Soil Health in High Tunnel Production

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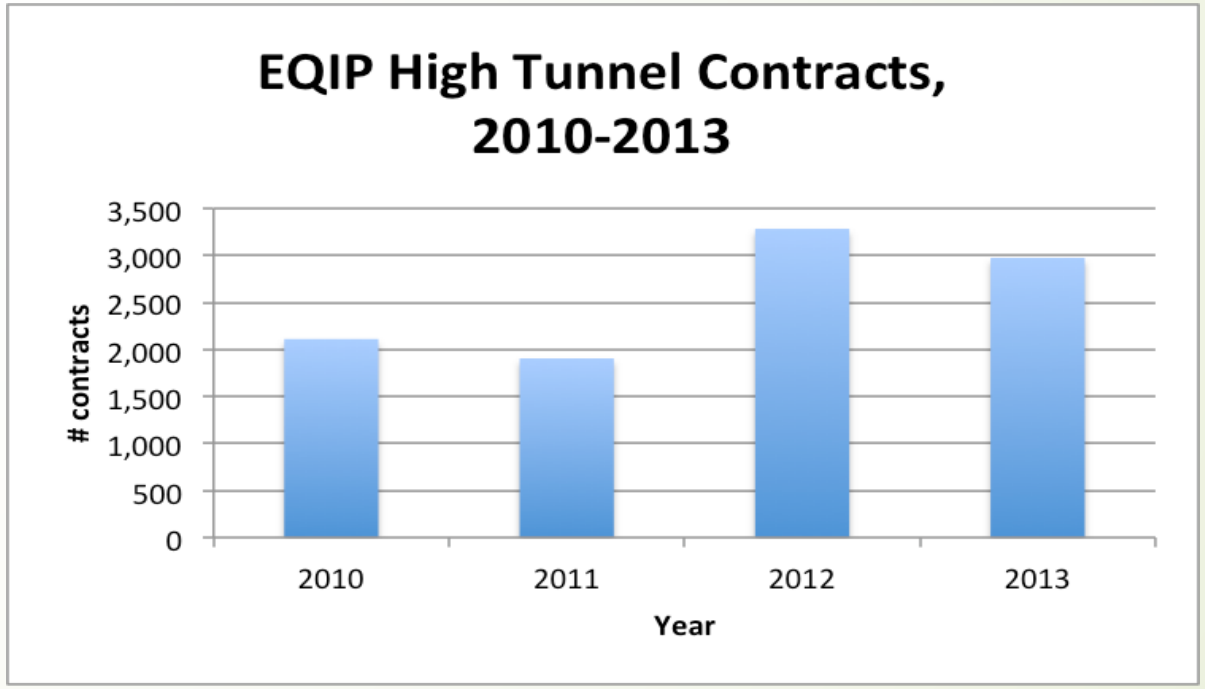
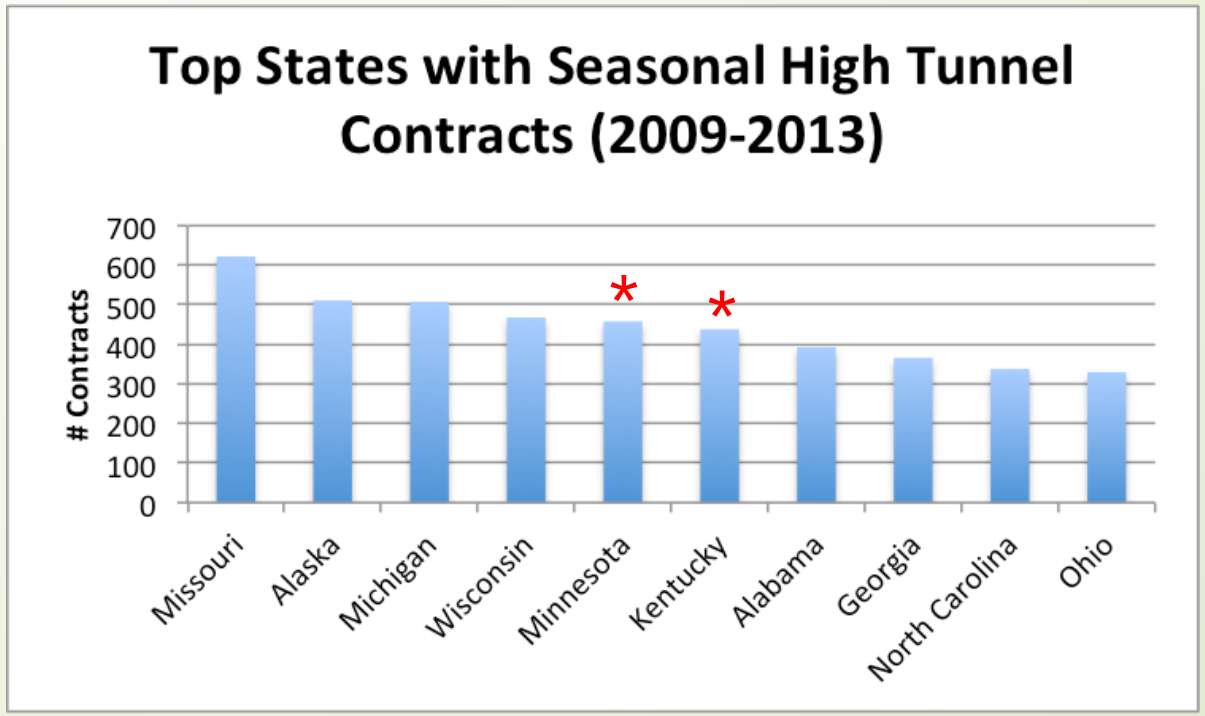
What we will cover today

- How the high tunnel environment is so very different than the field!
- Soil quality challenges looming in high tunnel management
  - Salinity
  - Nutrient Management
  - Organic Matter
- Potential solutions to meet these challenges





- Construction of 9,821 high tunnels supported by NRCS since program inception in 2010 (NRCS, 2014)
- EQIP has invested $56.8 million, representing a significant public investment.

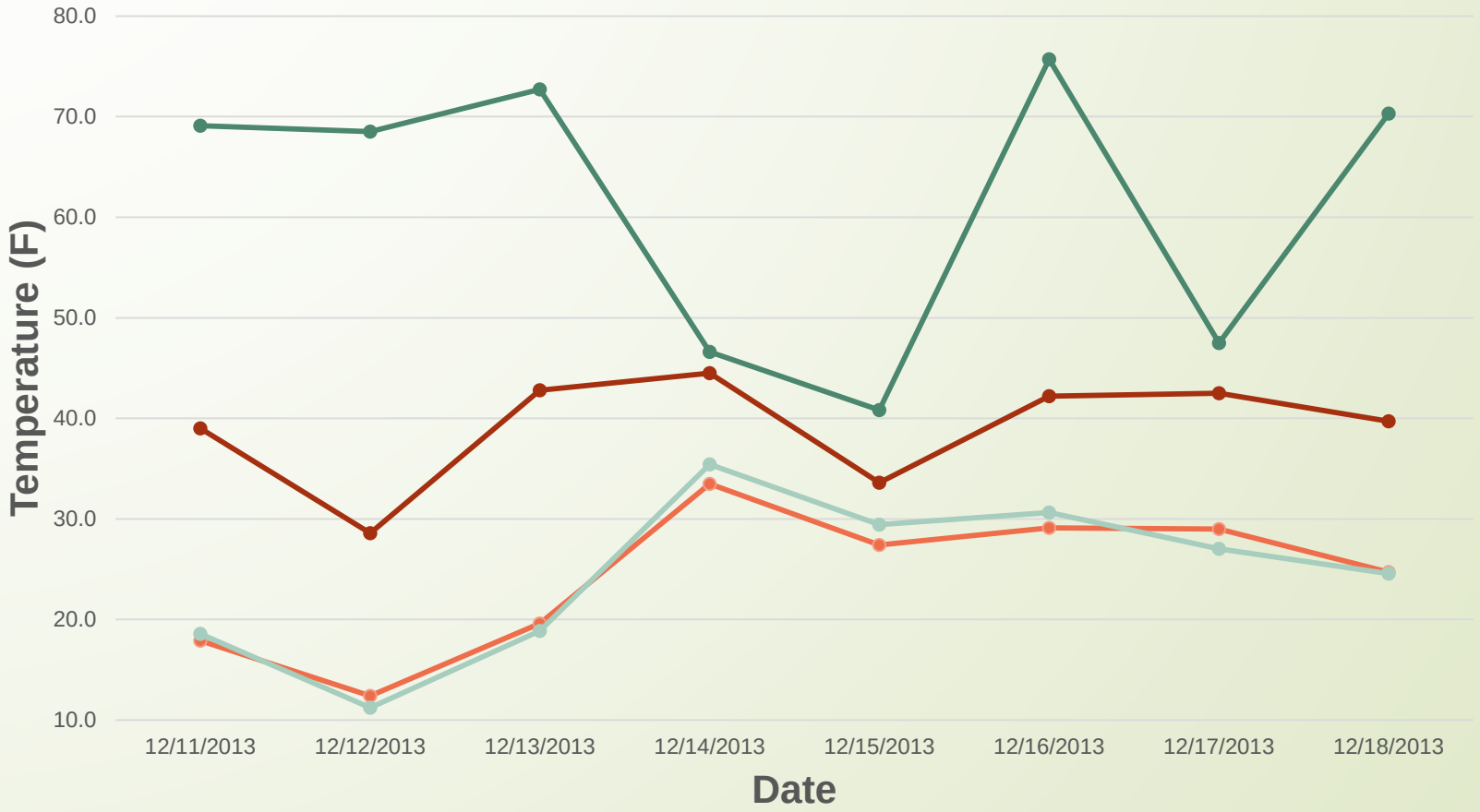
Differences from the Field

Basic differences: Intensive production

- Tunnels typically are….
  - Production-intensive
  - Tillage-intensive
  - Irrigation intensive
  - Warmer than the field
  - Variable in temperature

Differences from the Field

Temperature Dynamics



- Temperature variability can be much greater than the field. This influences plant growth (and everything that eats the plants).

Open Field, Maximum Temp (˚F)
Open Field, Minimum Temp (˚F)
High Tunnel, Maximum Temp (˚F)
High Tunnel, Minimum Temp (˚F)

Nutrient Management

Nutrient management differs in high tunnel environments

Nutrient management differs between conventional and organic

Conventional

- Drip lines supply nutrients
- Easier to supplied required rates

Organic

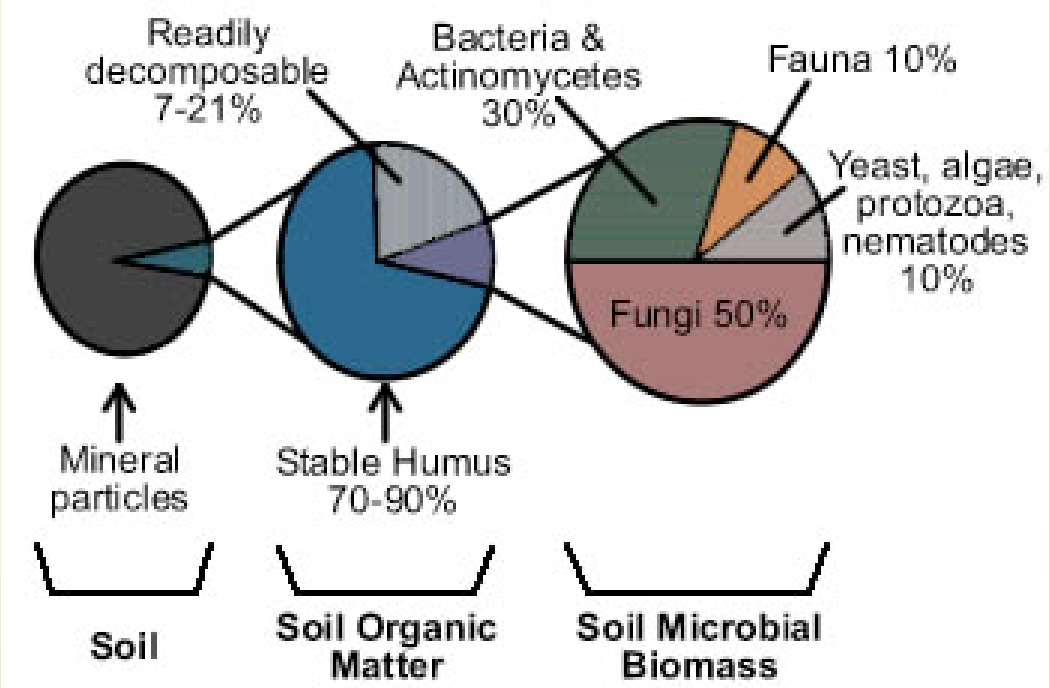
- Soil often supplemented by added manure or compost
- These require microbial breakdown before nutrient become available
- Some tests exist to measure ‘potentially’ available pool of nutrients, like N
- Driplines can supply additional, but few options exist
  - Fish emulsion and other sea products
  - Other soluble fertilizers, such as sodium nitrate or potassium nitrate blends, but can lead to salt build up

Organic Matter

Building organic matter in high tunnels

What does organic matter do?

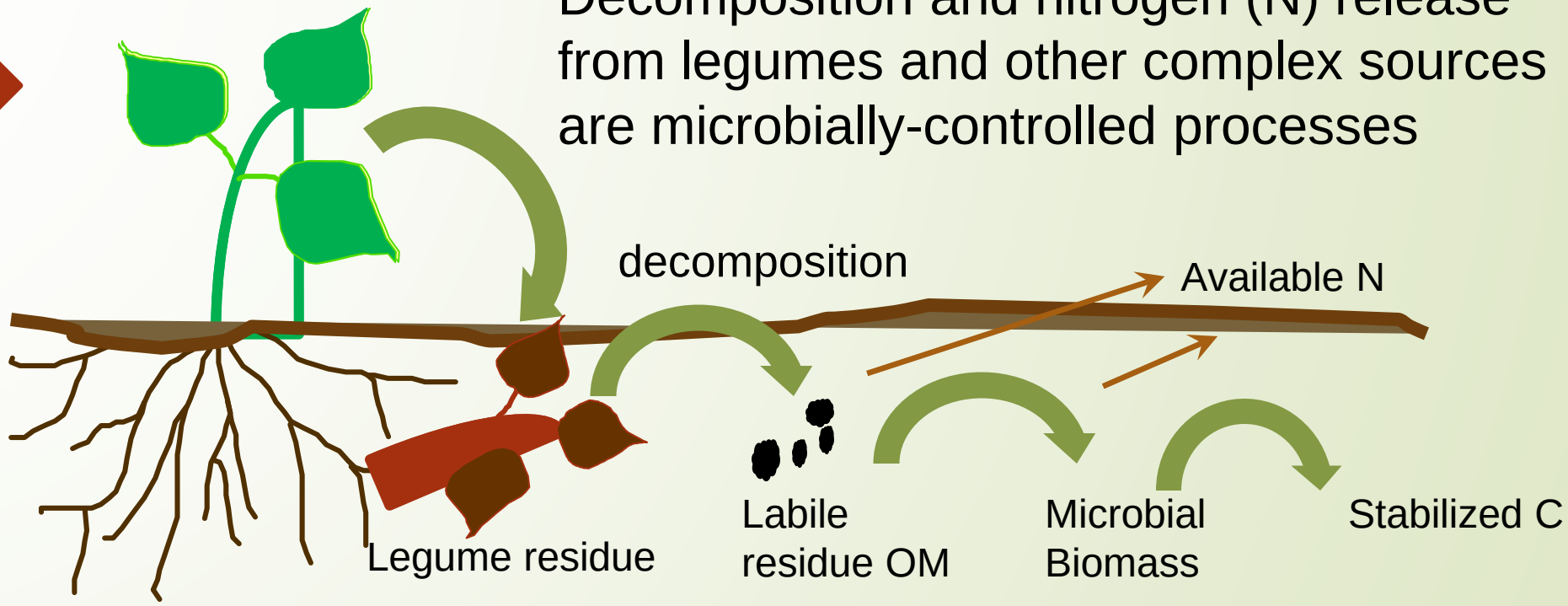
- Increases soil water holding capacity
- Stores nutrients by enhancing cation exchange capacity (CEC)
- Helps provide a physical structure suitable for root growth
- “Labile”, or readily decomposable, organic matter acts as a slow-release fertilizer as it breaks down



Labile organic matter is itself a nutrient source for microbes, releasing nutrients into the soil during decomposition

Organic Matter

Decomposition and nitrogen (N) release from legumes and other complex sources are microbially-controlled processes



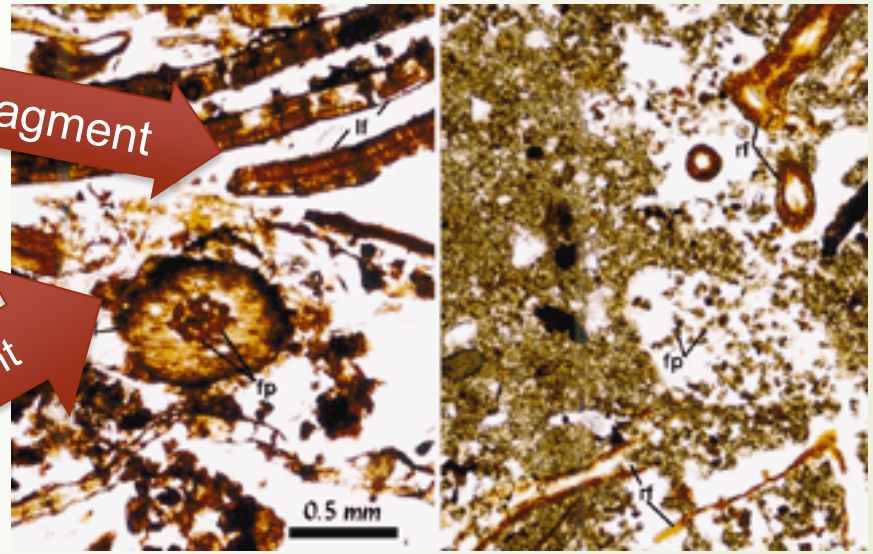
Methods to measure available nutrients in complex sources:

- Available N,
- “Potentially mineralizable” N
- Labile fractions of organic matter (POM and POX)
- Microbial biomass

Organic Matter

Leaf Fragment

Root Fragment



Particulate organic matter (POM) is a labile organic matter pool that includes leaf fragments and root fragments.

Density-based approaches can help to quantify these pools as a proxy for nutrient cycling.

Salinity

Tunnel soils are similar to arid lands – no flushing rains

50-80 lbs sodium per acre

700 lbs sodium per acre

Grower in Henderson or McLean county, photo courtesy of Dr. Tim Coolong, Univ. of Georgia.

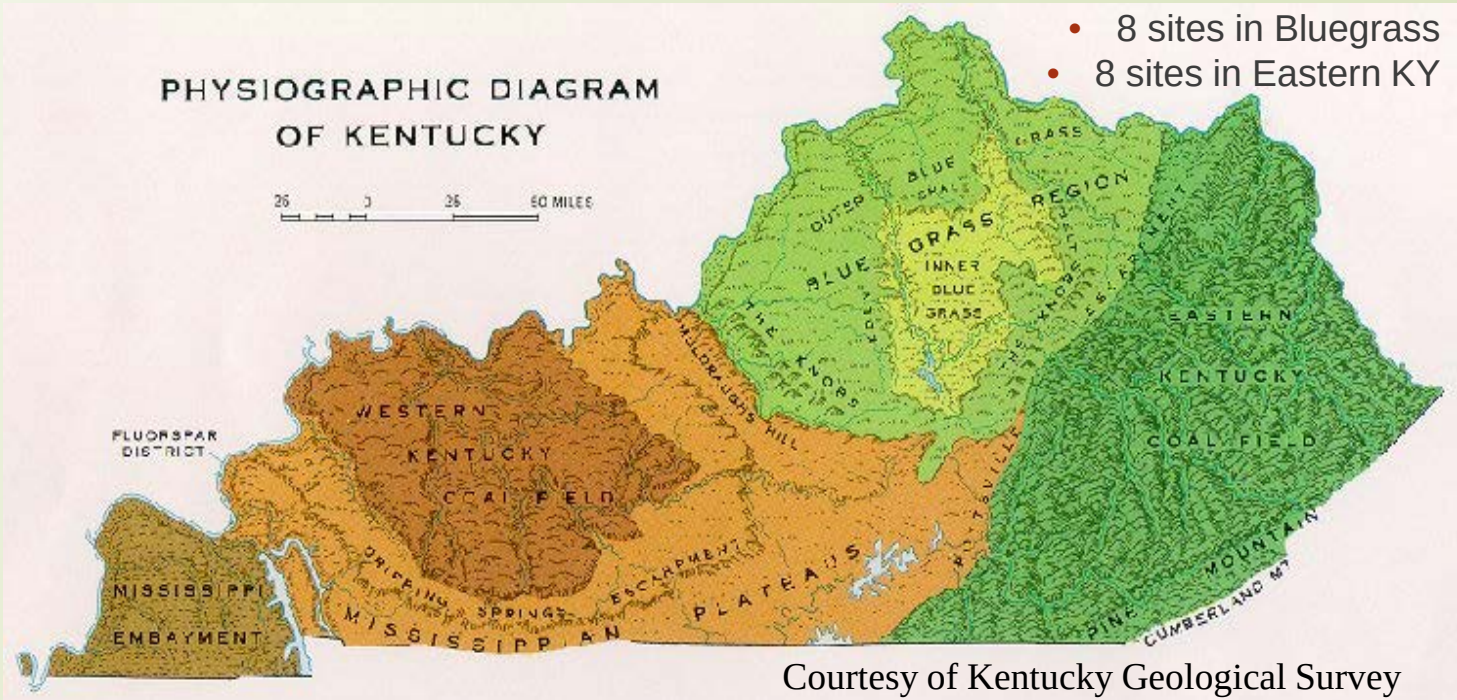
Soil Health Research

Current High Tunnel Soil Health Research at Univ. of Kentucky

Sustainable soil and water management (KY NRCS CIG)

- Rainwater catchments
- Ultra-low pressure drip irrigation systems
- Cover crops and conservation tillage in tomato and pepper-based systems
- Survey of soil health in high tunnels across Kentucky

- 8 sites in Bluegrass
- 8 sites in Eastern KY



Courtesy of Kentucky Geological Survey

Soil Health Research

Survey of Kentucky High Tunnels: Results

Test	Field	Tunnel
pH	**5.4±0.2**	**6.0±1.4**
Potentially Mineralizable N (lbs/ac)	**48.8±3.2**	**164.8±14.4**
Soluble salts (mmhos/cm)	**0.2+0.1**	**0.5+0.1**
CEC (meg/100g)	NS	NS
Meh P (lbs/ac)	**136.8±30.0**	**334.4±63.2**
Meh Ca (lbs/ac)	NS	NS
Exchg Mg (lbs/ac)	NS	NS
Exchg Na (ppm)	**16.2±3.8**	**82.0±7.8**

Survey of KY tunnels: Results

Build up of available nitrate is common in tunnels

Build up of sodium salts significant but not enough to harm crops

Underlying regional soil differences can be greater than management effects

Soluble salts are more than just sodium (salinity vs. sodicity)

- Include Ca, Mg, K, and Al, too

Test values in mmhos/cm	Interpretation
0-1	Satisfactory for most crops
1-2	Affects highly sensitive
2-4	Affects sensitive Crops
4-8	High for many Crops
above 8	Very high for most Crops

Salinity

Managing Soluble Salts

- Minimize soluble salts from inputs
  - Composts, manures, fertilizers, etc.
- Cover cropping (more on that later)
- Leave uncovered when changing plastic
  - 12” of rain needed (usually uncovered period over winter is sufficient)
  - Plastic typically has 4 year lifespan
- Flooding/leaching techniques
  - Trying to flush salts below root zone (12”)
    - 6 inches of water leaches about 50% of the salts
    - 12 inches to leach about 80%
    - 24 inches to leach about 90% of the salts*

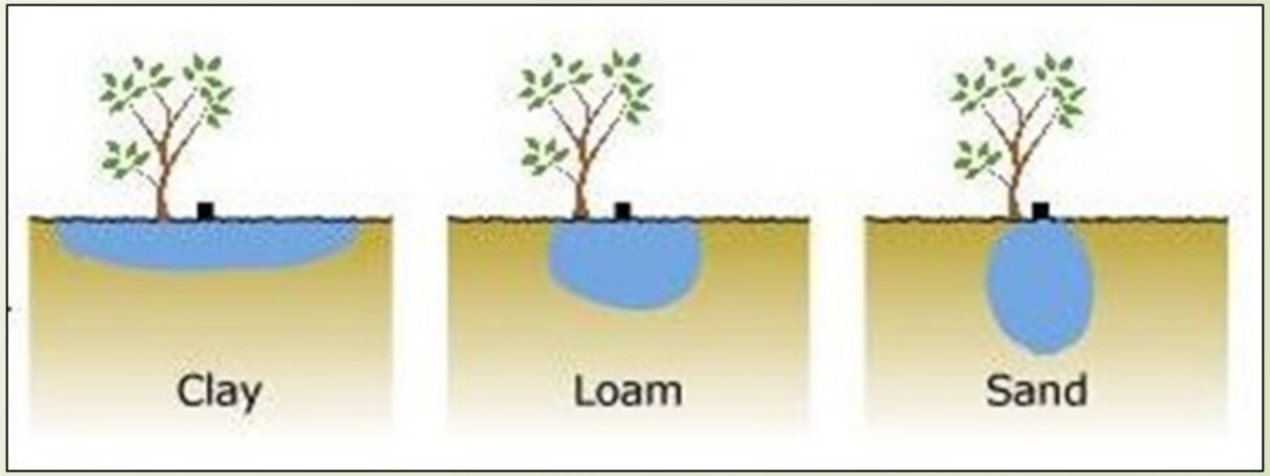


Illustration courtesy of Smart Fertilizer Management

*(California Fertilizer Association, Western Fertilizer Handbook, 8th Ed.).

Disease Management

Soil pathogen and disease management

Soil-borne disease issues

- Diseases of Solanaceous crops can be particularly problematic due to high demand for these crops and lack of rotation
- Sclerotinia can a big issue in winter production

What can we do to minimize soil-borne diseases?

- Rotation
- Movable tunnels

Moving our rolling high tunnel at the University of Kentucky Horticulture Research Farm

Photo courtesy of University of Kentucky Ag Communications Department.

Lessons Learned

Thinking outside of the box….or tunnel
Innovative solutions for soil quality

“Go beyond T, manage for C” - Why is this difficult in high tunnels?

- Fallow periods are short or non-existent
- Intensive tillage and high temperatures burn through soil organic matter
- Crop residues typically removed

How can we overcome this?

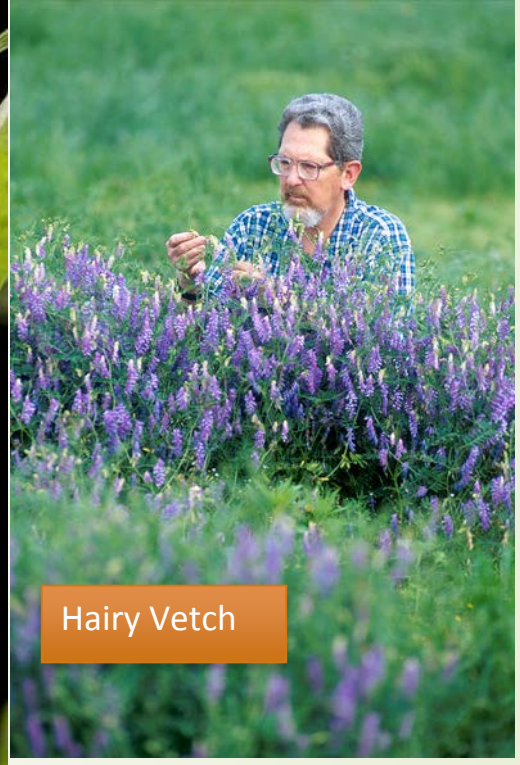
- Innovation solutions for soil health!
  - “Feed the soil to feed the crop” using cover crops and alternative management strategies

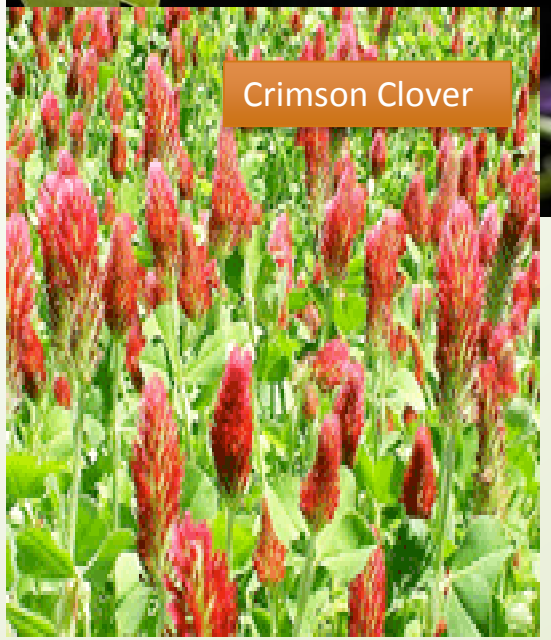
Can we use cold hardy cover crops in Minnesota, during the underutilized winter niche, to improve soil quality and fertility?

Objectives:

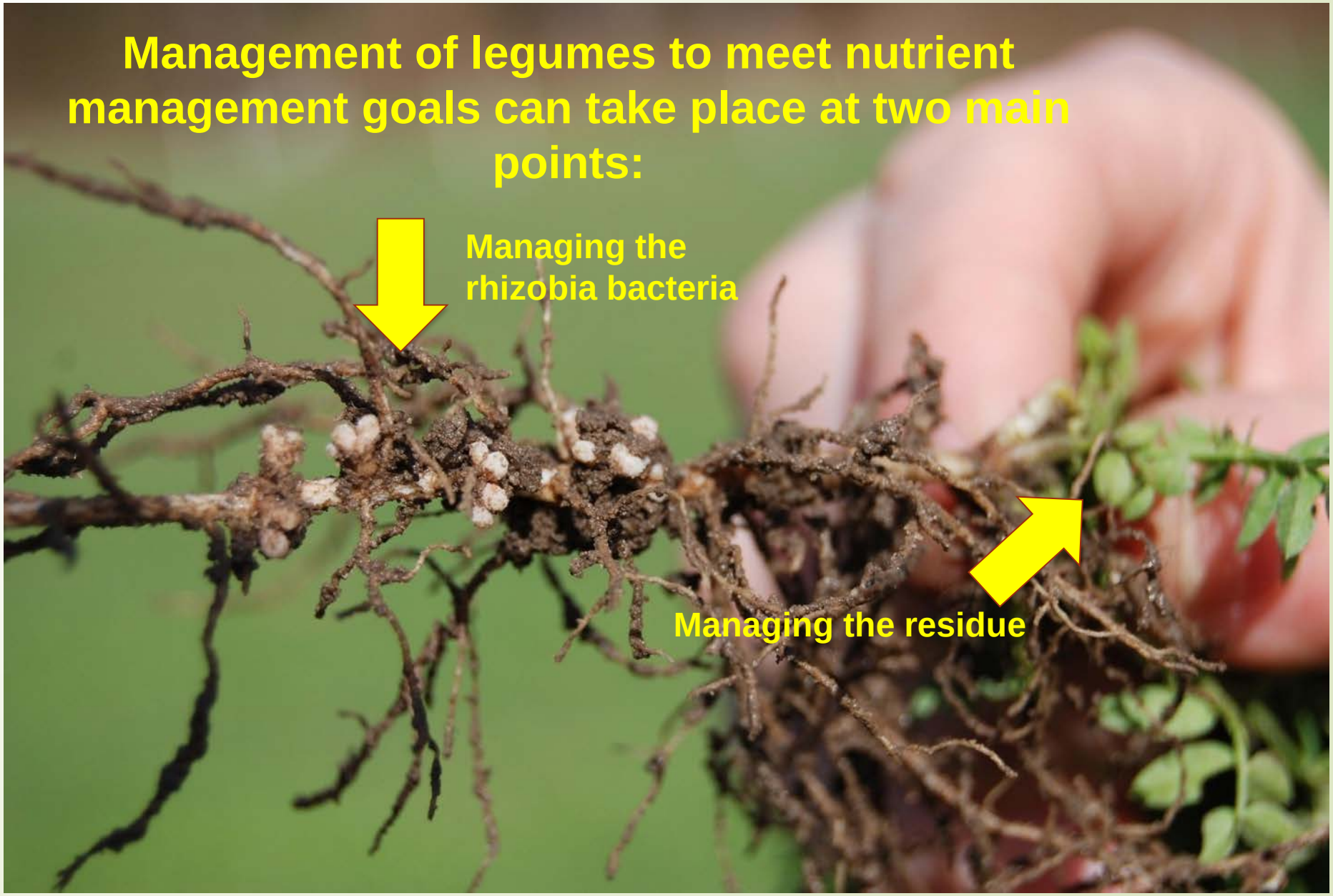
- **Identify optimal cover crop combinations for winter high tunnel environments in Minnesota**
- **Determine nutrient contributions delivered via cover crop legumes**

Popular Winter Cover Crop Species





http://aggie-horticulture.tamu.edu/extension/Texascrops/foragelegumes/index.html, NCAT


Management of legumes to meet nutrient management goals can take place at two main points:
Managing the rhizobia bacteria
Managing the residue

Cover Crop Trials

Treatments included four farmer-chosen mixtures of cover crops, compared to a control plot.

Vetch-Rye Mix (18 /56 lbs/acre)

Non-weeded control

Pea-Rye mix (37/37 lbs/acre)

Red clover (12 lbs/acre)

Year one, 2015

April | May | June | July | August | September

Cover crop seeding (April 16 and 17)

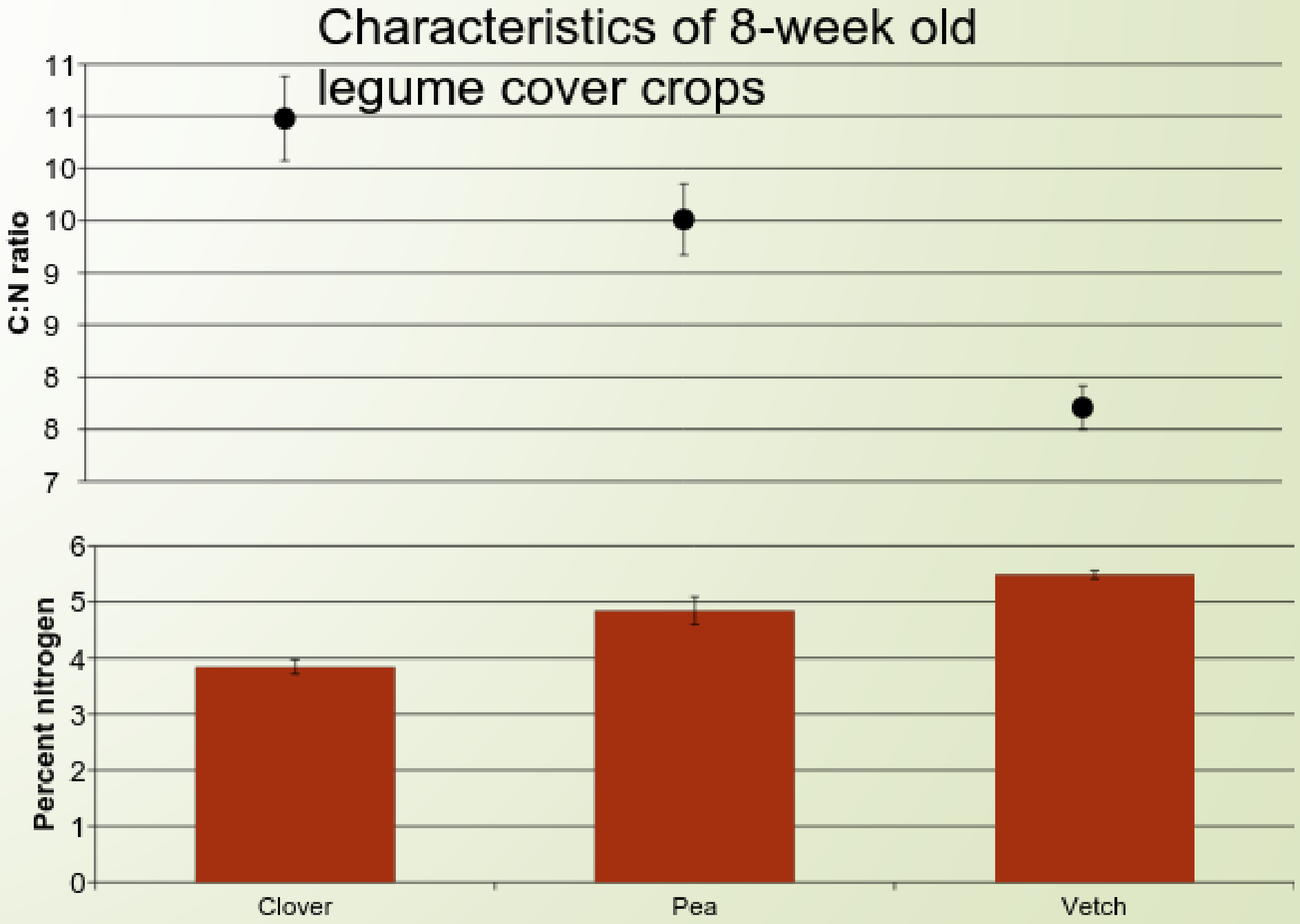
Biomass sampling and cover crop termination (June 6 and 11)

Pepper transplanting

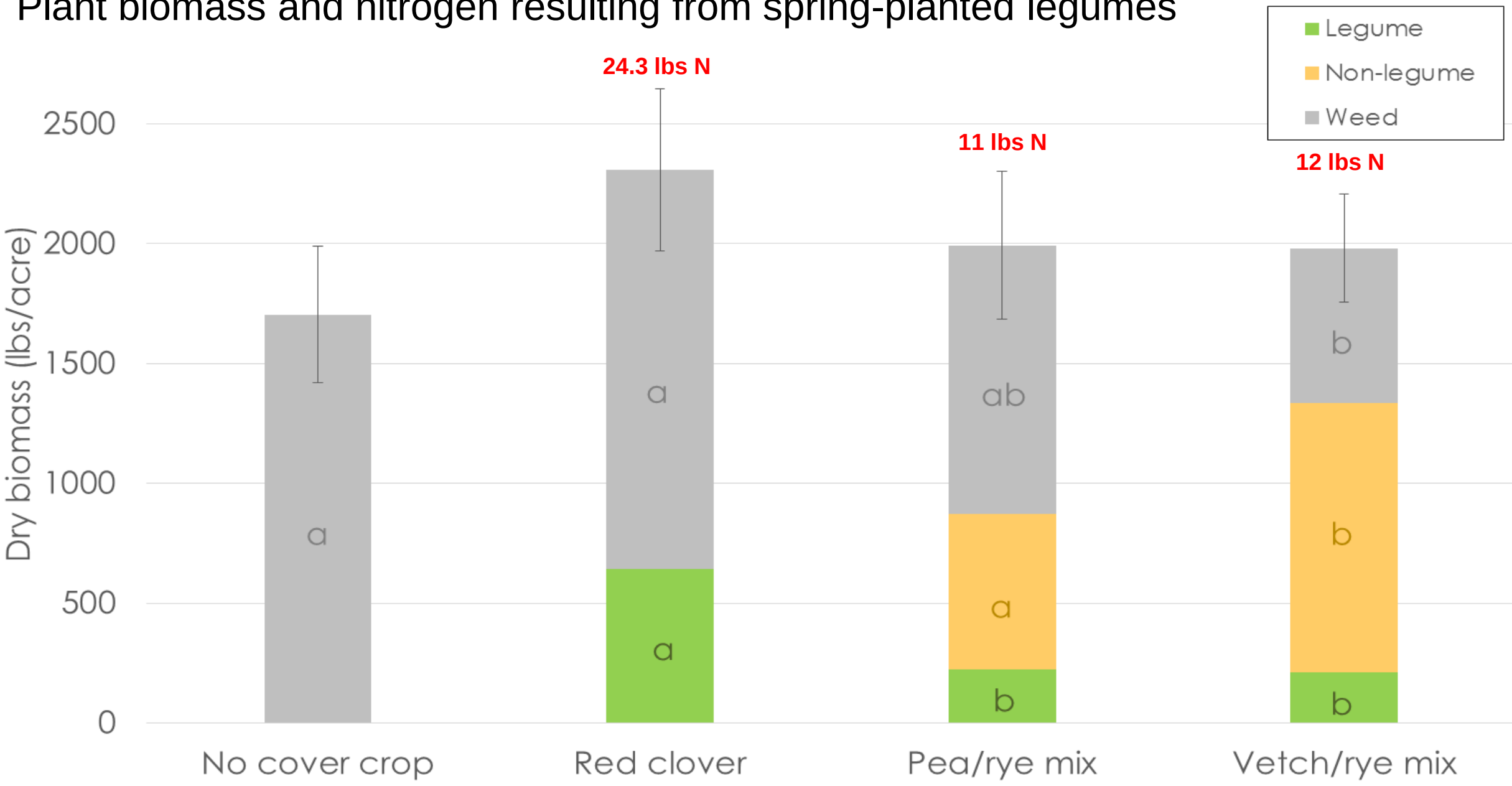
Pepper harvest

Year one: Be ready to be flexible!

Year 1


Characteristics of 8-week old legume cover crops
C:N ratio
11
11
10
10
9
9
8
8
7
Percent nitrogen
6
5
4
3
2
1
0
Clover
Pea
Vetch

Plant biomass and nitrogen resulting from spring-planted legumes



Lets try that again…year two, 2016

April | May | June | July | August | September

Fall, 2015

Cover crop seeding (Late August *and* early September)

Biomass sampling, cover crop termination and pepper transplanting (June 6 and 11)

Fall, 2016

In years two and three, inter-seeding cover crops between rows of fruiting peppers gives cover crops a head start without impacting pepper production.

We inter-seeded cover crops into fruiting peppers

We added secondary coverings to help protect young legumes

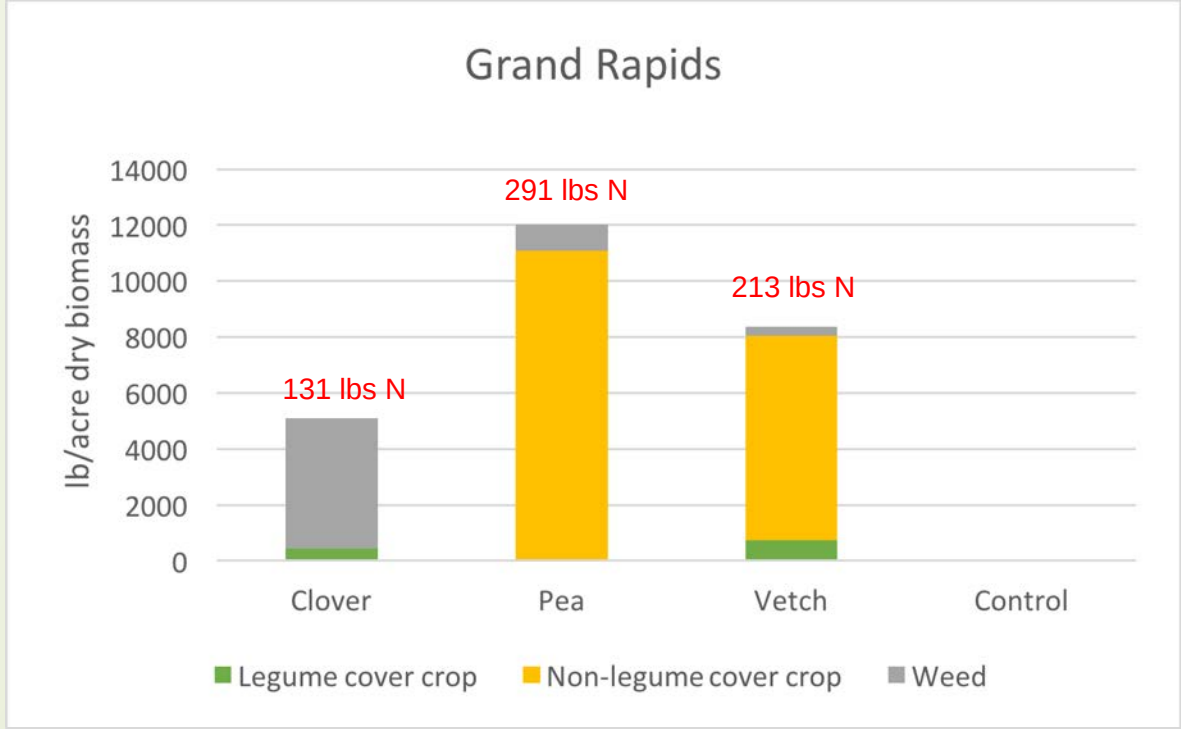
Success!

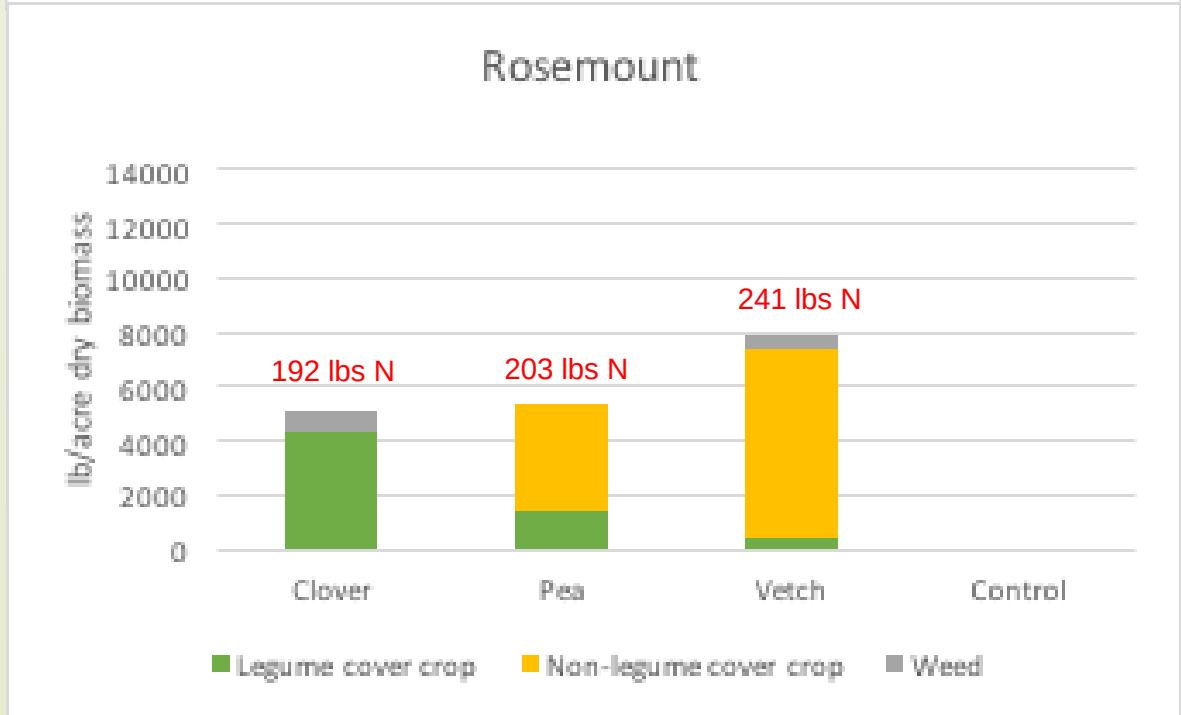
Cover crops legume mixtures in mid-May, zone 3b in Northern MN

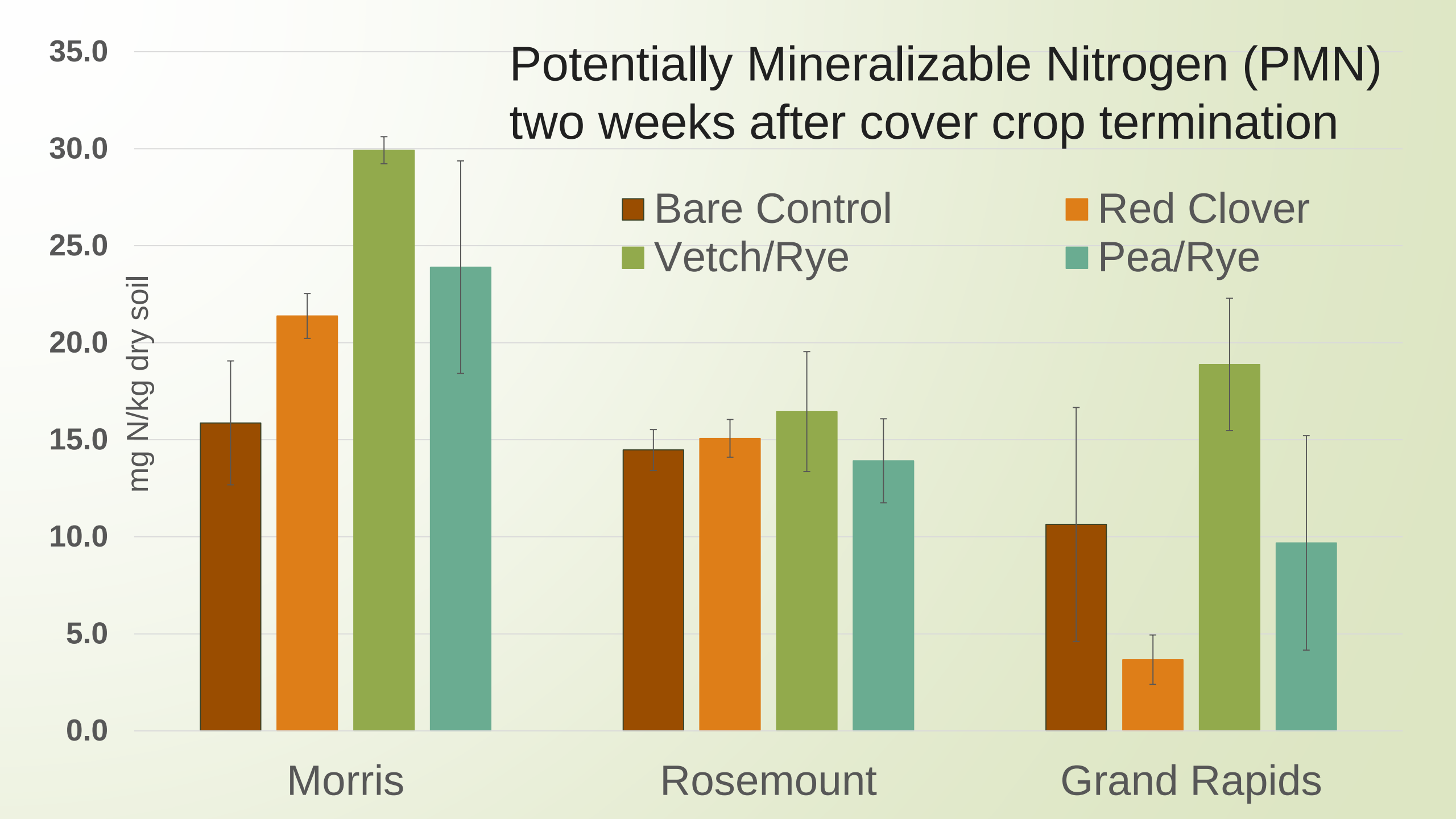
Vetch and Rye mixture

Year 2

Biomass for fall planted legume cover crops was sometimes more than 4x spring planted legumes, resulting in high N contributions






Potentially Mineralizable Nitrogen (PMN)
two weeks after cover crop termination
Bare Control
Red Clover
Vetch/Rye
Pea/Rye
mg N/kg dry soil
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Morris
Rosemount
Grand Rapids

Other Winter Cover Crops

Clovers and peas, wheat and oats, etc.

- Sometimes “less biomass is more”

Cover crop management considerations

- Vigor!
- Requires irrigation
  - A shift in thinking for field growers
- Must manage for growth *and* decomposition
  - Arid environment in tunnels inhibits decomposition
  - Regular watering with 2-3 week breakdown time before crops are planted

Cover Crop Management Alternatives

Winter-killed summer covers for earlier planted crops, when vigor of winter cover crops might be a problem

Buckwheat, Japanese millet and cowpea summer cover crop planted in early fall (picture taken mid-October). Planted prior to early tomatoes.

Consider looking outside your region for *alternative cover crops* with desirable traits

Novel cover crop work funding courtesy of Southern SARE Research and Education Program

Movable Tunnels

Movable High Tunnels at Univ. of Kentucky

Advantages

- Allows for incorporation of cover crops, fallow periods, stale seed bedding
- Multiple moves per year can be part of highly productive rotations
- Breaks disease cycles
- Allows for rainfall to leach salts

Challenges

- Structures are more costly and management intensive

Movable vs. Stationary Tunnel Soils, After 4 Years of Year-Round Growing

Soil Test Parameter	Stationary Tunnel	Movable Tunnel	Open Field	P-value
Total C (%)	2.01	1.91	1.77	*NS*
Total N (%)	0.17	0.16	0.14	*NS*
pH	6.63	6.31	6.90	*NS*
Phosphorus (lbs/ac)	253 a	218 b	152 c	P=0.012
Potassium (lbs/ac)	414 a	400 a	661 b	P=0.0006
Calcium (lbs/ac)	5585 a	5570 a	8235 b	P=0.0017
Magnesium (lbs/ac)	790 a	425 b	436 b	P<0.001
Sodium (lbs/ac)	100 a	31 b	11 c	P<0.001
Total Soluble Salts (mmhos/cm)	0.46	0.377	0.314	*NS*

**Letters indicate significant differences between means of different systems.*

Lessons Learned and Next Steps…

Lessons learned…

- The many “moving parts” in complex high tunnel rotations
  - Including weather, management and money-dependent factors – and results may vary year-to-year
  - Requires adaptive management and creative thinking

Next research steps…

- Novel cover crops for high tunnels, particularly for the south (KY, TN, GA)
- *Developing a multi-regional research and education network to improve nutrient management in organic high tunnels*
  - Funded USDA – OREI grant, 2016-2020
  - Ecosystem services and economic trade-offs of cover crops in tunnels (MN, KY, KS)

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