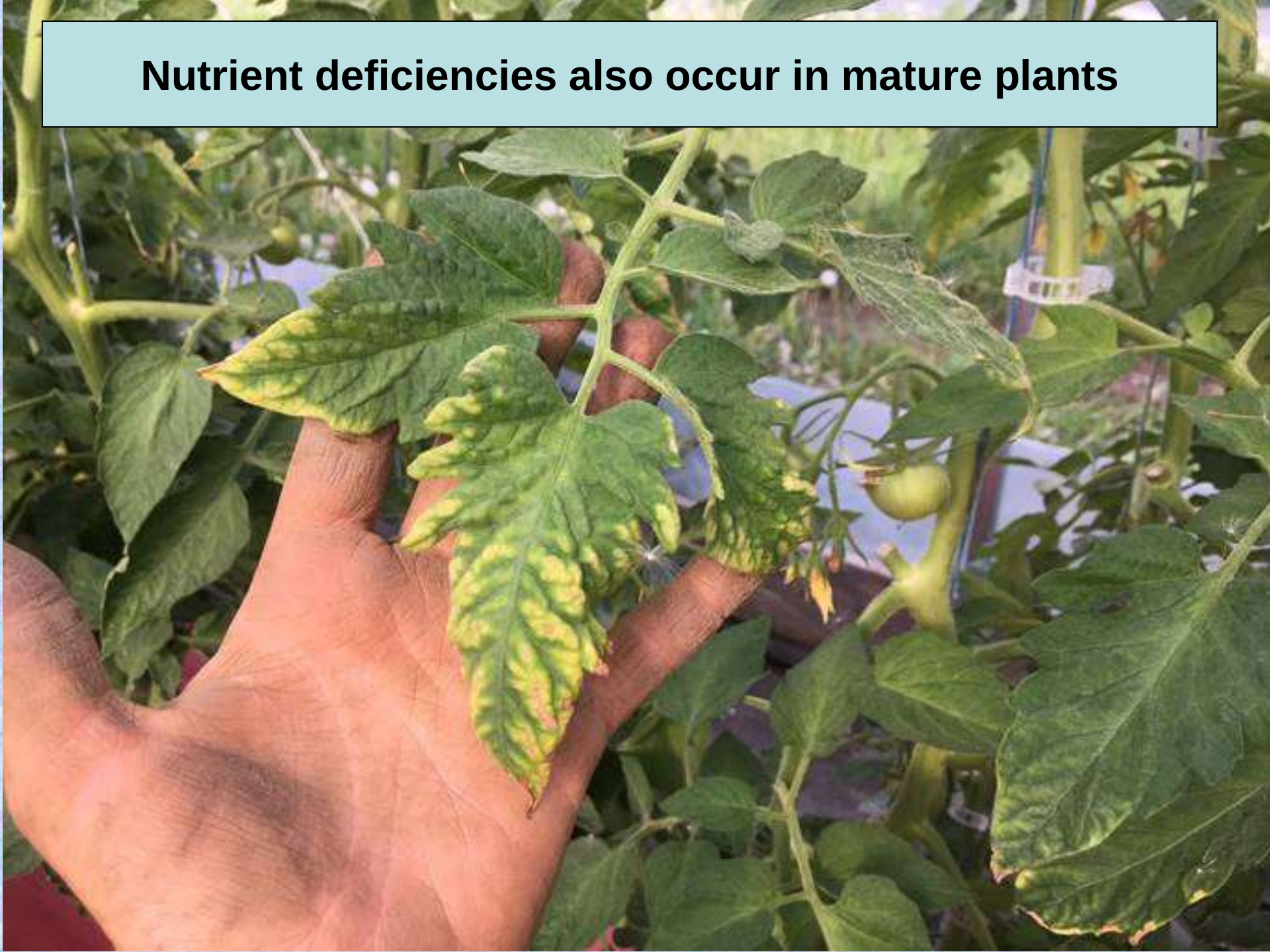
**The ground is typically amended with lots of compost and nutrients so it is somewhere between a field soil and a potting soil**

# If soil on site is poor quality or compacted, make raised beds

# Nutrients affect quality not just yield

# Nutrients may run out when growing transplants in a mix

# Nutrient deficiencies also occur in mature plants



# Excess nutrients can lead to high salts in a potting mix

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

**Organic growing medium is a ‘black box’**
**It may look good, feel good, smell good…what’s in it?**

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

# Different tests for different information

**Field soil test** for reserve nutrients
(modified Morgan's, Brays, Melich-3)

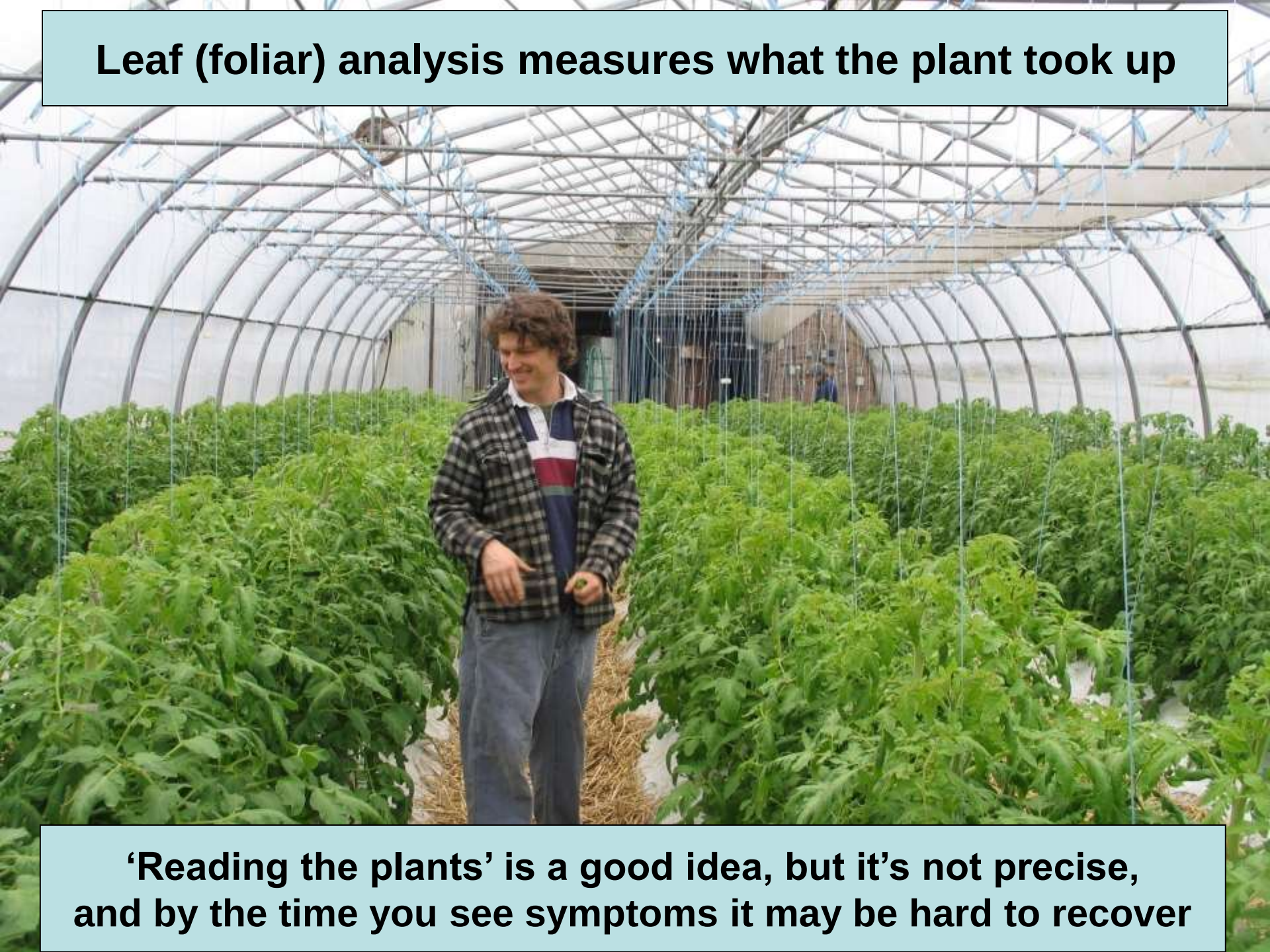
**Potting soil test** for soluble nutrients
(Saturated Media Extract)

**Tissue analysis** for nutrient levels in plants
(concentration of elements in dry leaves)

**What's available now (soluble)… and later (reserve)... and what was used by plants (uptake)**

**SME, field soil test, and tissue tests can provide answers**

# Leaf (foliar) analysis measures what the plant took up



**‘Reading the plants’ is a good idea, but it’s not precise, and by the time you see symptoms it may be hard to recover**

# Different tests require different samples

**all should be a composite sample from 'representative' area**

**Field soil test.** 1 cup soil, stick to same time of year

**Saturated media extract.** 1 pint of soil, warm and moist, several weeks before setting transplants

**Tissue analysis.** Youngest fully mature leaf (4$^{th}$ or 5$^{th}$ from top of tomato plants) starting at fruit set

# All types of tests have this process

1) Proper sampling

2) Analysis by the lab

3) Interpretation of results

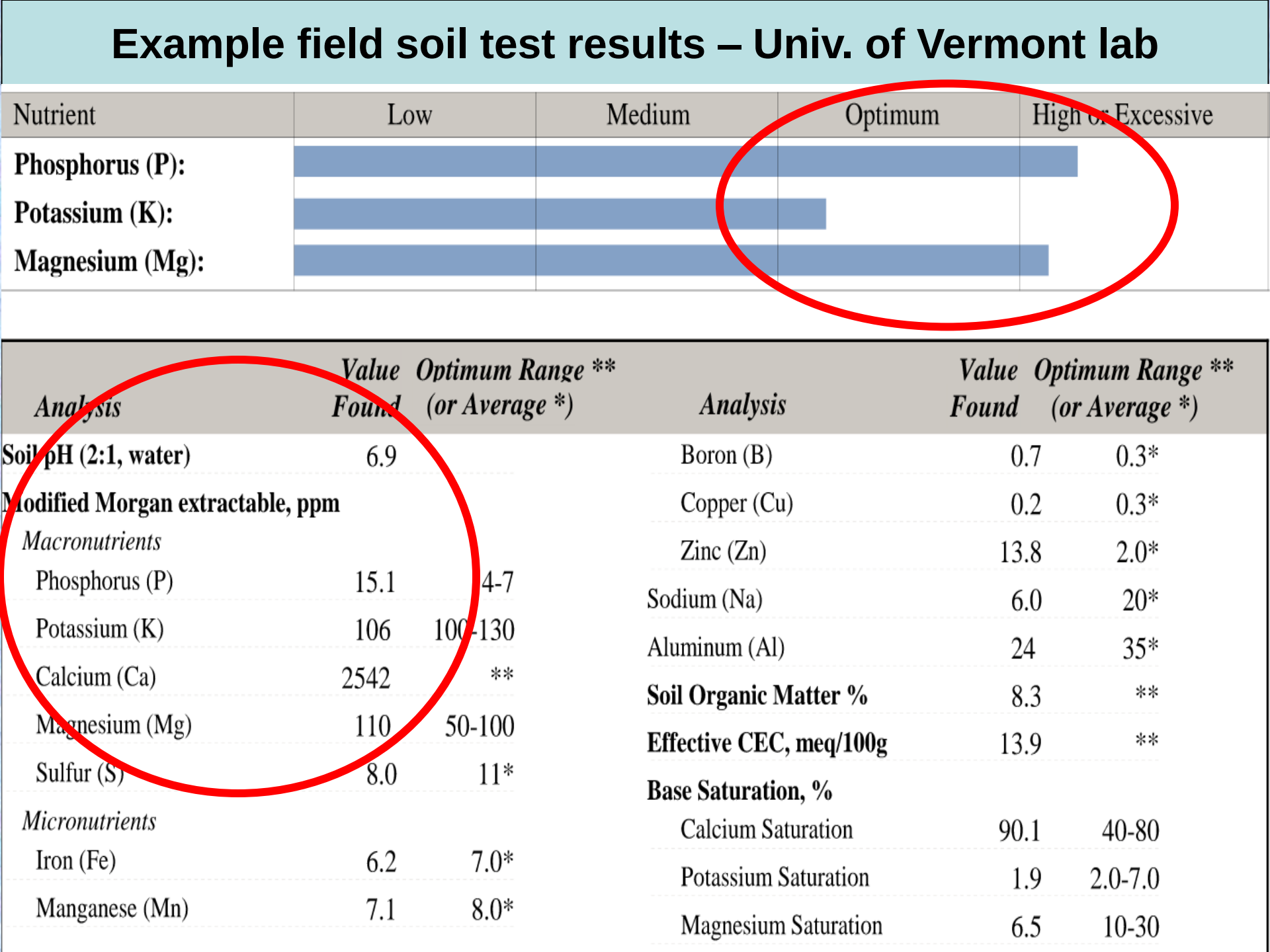
4) Recommendations

# Are you ready for some examples of test results?

**The next few slides have lots of data. This may disturb some brains. Viewer discretion advised.**

# Example field soil test results – Univ. of Vermont lab

| Nutrient | Low | Medium | Optimum | High or Excessive |
|---|---|---|---|---|
| **Phosphorus (P):** | | | | |
| **Potassium (K):** | | | | |
| **Magnesium (Mg):** | | | | |



| *Analysis* | *Value Found* | *Optimum Range ** (or Average *)* |
|---|---|---|
| **Soil pH (2:1, water)** | 6.9 | |
| **Modified Morgan extractable, ppm** | | |
| *Macronutrients* | | |
| Phosphorus (P) | 15.1 | 4-7 |
| Potassium (K) | 106 | 100-130 |
| Calcium (Ca) | 2542 | ** |
| Magnesium (Mg) | 110 | 50-100 |
| Sulfur (S) | 8.0 | 11* |
| *Micronutrients* | | |
| Iron (Fe) | 6.2 | 7.0* |
| Manganese (Mn) | 7.1 | 8.0* |

| *Analysis* | *Value Found* | *Optimum Range ** (or Average *)* |
|---|---|---|
| Boron (B) | 0.7 | 0.3* |
| Copper (Cu) | 0.2 | 0.3* |
| Zinc (Zn) | 13.8 | 2.0* |
| Sodium (Na) | 6.0 | 20* |
| Aluminum (Al) | 24 | 35* |
| **Soil Organic Matter %** | 8.3 | ** |
| **Effective CEC, meq/100g** | 13.9 | ** |
| **Base Saturation, %** | | |
| Calcium Saturation | 90.1 | 40-80 |
| Potassium Saturation | 1.9 | 2.0-7.0 |
| Magnesium Saturation | 6.5 | 10-30 |

# Example SME results – Univ. of Maine soil test lab

| | | | | |
|---|---|---|---|---|
| pH | 6.0 - 7.0 | 7.4 | | HIGH |
| Soluble Salts | 2.0 - 4.0 mmhos/cm | 2.57 | mmhos/cm | OK |
| Organic Matter | 8 - 12 % | 8.3 | % | OPTIMUM |
| Nitrate-N | 100 - 200 ppm | 30.5 | ppm | LOW |
| Ammonium-N | < 10 ppm | < 0.5 | ppm | OK |
| Phosphorus | 1 - 5 ppm | 1.4 | ppm | OPTIMUM |
| Potassium | 150 - 275 ppm | 12 | ppm | LOW |
| Magnesium | > 60 ppm | 151 | ppm | OPTIMUM |
| Calcium | > 250 ppm | 403 | ppm | OPTIMUM |
| Aluminum | < 10 ppm | 0.1 | ppm | OK |
| Boron | 0.05 - 0.50 ppm | 0.05 | ppm | OPTIMUM |
| Copper | 0.01 - 0.5 ppm | 0.027 | ppm | OPTIMUM |
| Iron | 0.3 - 5.0 ppm | 0.06 | ppm | LOW |
| Manganese | 0.1 - 3.0 ppm | 0.02 | ppm | LOW |
| Sodium | < 100 ppm | 74 | ppm | OK |

# Tomato tissue test (leaf analysis) results – UMaine lab

PERCENT (MAJOR NUTRIENTS), PPM(ALL OTHERS)

| Nutrient | GNU 5 MAT | GH2 Duchess | Optimum Range |
|---|---|---|---|
| N | 3.80 | 1.79 | 3.0 - 5.0 |
| Ca | 1.88 | 2.91 | 0.9 - 3.0 |
| K | 2.27 | 1.11 | 2.5 - 5.0 |
| Mg | 0.697 | 0.407 | 0.3 - 1.0 |
| P | 0.359 | 0.213 | 0.2 - 1.0 |
| Al | 223 | 155 | ---------- |
| B | 37.0 | 39.7 | 20 - 50 |
| Cu | 9.67 | 6.79 | 5 - 20 |
| Fe | 86.8 | 303 | 40 - 200 |
| Mn | 22.3 | 42.9 | 30 - 125 |
| Zn | 21.8 | 10.1 | 25 - 60 |

**Tunnel tomatoes: plan for heavy nutrient demand, yields can be much greater than in the field**

# Nutrient needs depend on yield potential

## Nitrogen 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 |

https://go.uvm.edu/tunnel-recs

# $K_20$ application rate based on Modified Morgan's soil test result

| soil test result: | Low <400 lb./A | | Medium 400-800 lb./A | | High/optimum 800-1200 lb./A | | Excessive > 1200 lb./A | |
|---|---|---|---|---|---|---|---|---|
| | lbs/acre | lbs/ 1000 ft$^2$ | lbs/acre | lbs/ 1000 ft$^2$ | lbs/acre | lbs/ 1000 ft$^2$ | lbs/acre | lbs/ 1000 ft$^2$ |
| **Low yield** | 300 | 6.9 | 200 | 4.6 | 100 | 2.2 | 0 | 0 |
| **Medium 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 |

# What about leafy greens, winter growing?

**A lot less nutrients are needed, but data are lacking.**
**Soil testing before planting still makes sense**


**Know your organic fertilizer options, beyond compost**

# Common organic soil amendments

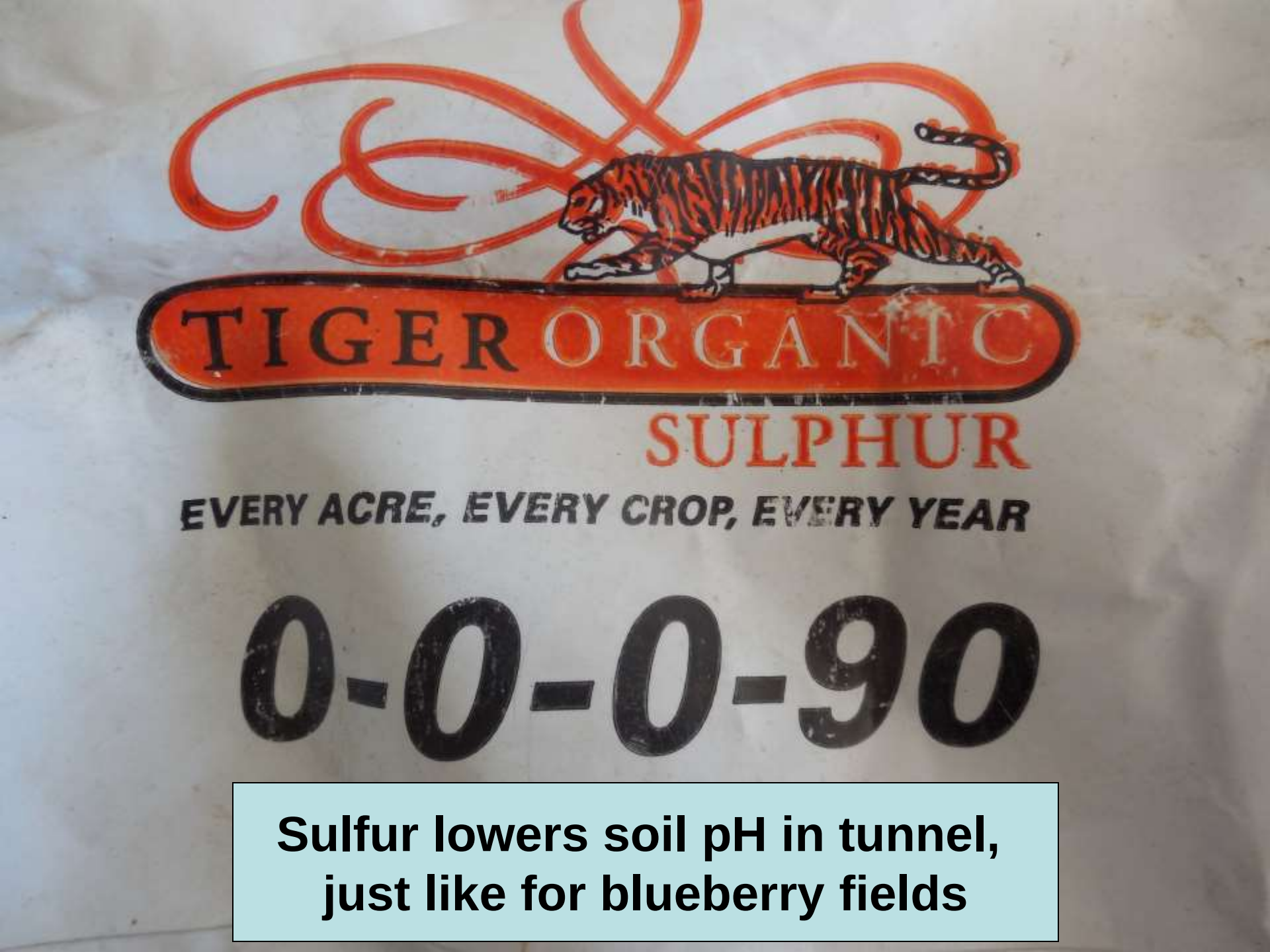
- **N**: soy, peanut, feather meal; Chilean (sidedress)
- **P**: bone meal, bone char, rock phos
- **K**: potassium sulfate, sul-po-mag, greensand
- **Ca**: lime, gypsum
- **Mg**: dolomitic lime, sul-po-mag, epsom salts
- **Blends**: ProGro, Cheep-Cheep, alfalfa meal etc.
- **Micros**: compost, borax, Azomite, chelates
- **Organic matter**: compost, peat moss

**Agricultural limestone**

Calcite ($CaCO_3$) or Dolomite ($CaCO_3 + MgCO_3$)

Calcite: ~ 40% Ca and 0.5% Mg

Dolomite: ~ 22% Ca and 13% Mg




**Sulfur lowers soil pH in tunnel, just like for blueberry fields**

**Peat moss helps maintain or increase organic matter when compost is not needed or is unavailable**


**Apply 1 to 3 bales (3 cu. ft.) of compressed peat moss per 1,000 sq. ft. (plus 10 lb lime/bale if needed)**

**Use blended fertilizers only if all 3 of N-P-K are needed**

# PRO-GRO 5-3-4
# A NATURAL/ORGANIC FERTILIZER

This product is blended from the following list of natural ingredients:

BONEMEAL
ROCK PHOSPHATE
COLLOIDAL PHOSPHATE
OYSTER MEAL
KELP MEAL

GREENSAND
LANGBEINITE
VEGETABLE PROTEIN MEALS
MEAT AND BONE MEAL

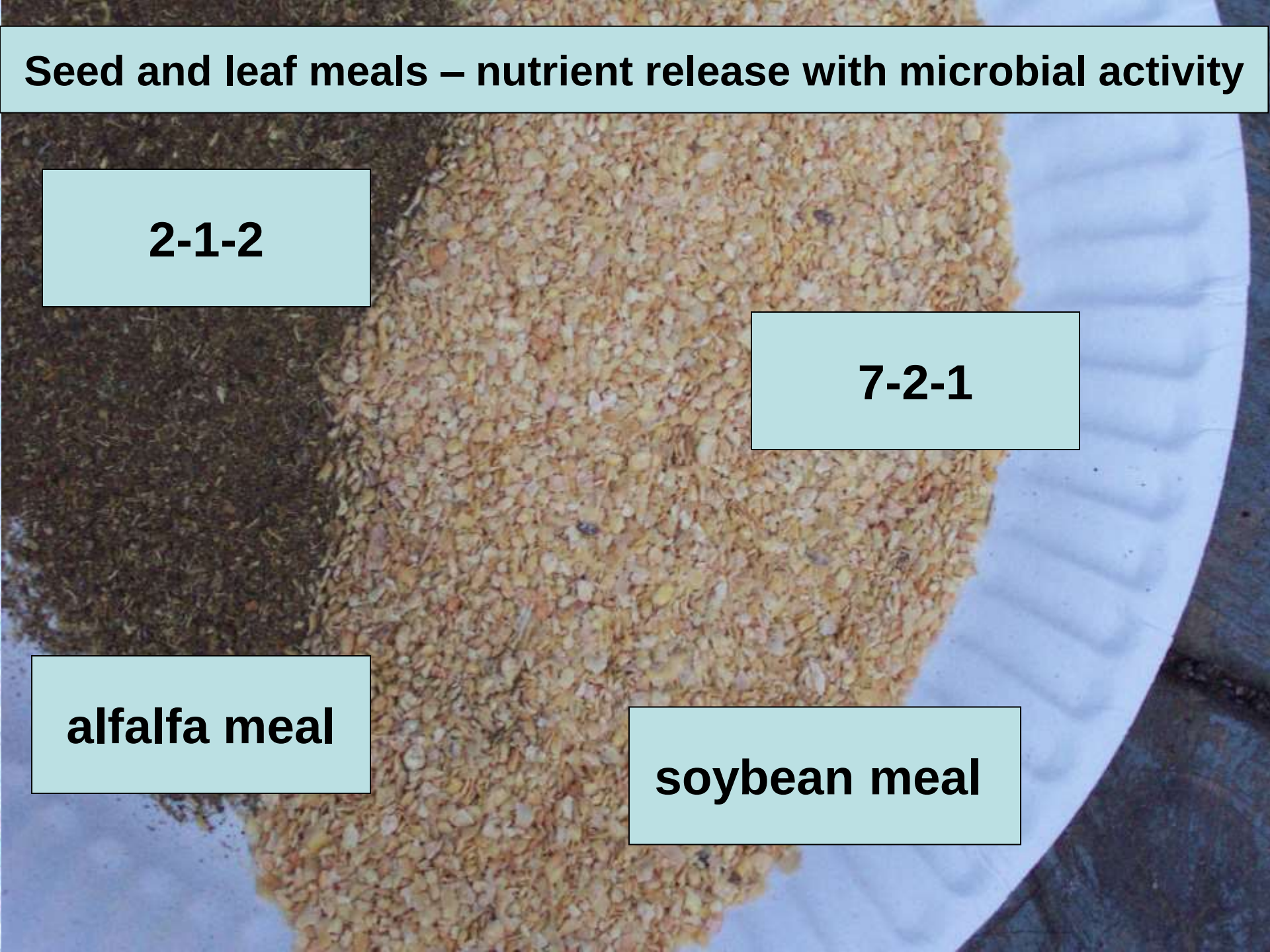
NATURAL NITRATE OF SODA
LEATHER MEAL
FISH MEAL
BENEFICIAL BACTERIA
HUMATES
TRACE MINERALS

**An organic N fertilizer, allow time for microbial activity to convert all the way to nitrate-N**

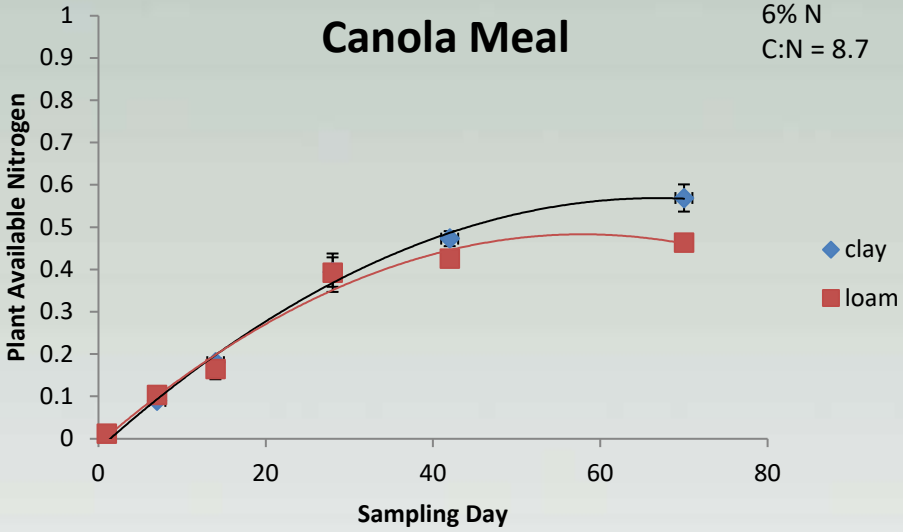
# “Chilean nitrate” is soluble, good for fertigation if needed

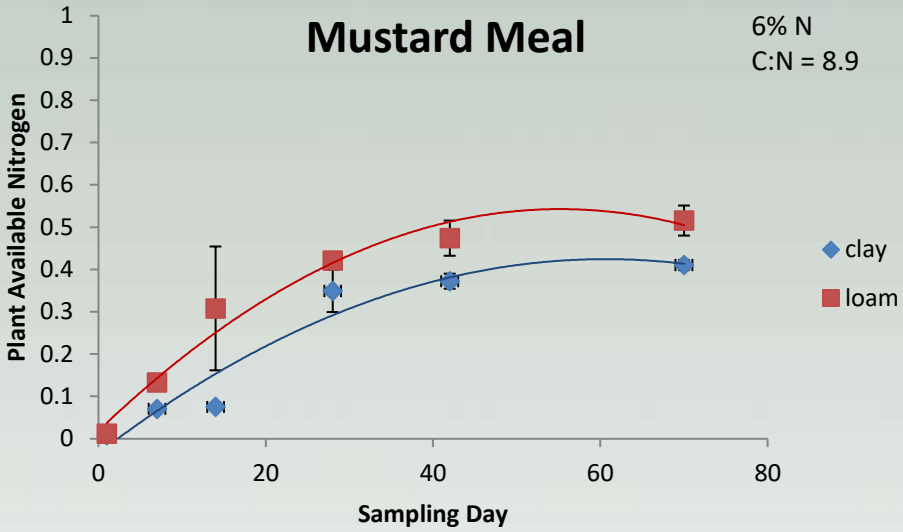

**Use about 1 lb per 1,000 sq. ft. in at least 100 gal. water**

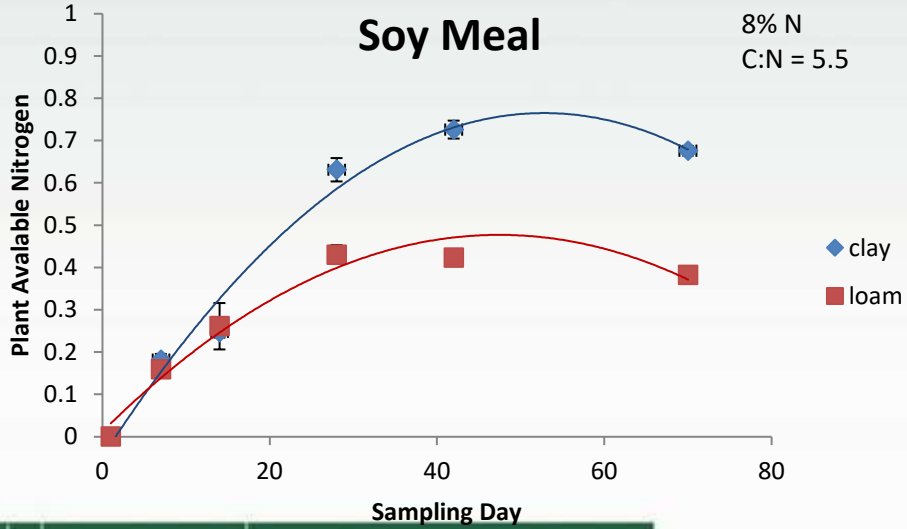
# Seed and leaf meals – nutrient release with microbial activity

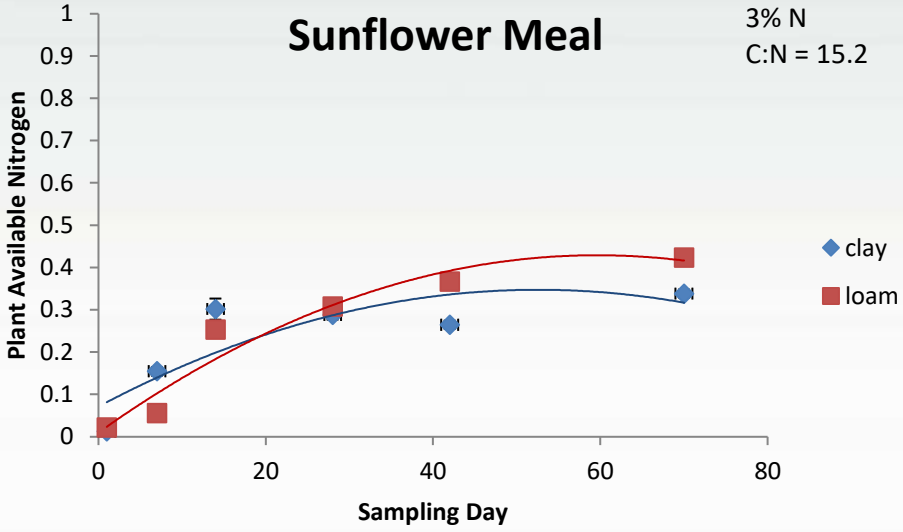


# Seed meals – slow steady N release over growing season

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CULTIVATING HEALTHY COMMUNITIES

slide courtesy of Dr. Heather Darby

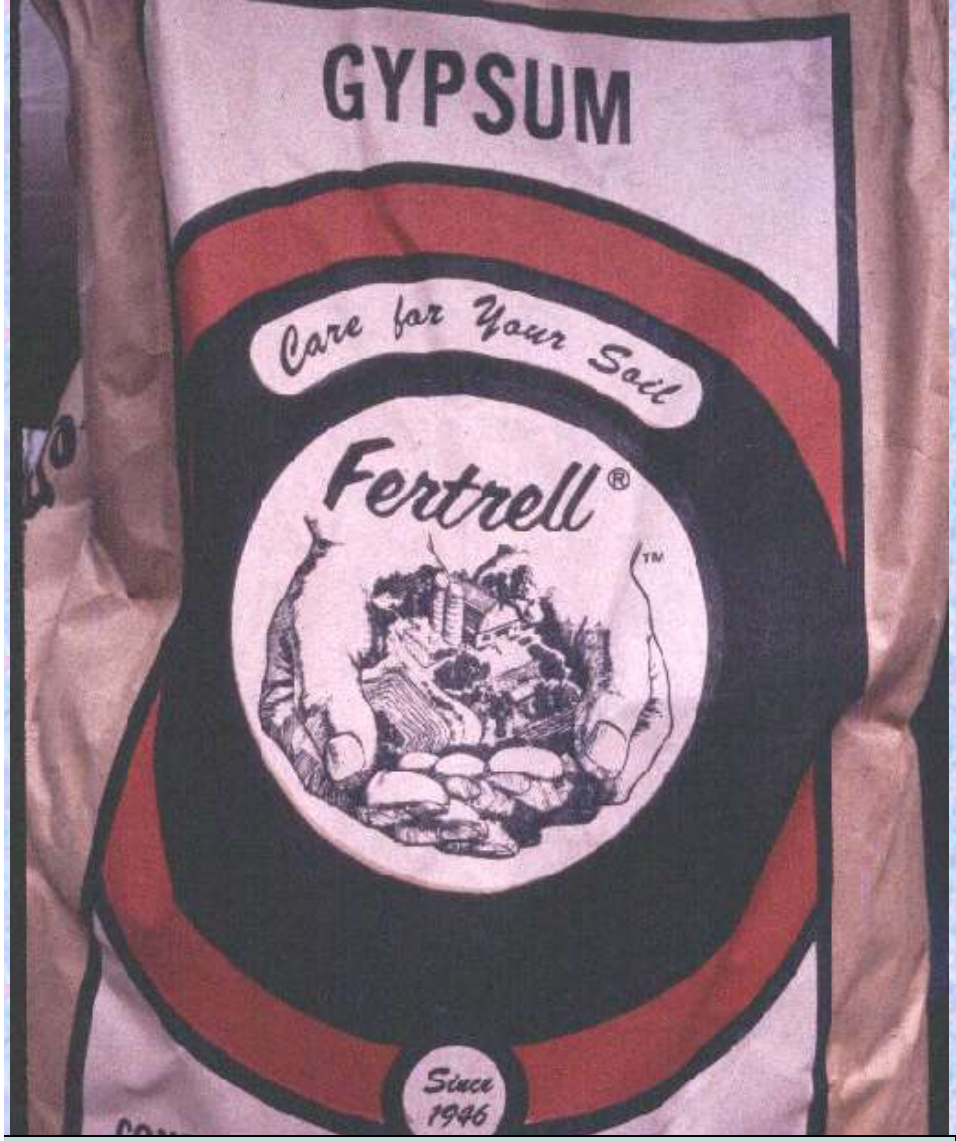

P fertilizer, relatively high availably.
Steamed bone meal is another, similar option
BONE CHAR 0-16-0
BONE CHAR 0-16-0
BONE CHAR 0-16-0

**For K, use potassium sulfate, 0-0-50, unless you also need magnesium**

**Sul-po-mag 0-0-22-11 Mg**
(same as langbenite, K-mag)



**Potassium sulfate “fines” are small particles, more soluble. Can be used to fertigate,**


**Epsom salts for Mg**

**Gypsum adds Ca, doesn't change soil pH**

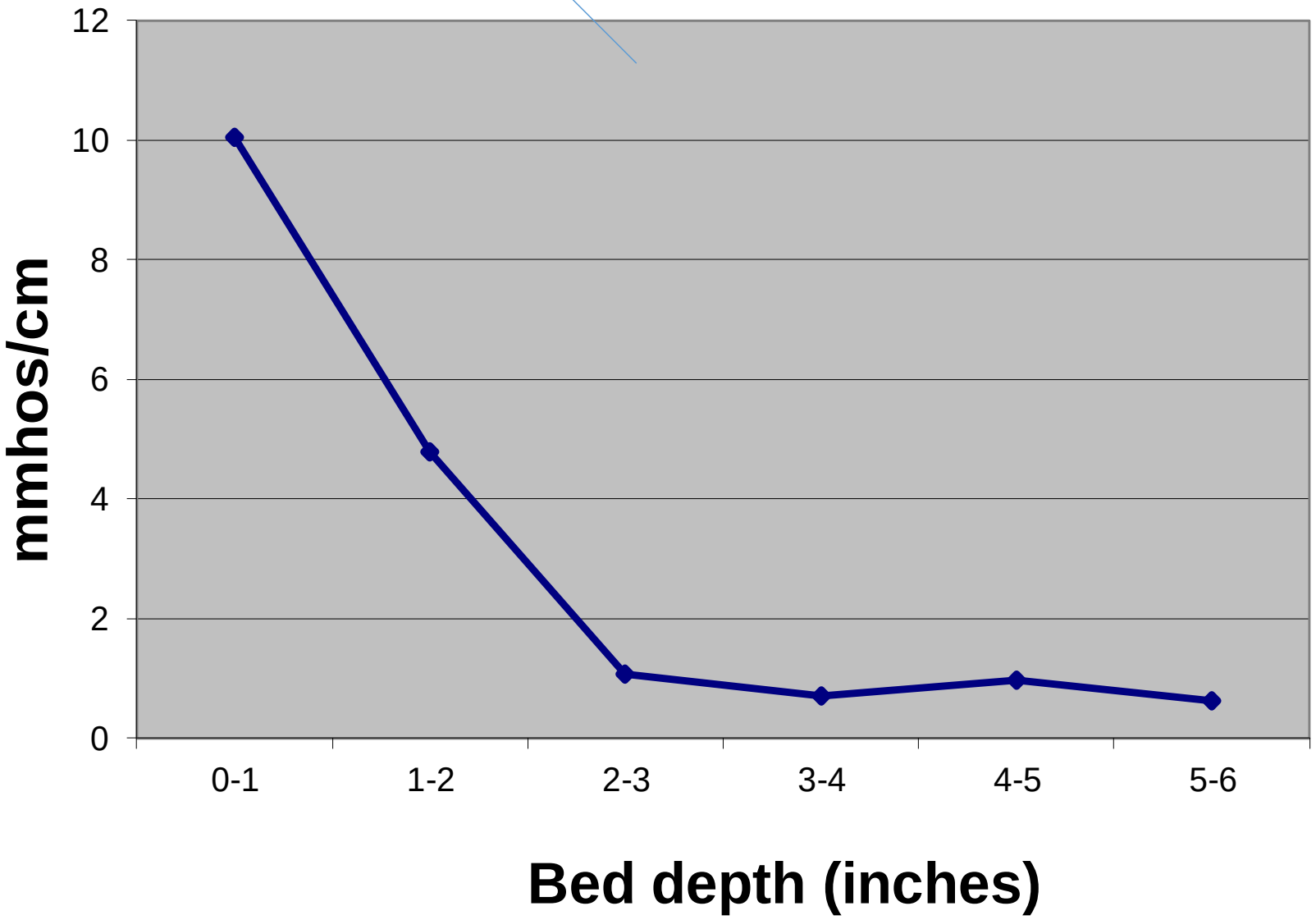
**If pH is neutral, and compost has been added, trace elements should not be OK. Can add volcanic minerals just in case.**


**Use about 1 lb per 1,000 sq. ft. of growing area**

# Spread “front loaded” soil amendments evenly, mix in well

**Many tunnels have lower yields in areas by sidewalls due to lower fertility, cold air and water infiltration, low TLC?**

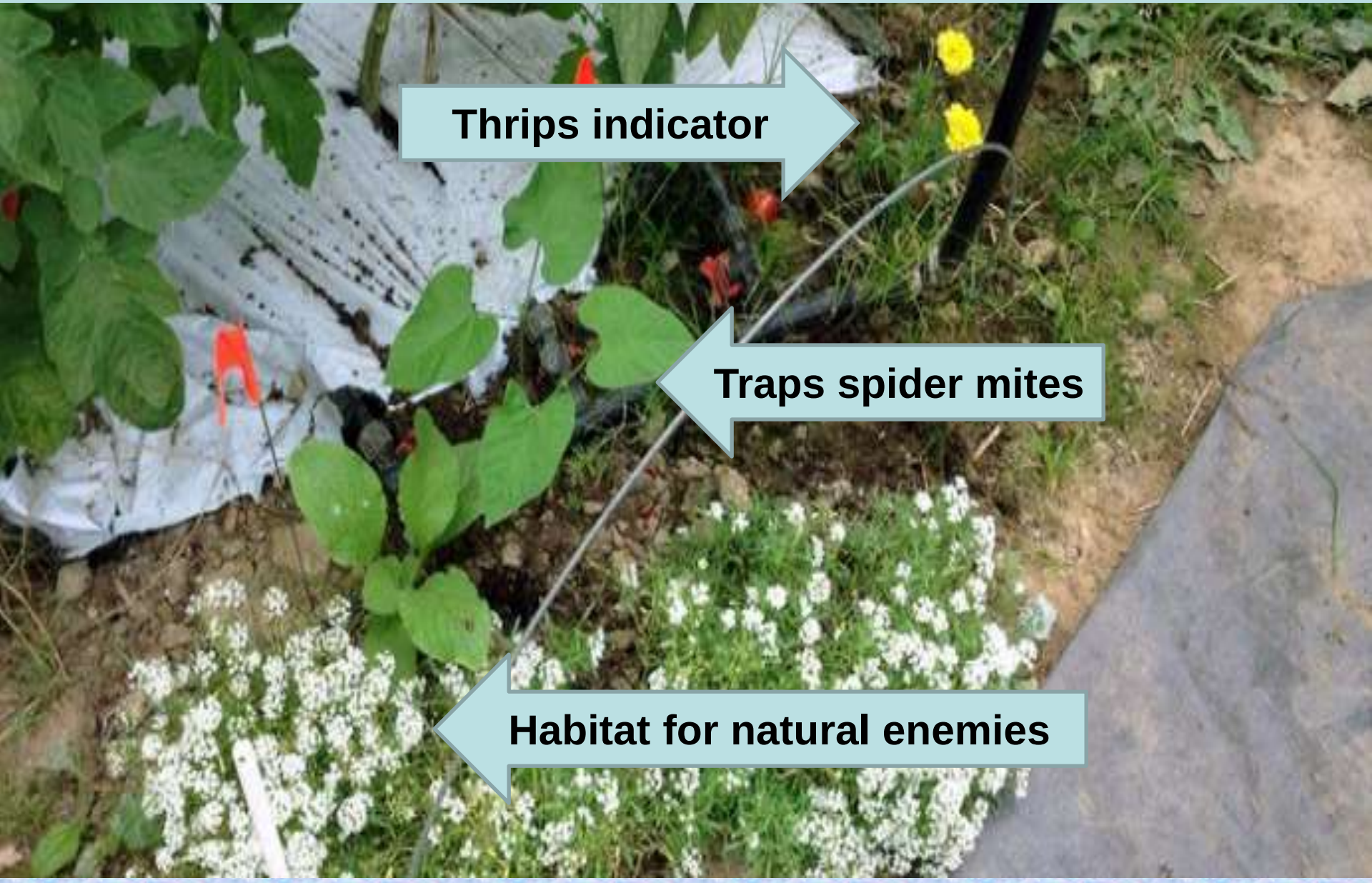
# Mix soil deeply to dilute surface salts and distribute nutrients



# 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

# “Plant-mediated IPM”
# visit the UVM high tunnel IPM pages



# Get to know your beneficial insects, order in advance for control of expected pests

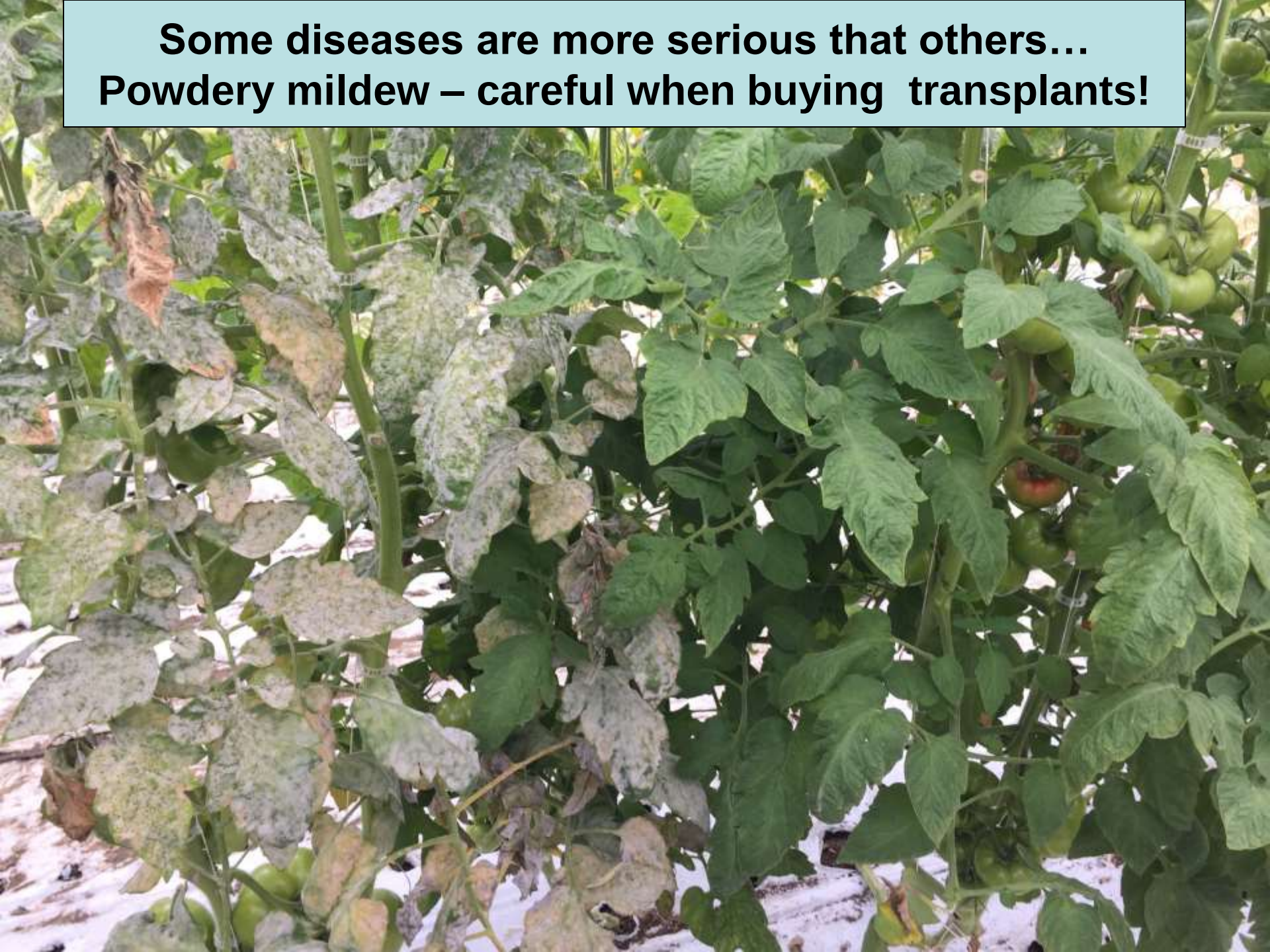


# Monitor and scout for early pest detection

**Insect screen is being used primarily to exclude cucumber beetle**

**Need to account for reduction in air movement/ventilation**

**Some diseases are more serious that others…**
**Powdery mildew – careful when buying transplants!**




If you’re going to spray,
get a good (electric) sprayer

# Leaf mold (*ugly but not so scary*): varieties and ventilation for management

# Ventilation is key to good yields, and disease prevention


High roll up sides help with passive air flow
You can extend short ground posts


Simple peak vents at top of end walls can help a lot


Horizontal Airflow Fans (HAF) mix the air
to prevent temperature, humidity, $CO_2$ gradients
Air circulation is important, along with ventilation

**Prune to 1 or 2 stems, remove suckers, remove lower leaves to promote air flow and reproductive growth**

# Steaming soil reduces chickweed; may reduce soil diseases. Mostly being used for winter greens production

# “Sock” distributes steam under tarp, heats soil surface to ~160º F +/-

# Many growers use grafted tomato plants with rootstocks that tolerate soil disease and increase vigor

**Warm irrigation water avoids ‘thermal shock’ to plants**

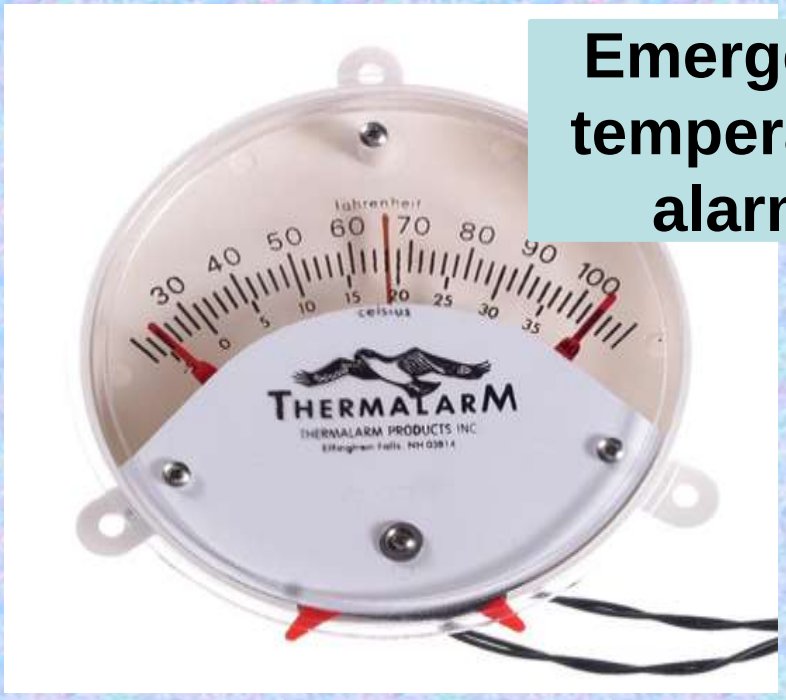
**Use enough drip lines to moisten the entire rooting area when irrigating; dry areas = no roots = no nutrient use**

# Plastic mulches control weeds and also allow roots to proliferate near surface: warm, fertile, $O_2$

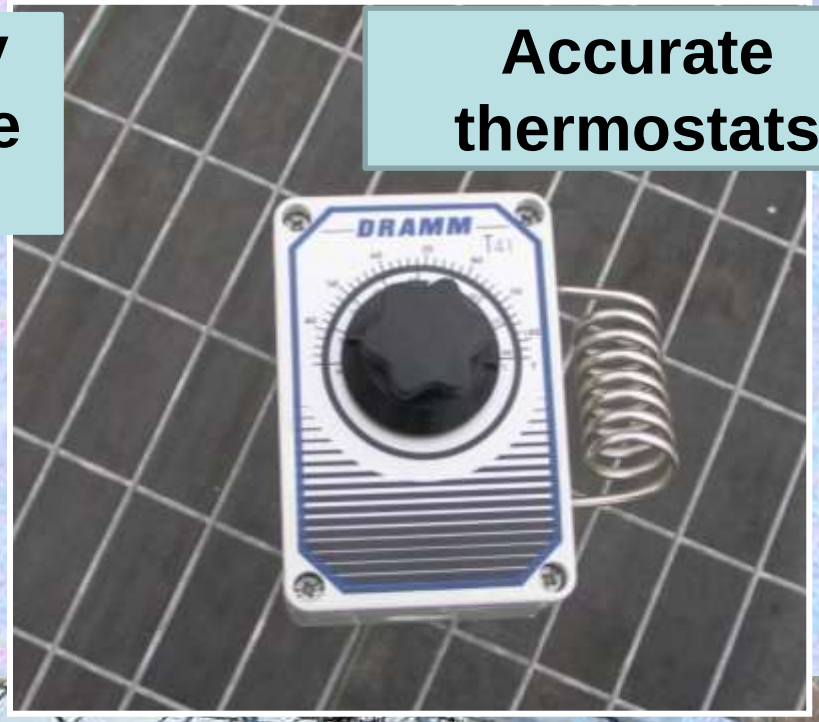
# Soil compaction does not appear to be widespread, but it can be a problem in tunnels

**Test before planting using a penetrometer in multiple locations.**
**If average PSI is over 300, subsoil or form raised beds.**

Emergency temperature alarms



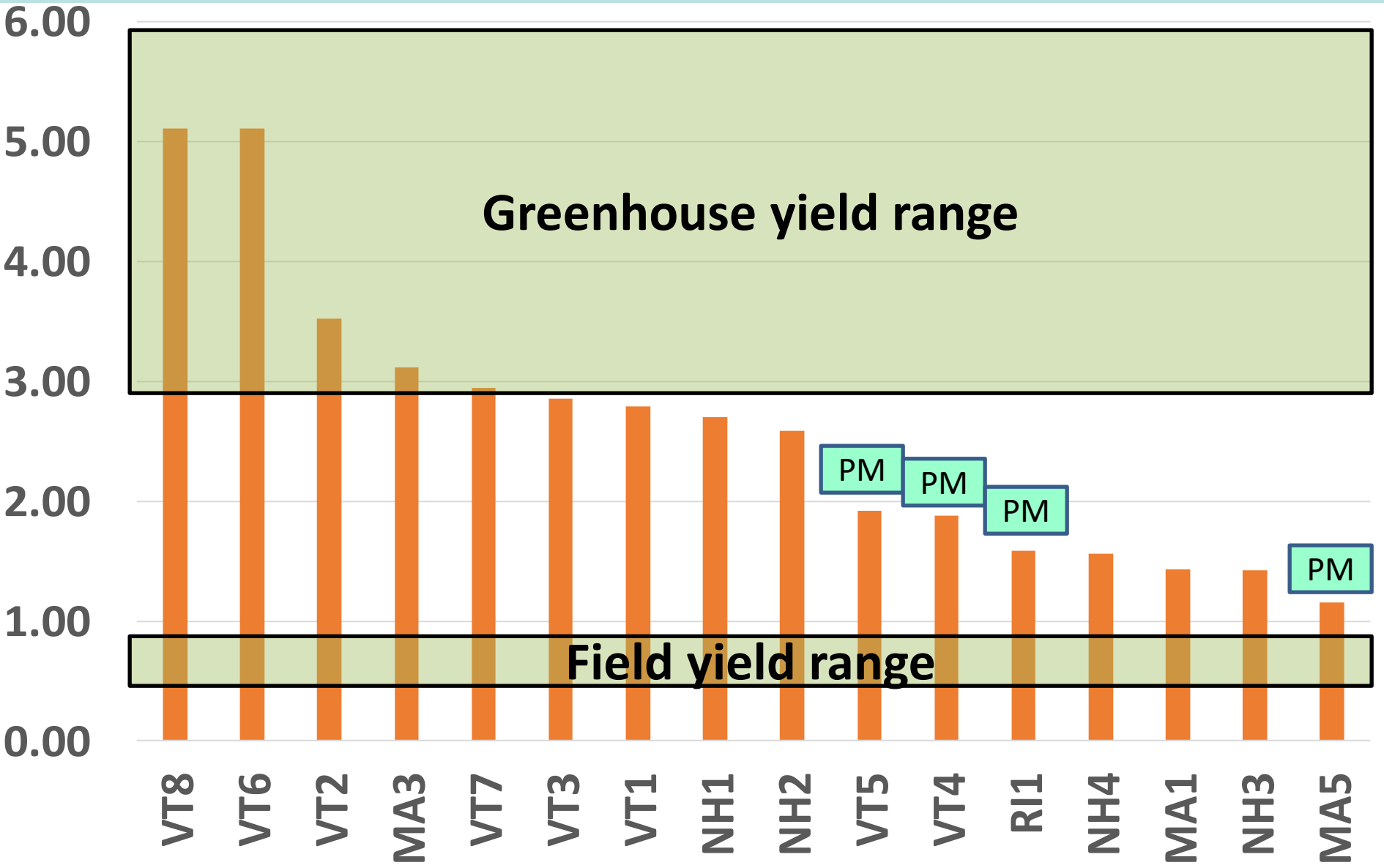

Accurate thermostats



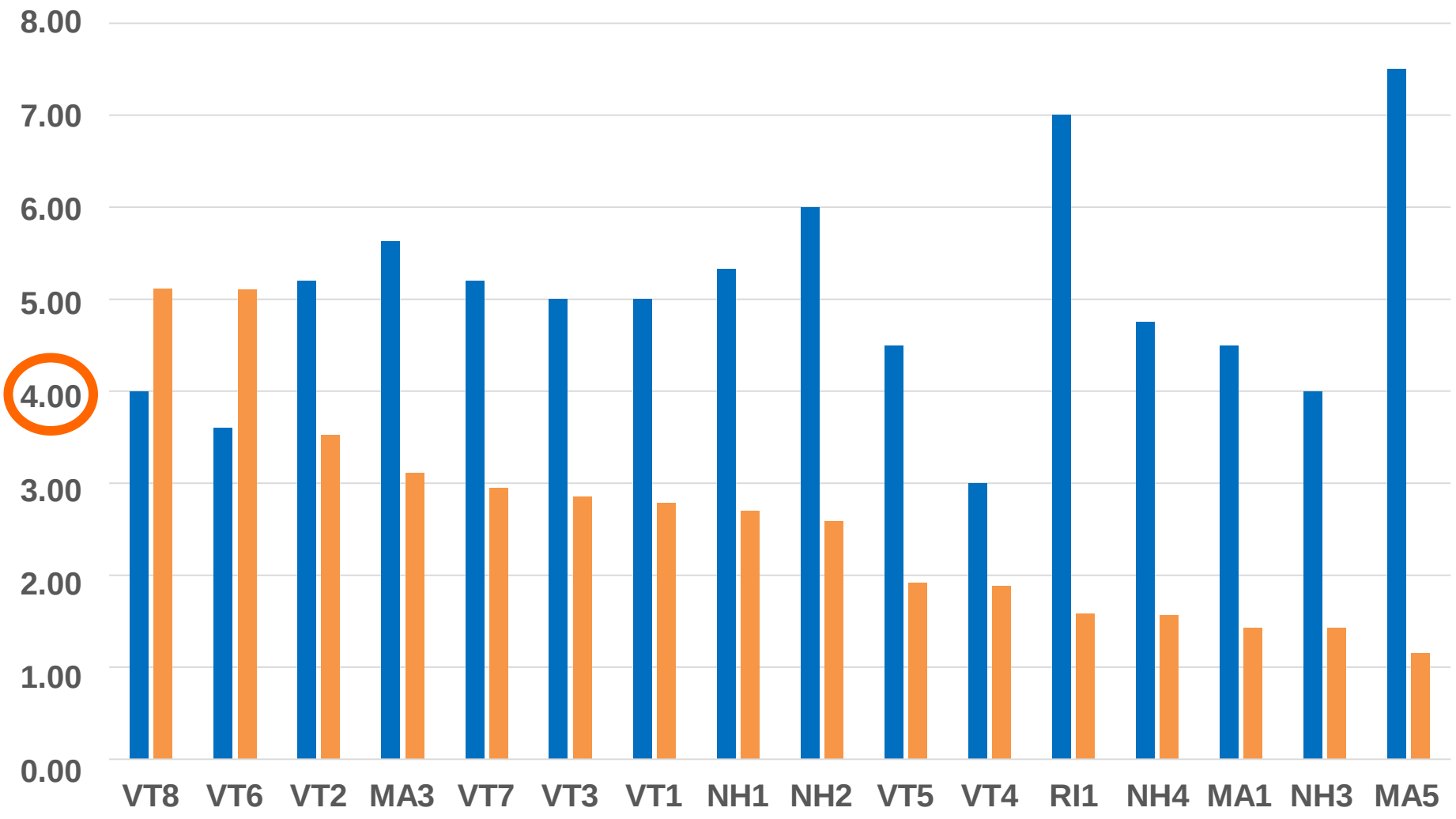

Strong door latches, with a good seal

Curtains and corner panels to seal roll-up sides

# Tunnel tomato yields in lbs./sq. ft. on 16 farms

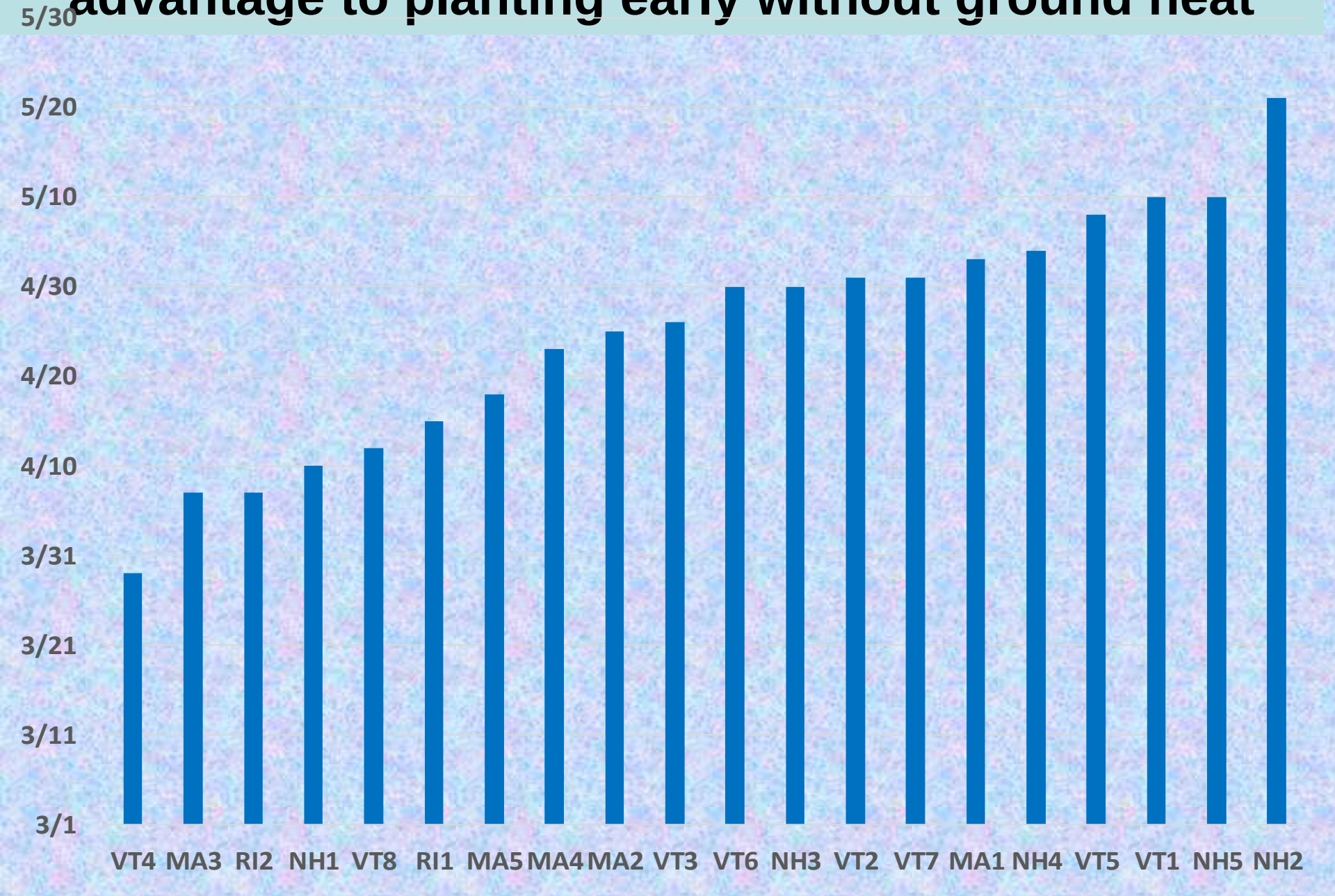


# Tomato yield (orange) in lbs./sq. ft. and plant density in sq. ft./stem (blue)



# While high density can increase yield, it can also increase humidity and foliar diseases

# Transplant date often depends on markets; little advantage to planting early without ground heat



https://farm-energy.extension.org/root-zone-heating-systems-for-greenhouses/

May

June

July

August

September

November

**Long season, high density, good management, high yield = 6.8 lb/sq ft**

May

June

July

August

**Short season, low density, disease issues, low yield = 1.3 lb/sq ft**

# Summary recommendations

- Estimate your target yield, then track yields
- Consider tighter plant spacing, grafting
- Improve passive ventilation, use HAF for circulation
- Assure irrigation lines provide uniform soil moisture
- Keep up with leaf pruning, scout for pests often
- Use biocontrols, habitat plants; spray properly if you do
- Adjust soil pH to 6.5 to 7, use compost then peat for OM
- Monitor available, reserve, and plant tissue nutrients
- Provide sufficient N and K based on realistic yield goal

# Thanks!

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