Managing legume cover crops for multiple benefits on farms

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Acknowledgements and team


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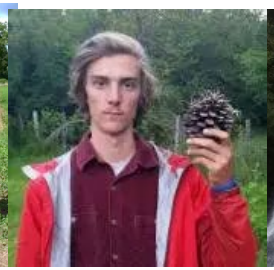
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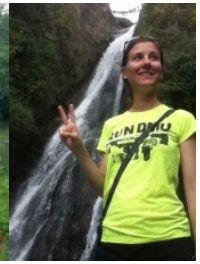
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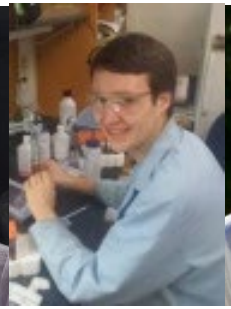
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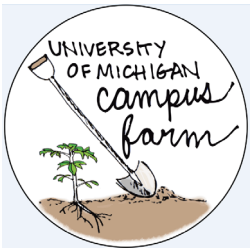

Collaborators: Dan Brainard and Sieg Snapp at MSU
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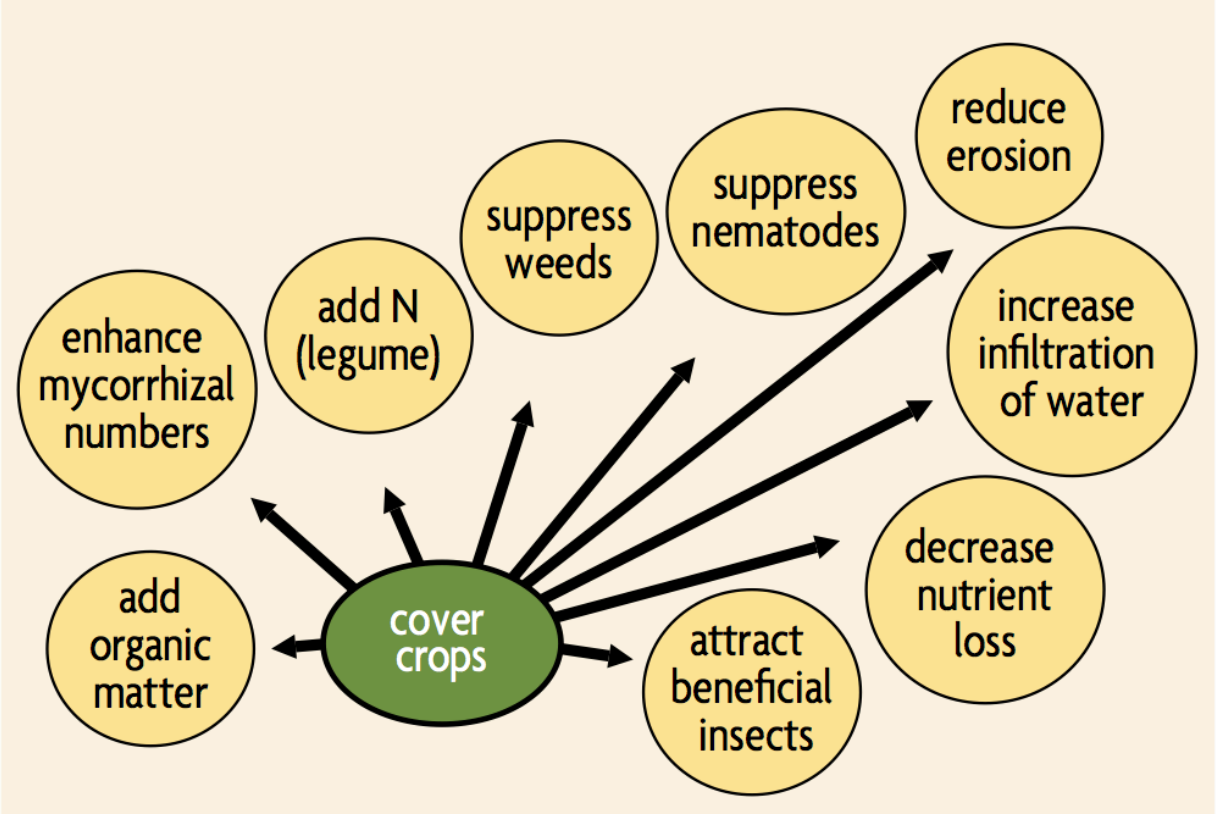
Outline

- Benefits of cover cropping and resources to help get started
- Focus on legumes- review legume N fixation process
- Show results of legume N supply measured on 10 farms in MI
- How to estimate legume N inputs on your farm
- Discuss how legume N gets into soil and the following crop, and how the legume changes soil organic matter
- Results of legume fixation in 2-3 species cover crop mixtures, and other benefits of mixes

Cover crop *(n)*: A crop planted between periods of regular crop production to provide other benefits besides food production .

Cover crops are "multi-functional"



Magdoff, F.R., and H.M. van Es. 2009. **Building Soils for Better Crops: Sustainable Soil Management**. Handbook Series Book 10. SARE

Cover crop *(n):* A crop planted between periods of regular crop production to provide other benefits besides food production.

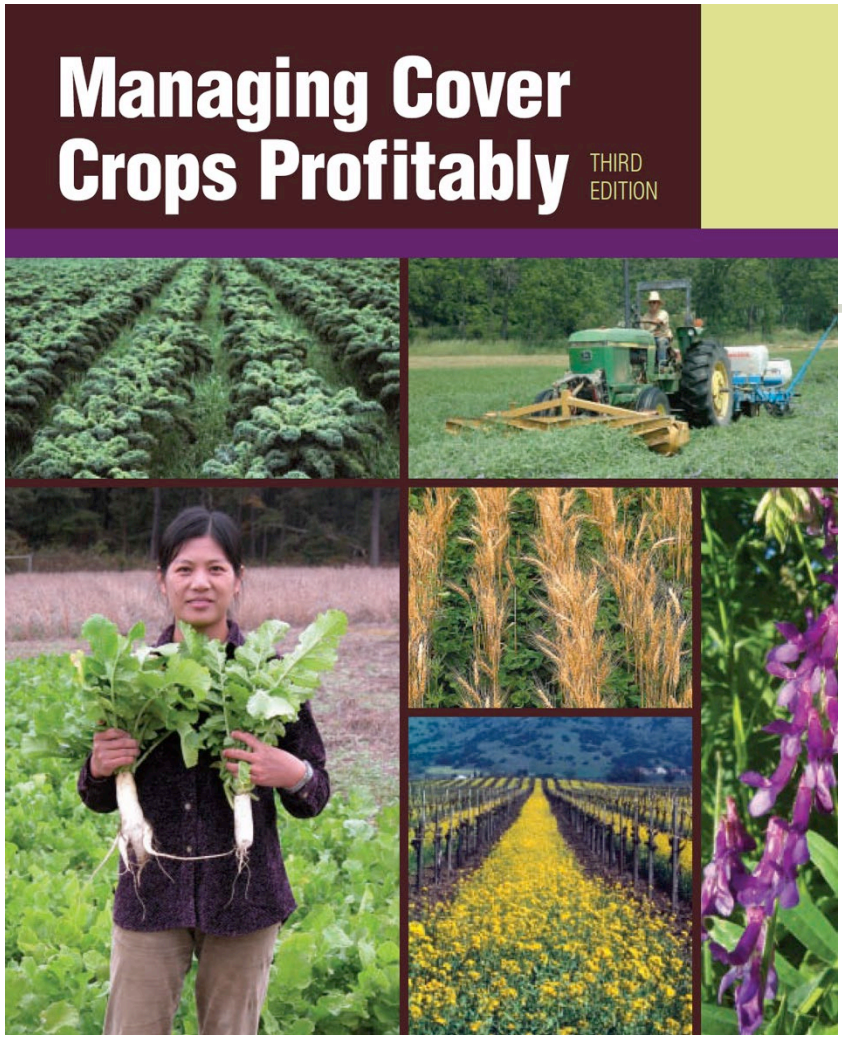
Green manure: Legume cover crops can contribute up to 300 kg N ha^{-1} yr^{-1} (about 267 lbs / acre) depending on species, climate, management, and soil properties (Ledgard, 2001; Tonitto et al., 2006)

Soil organic matter increases with regular use of legume cover crops in rotation (Drinkwater et al. 1998; Marriot and Wander, 2006; King and Blesh, 2018)

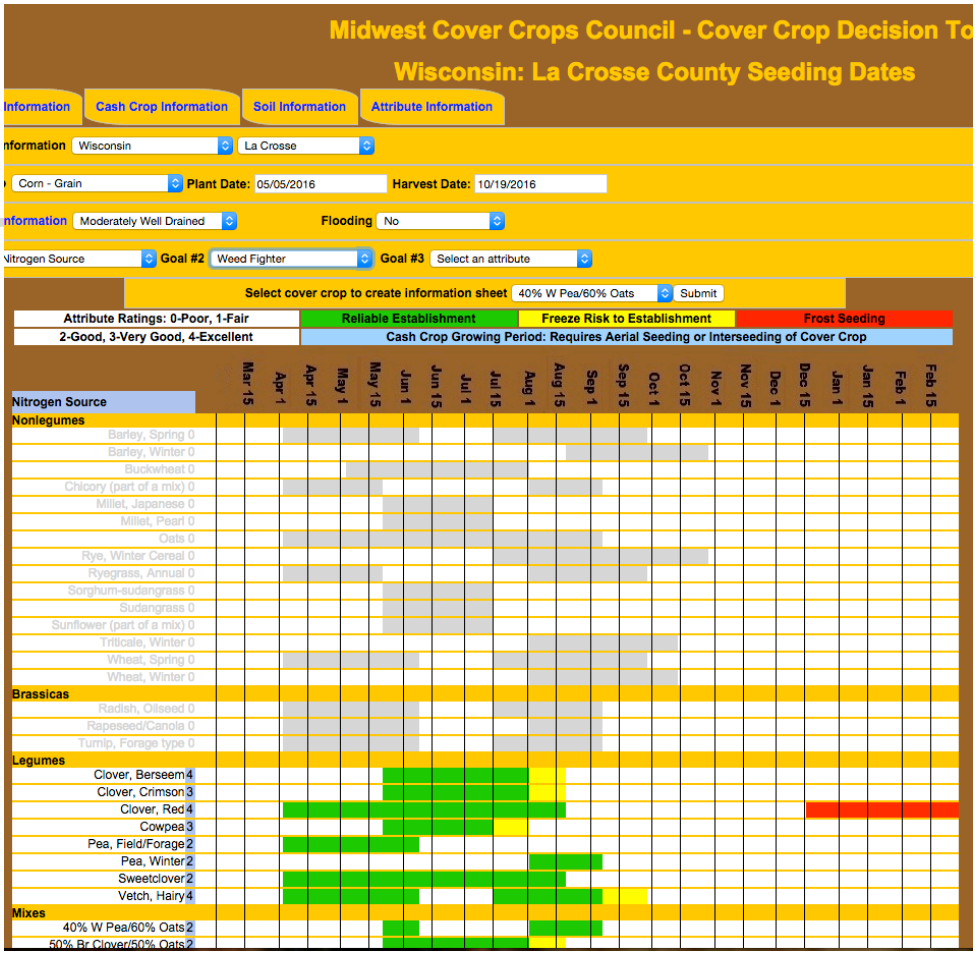
Where to start…

- Is your cover crop planting window in the spring, summer, or fall?
- How long do you have to grow the cover crop (e.g., in a short window between crops, or before or after frost)?
- How does it fit into your crop rotation?
- What are your main goals (soil fertility, control weeds, economic value, etc.)?

Helpful resources

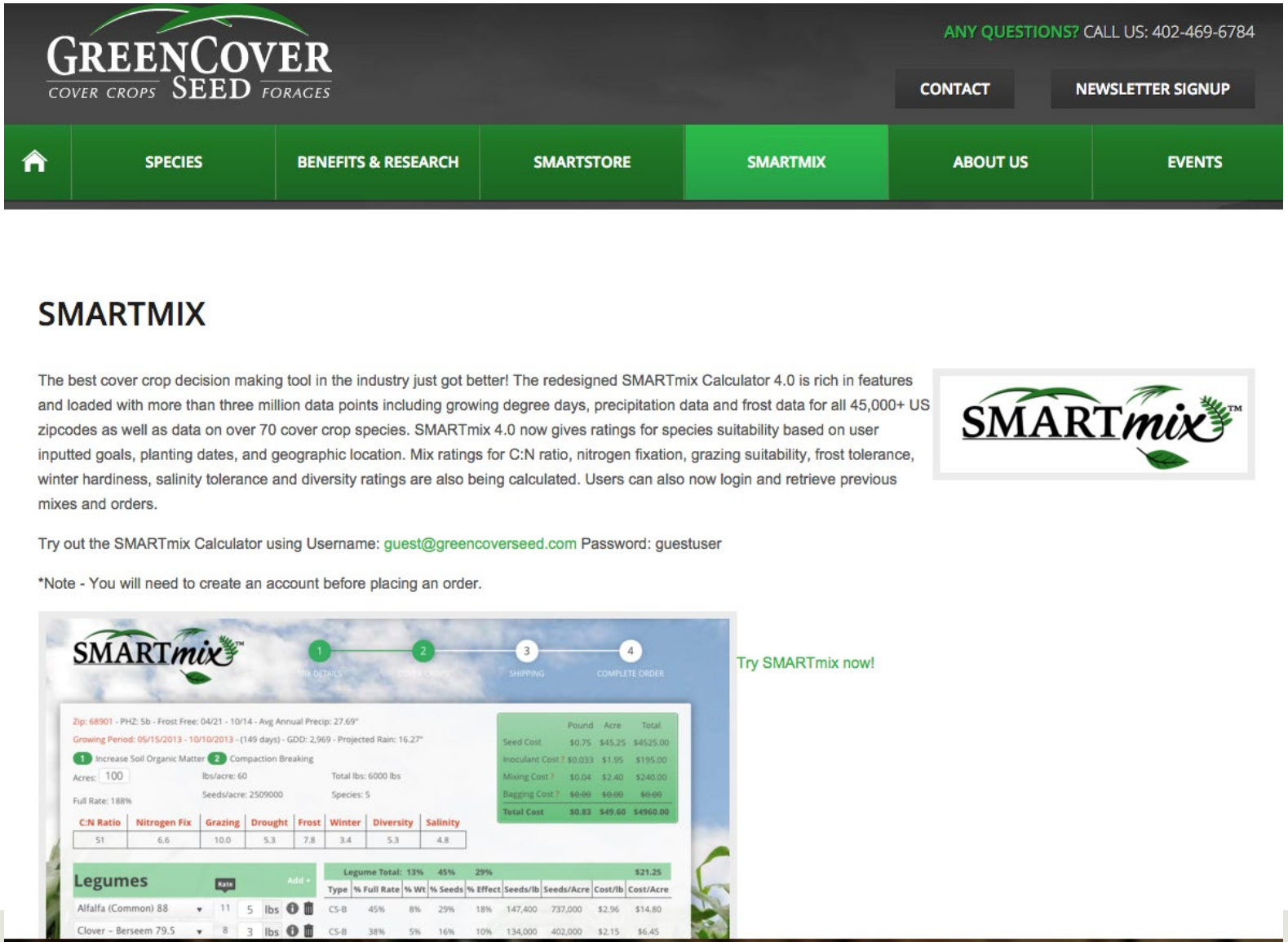


Midwest cover crops council: www.mccc.msu.edu



Resources: GreenCover seed calculator

https://smartmix.greencoverseed.com/



Cover crops for the winter niche

Cover Crop	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Hairy vetch					T			E				
Red clover		E			T				Frost seeded in wheat, terminate in 2nd year			
Cereal rye					T				E			
Winter wheat					T				E			
Spring oats								E			Winter-kill	
Forage radish								E			Winter-kill	

Hairy Vetch

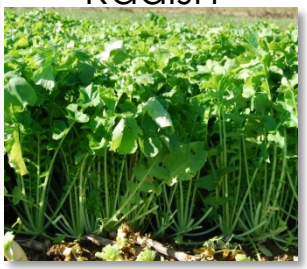
Red Clover

Cereal Rye

Winter Wheat

Oats

Forage Radish



Can legume cover crops supply all or part of your nitrogen needs?

Why focus on legume N sources ?

- Can reduce the need for costly N fertilizer inputs and reduce losses of fertilizer from farm fields
- If you farm organically, there are some potential concerns with manure and compost as N sources
  - Applying manure to meet crop N needs can lead to excesses of P and K, which can increase weed and pest pressure
  - Manure N often ultimately derived from N fertilizer applied to feed crops
    - i.e., originally fossil fuel energy vs. legumes, which are solar-powered

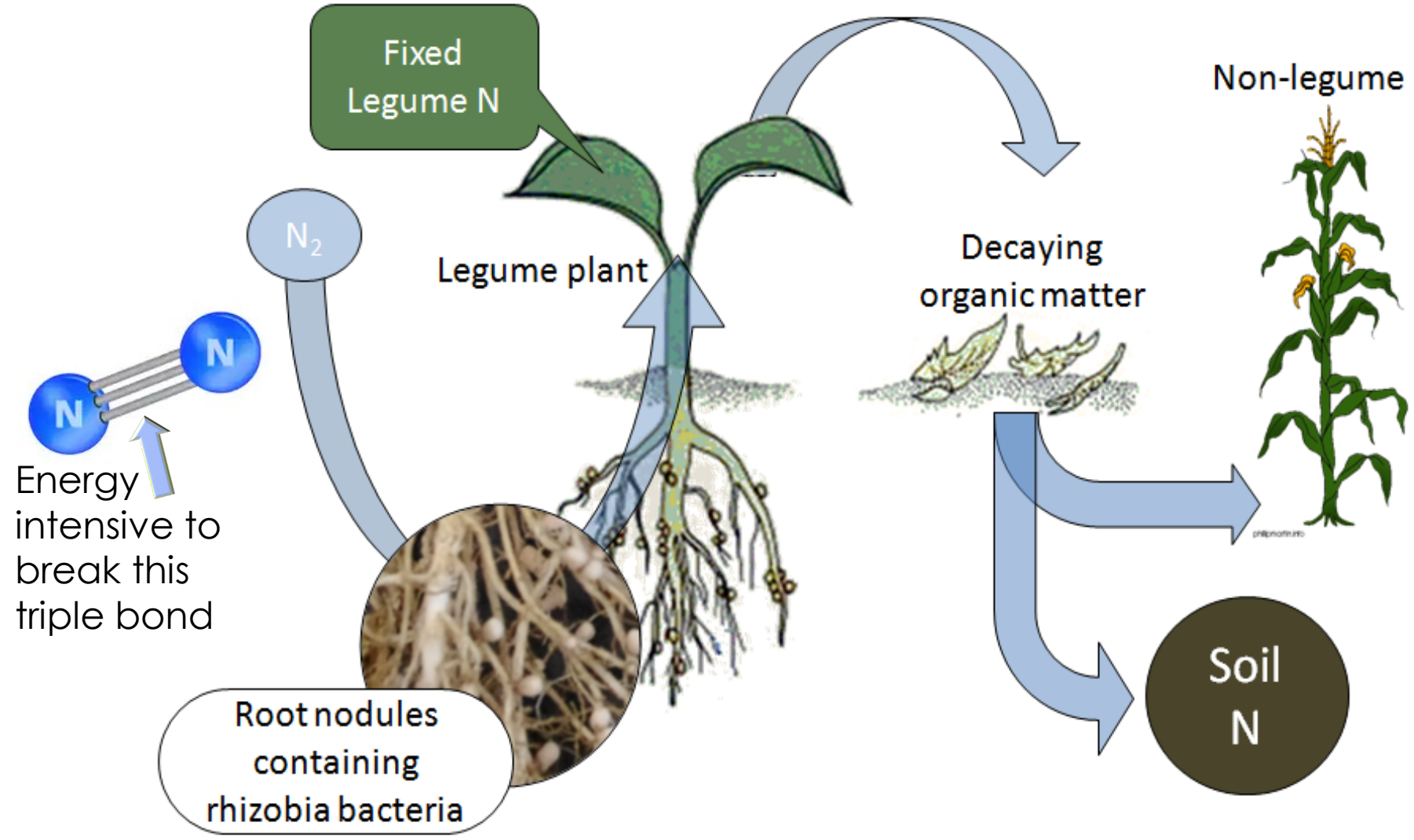
Biological nitrogen fixation (BNF)

photo by Meagan Schipanski

Pea root with fully developed, active nodules. The presence of leghemoglobin and thus nitrogen fixation is indicated by the pink coloration.

The Natural Farmer Summer, 2011

Most of the N fixed by legumes is released during decomposition



On-farm research goals

- Understand how legume cover crops impact:
  - Nitrogen supply from legume nitrogen fixation: rates on real farms
  - Soil organic matter and soil health
- Across 10 vegetable farms with different management histories and soil conditions:
  - Do differences in soil properties influence cover crop performance?
  - Evaluate traits and functions of different cool season cover crops
- Share knowledge, experiences, and identify best management practices

Overview of two studies

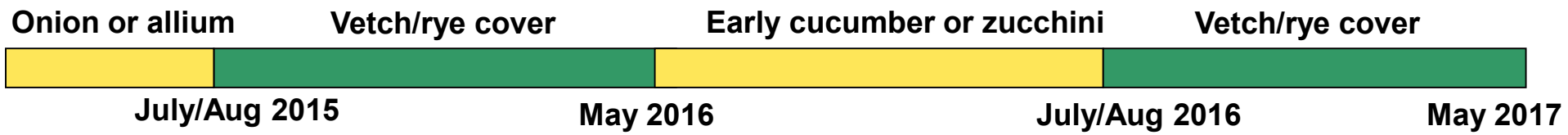
1. A field managed as similarly as possible on all farms for measurement of hairy vetch N fixation (N supply) and soil health with a vetch/rye mix over 2-3 years

2. A single season trial to screen traits and benefits of multiple cover crops of interest, planted in 2-3 species mixtures

Field 1: Legume N supply

- All farms planted a hairy vetch/cereal rye mixture between August 21-28, 2015
  - Broadcast at 50 lbs/ac rye; 22 lbs/ac vetch
- Same management for that field:
  - Tillage
  - Seeding method
  - Seeing timing and rate
  - Incorporation method (tillage)
  - Cash crop (same family- vegetable farms)
- All farms had a **no cover crop** control section of the field

Field 1 study crop rotation

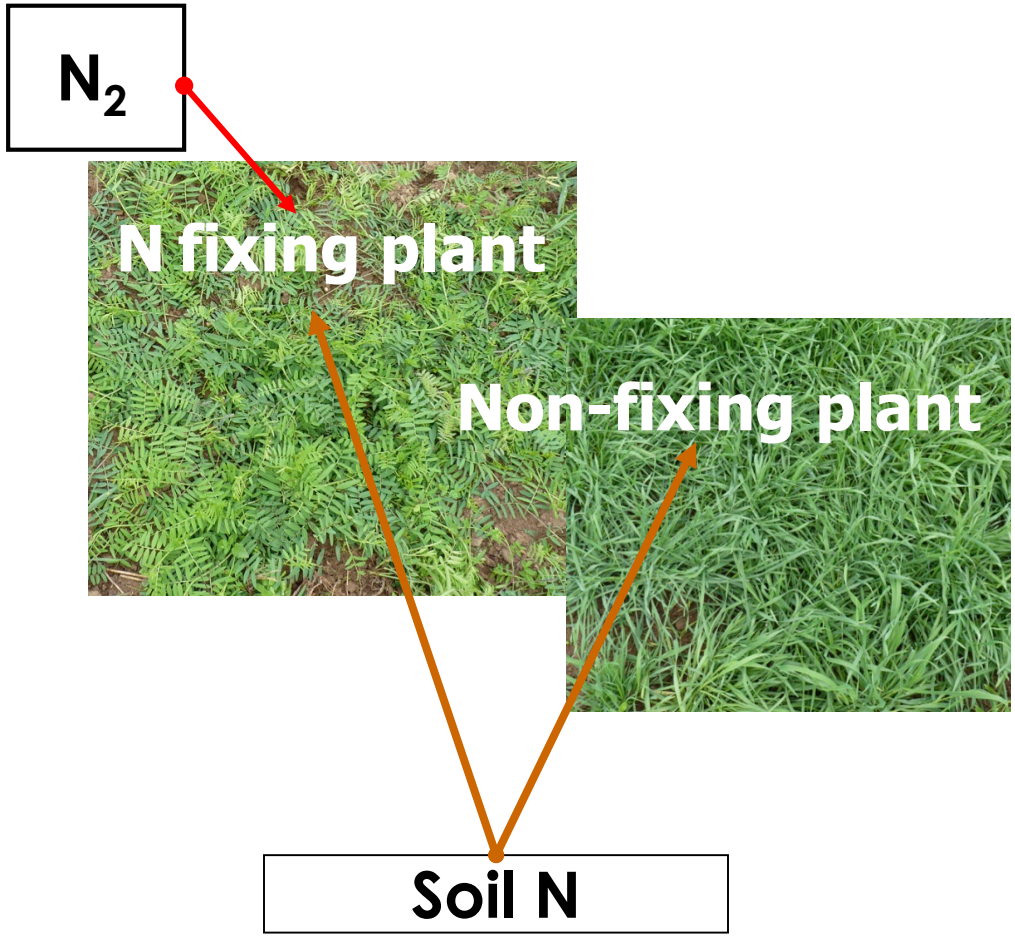


- For grain farms- vetch/rye can be planted in this same window; typically works best following harvest of a small grain

Example replicate for field 1

Vetch	Vetch/Rye	Rye
		

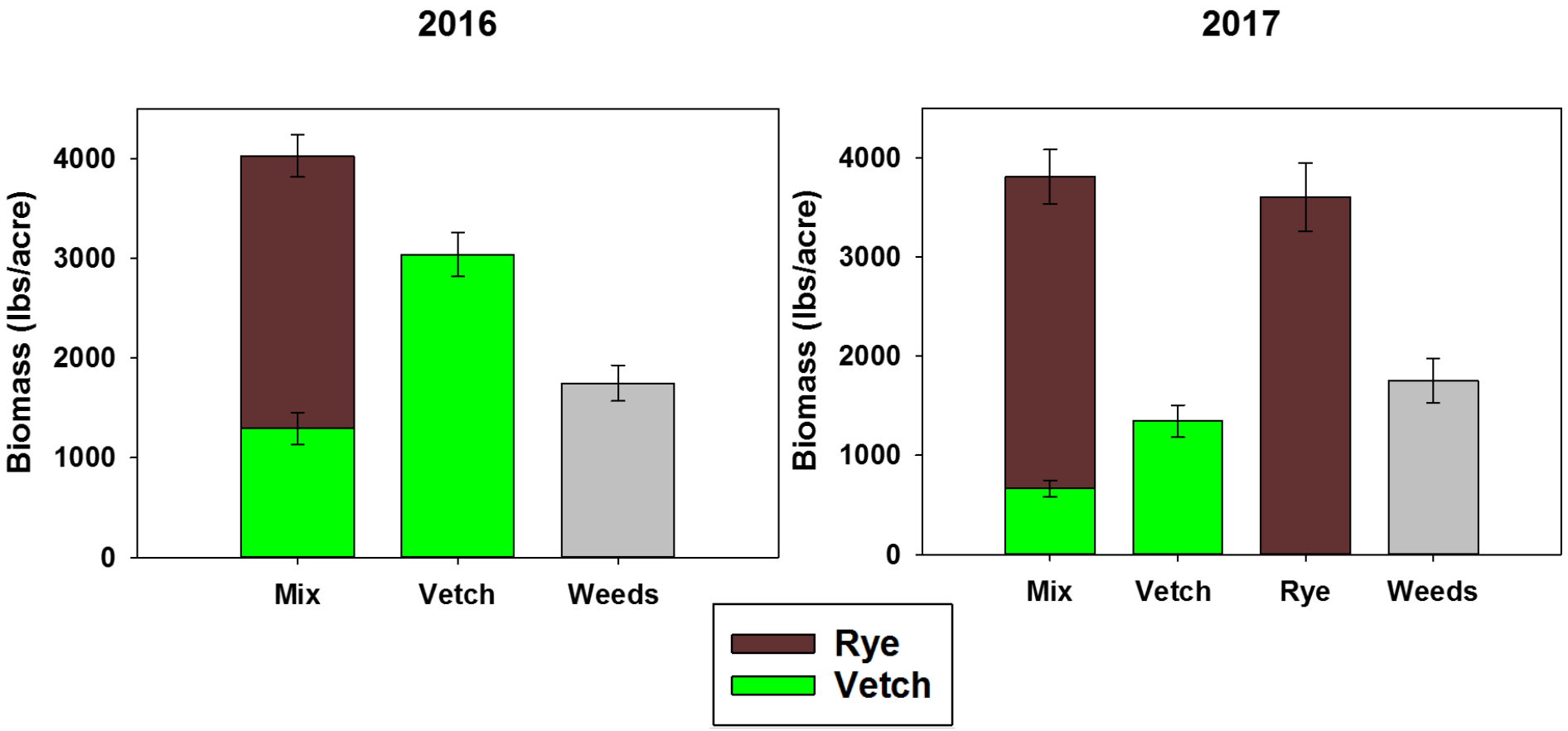
Method for measuring N fixed by legume



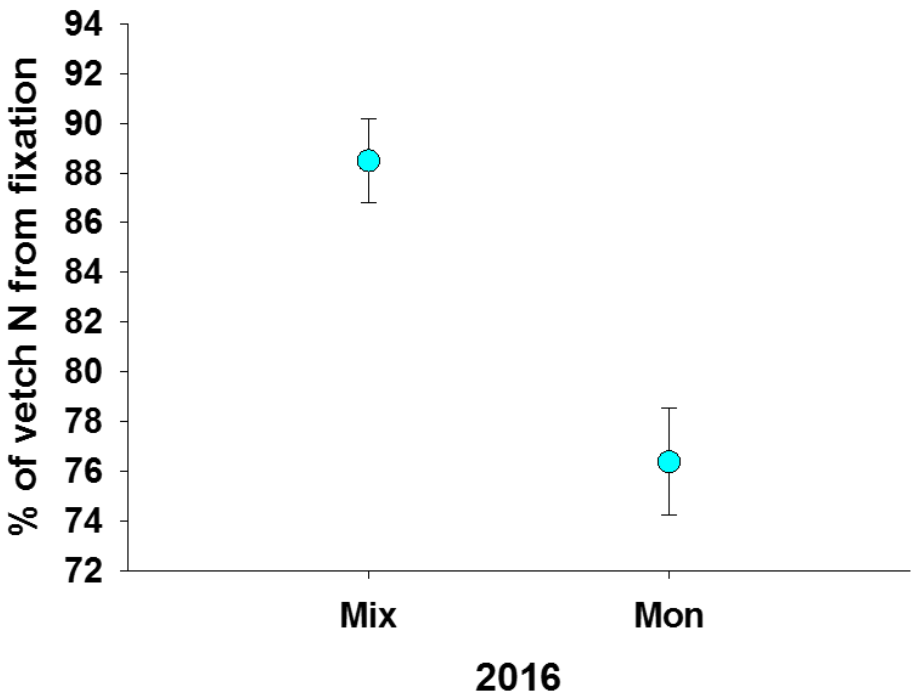
N isotope ratio ($^{15}N/^{14}N$) of soil is different than air.

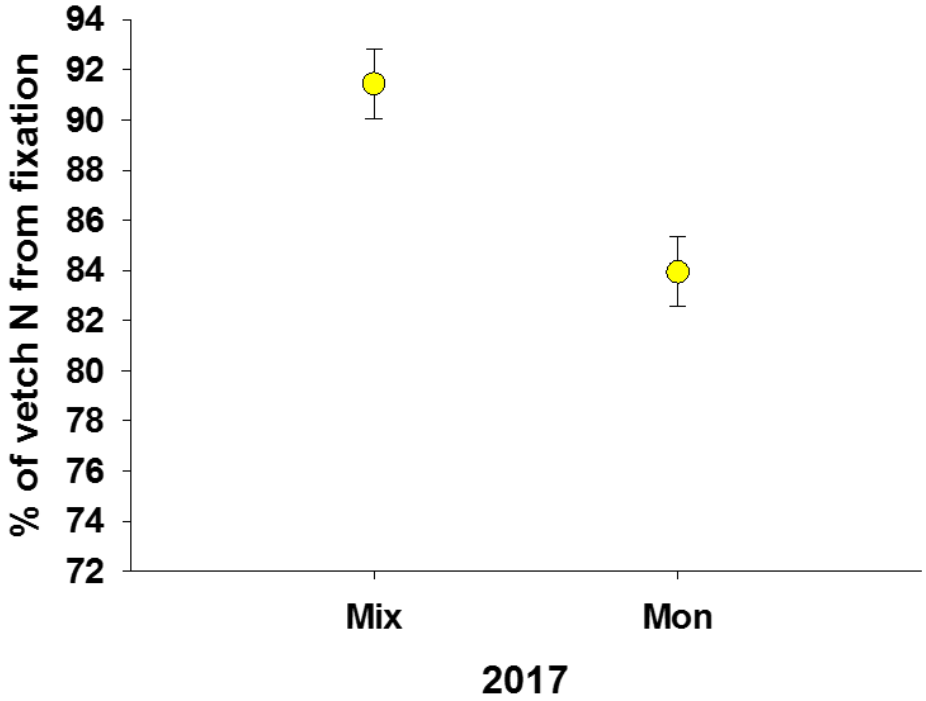
Compare N isotopes of a legume (vetch) with an adjacent non-fixing cover crop (rye) to calculate the **% of legume N that comes from the air**

Cover crop biomass: Years 1and 2

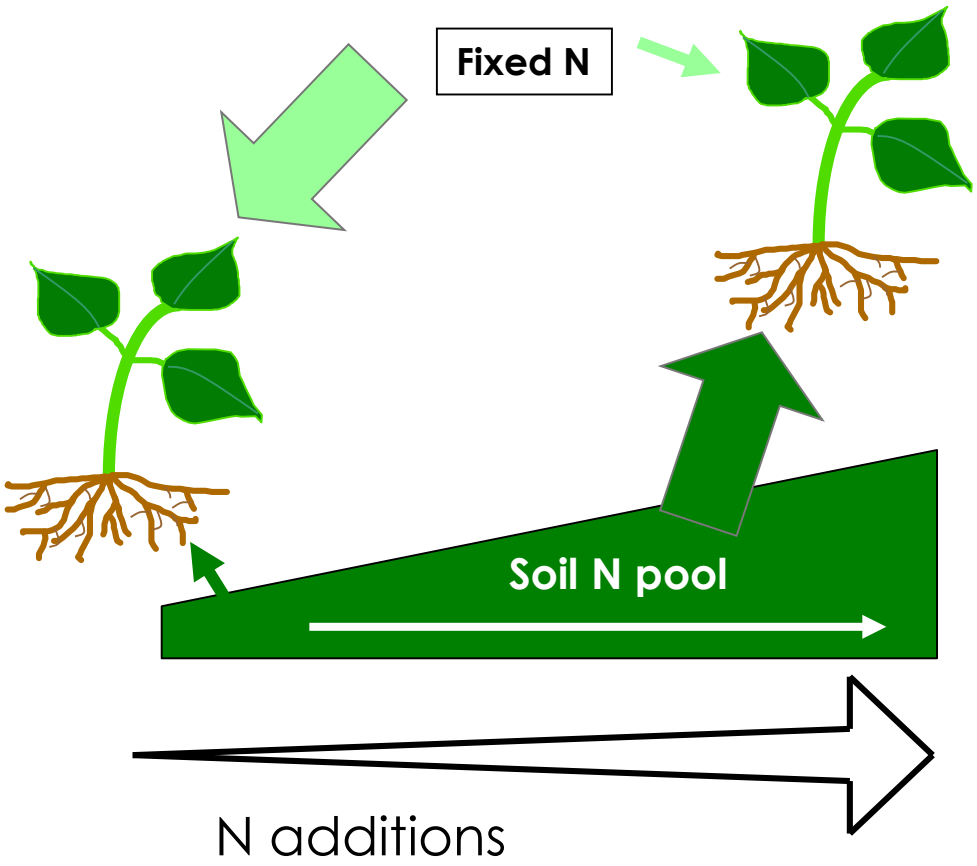


% of vetch shoot N from fixation

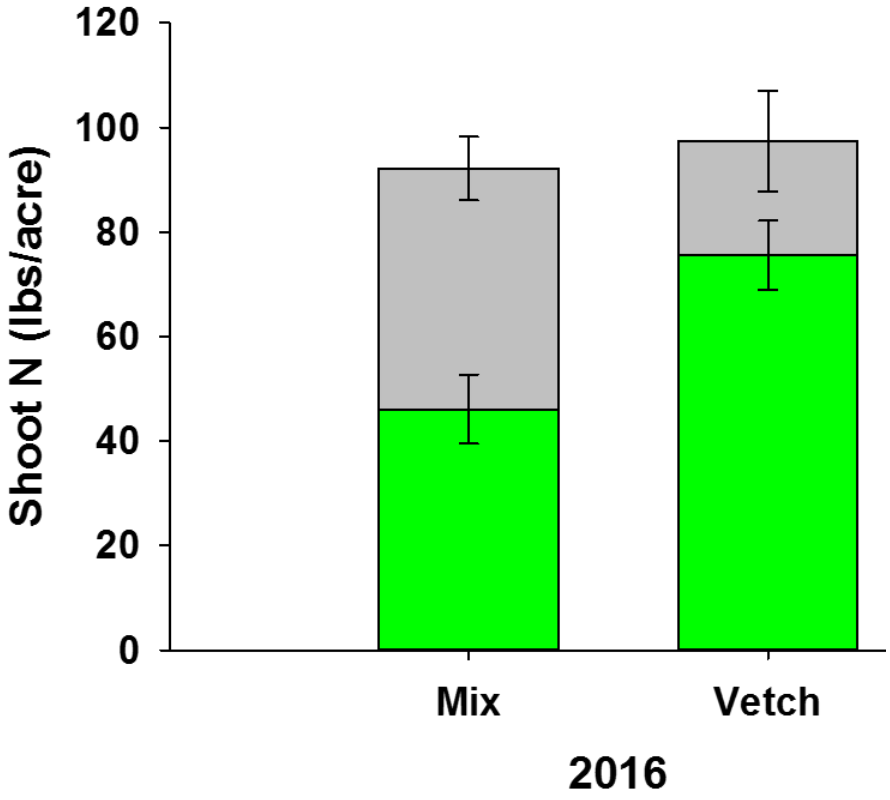


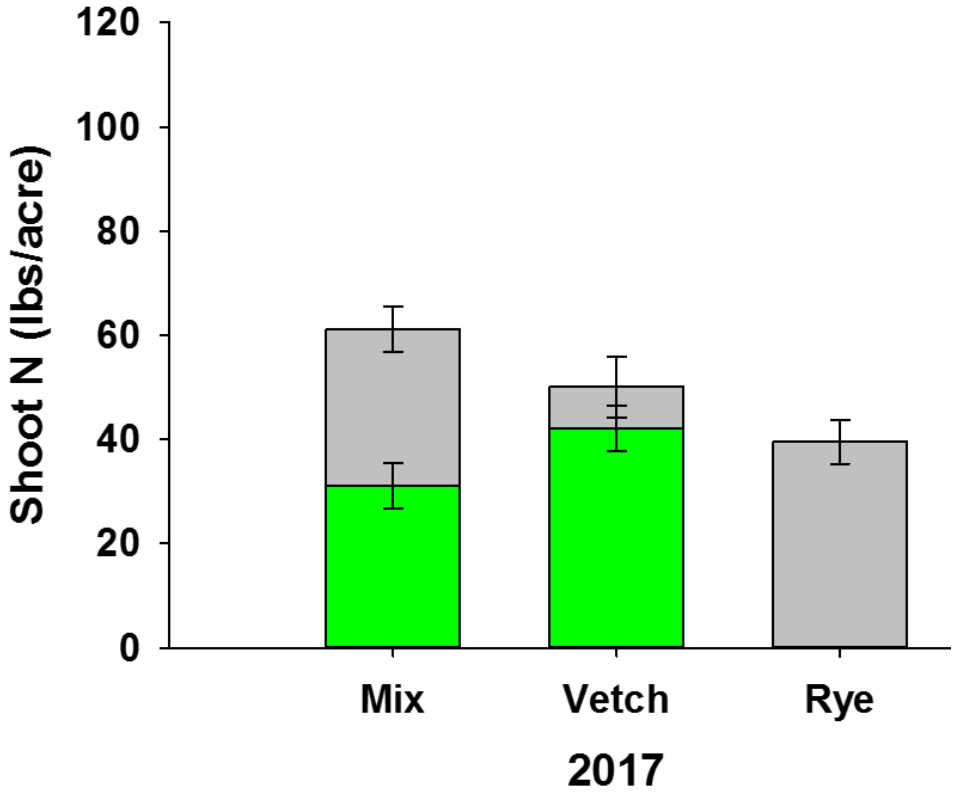


Legume N fixation increases when there is low available soil N

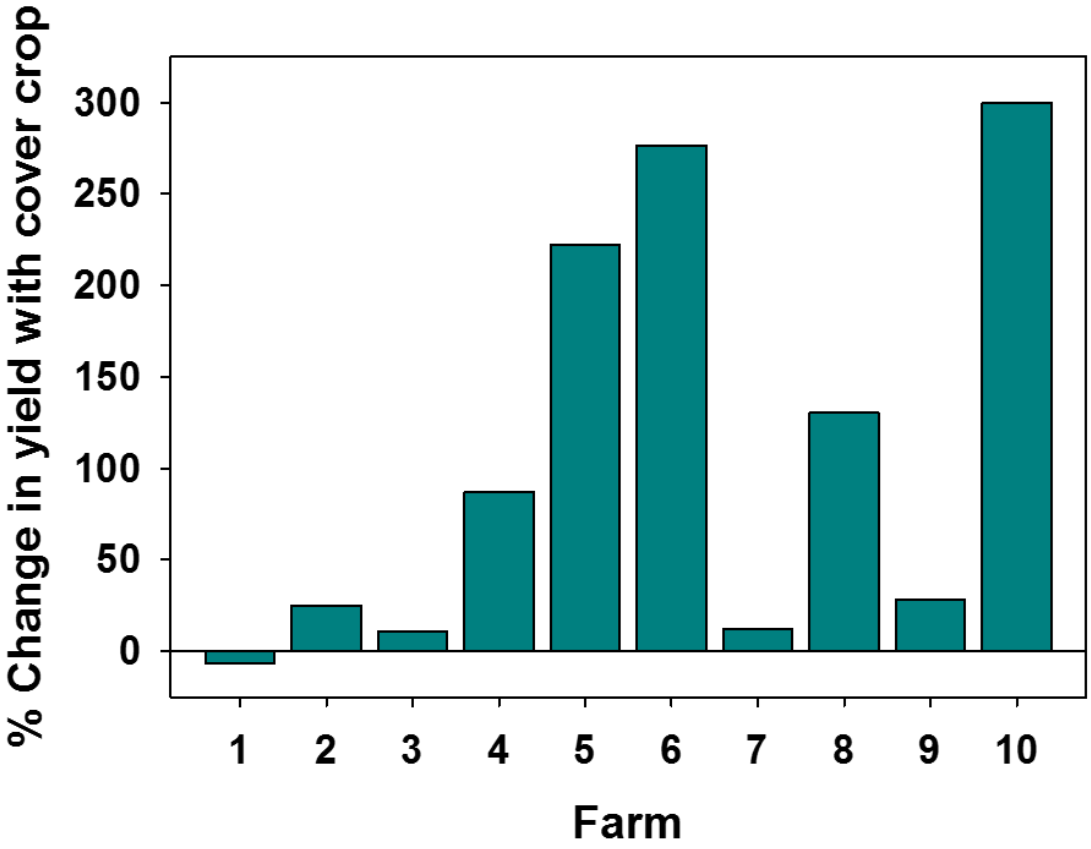


Aboveground N from fixation





Cucurbit yield increase on most farms following cover crop



So, how does the fixed N get into my crop?

Decomposition basics

- Dead organic material (detritus) is broken down to its constituent parts, ultimately to CO_2 and inorganic nutrients such as NH_4^+, Ca^{2+}, K^+, and other elements
- Rates vary with structure and chemical composition of the OM being decomposed (its quality), the environment, and exposure to decomposer organisms (microbial and faunal)

Controls on decomposition and nutrient mineralization

- Climate
  - Moisture/aeration: faster when moist, but very wet sites have limited O_2 diffusion to microbes, limiting their effectiveness
  - Temperature: exponential increase in soil respiration with higher temperatures
- Substrate properties
  - Litter quality: chemical composition matters
  - Nutrient content: sometimes microbes N or P limited

Quality of cover crop residue

- C:N is really just another way to look at %N
- High C:N ratios have a LOW % of N
- C:N ratios over 40 may tie up N, and cause a short-term lack of available N

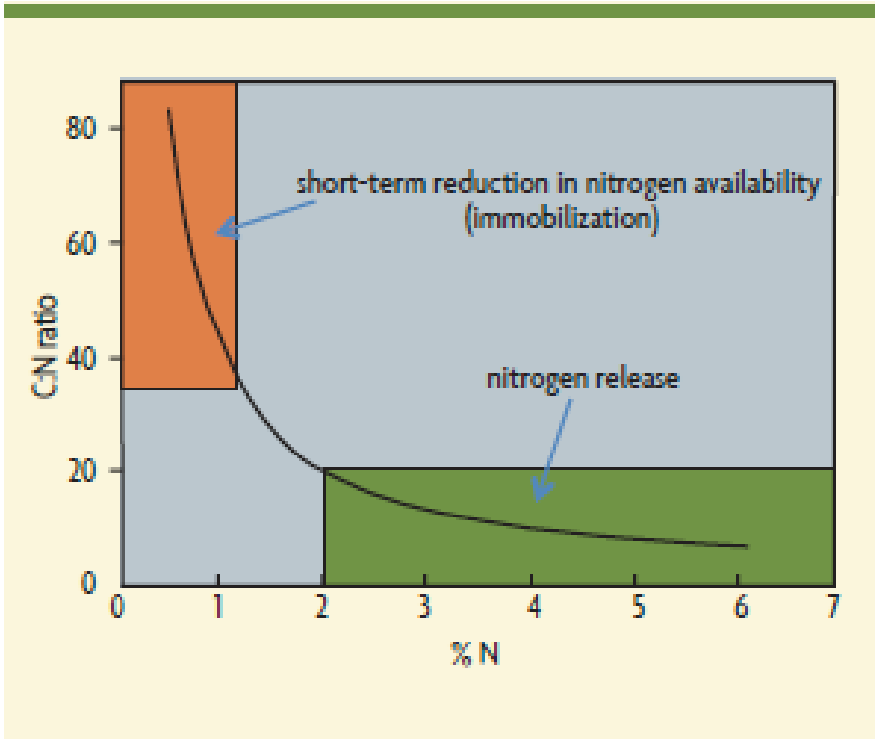
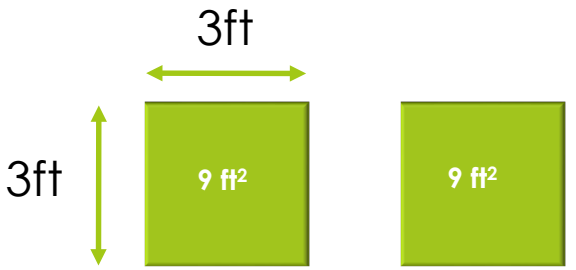


Figure 9.3. Nitrogen release and immobilization with changing nitrogen content. Based on data of Vigil and Kissel (1991).

How to estimate legume N supply on your farm

First step: determine your biomass

1. Find a yardstick or metal frame of known dimensions.
2. In several areas of your field, clip the plants at ground level within the known area.
3. Dry the samples in an oven at about 140°F for 24 to 48 hours until they are crunchy dry



You have sampled **two** 3x3 ft regions of your field. The dried samples together weigh 2.5 lbs. How much biomass per acre do you have?

ANSWER: 6,050 LBS/ACRE

Area sampled:
3x3 = 9 ft^2 X 2 = (18 ft^2)

2.5 lbs / 18 sq ft X 43,560 sq ft / 1 acre = 6050

Cover crop biomass (lbs/acre) =

$$\frac{\text{Total dried sample weight (lbs)}}{\text{Total area sampled (sq ft)}} \times \frac{43{,}560 \text{ sq ft}}{1 \text{ acre}}$$

Another way to determine biomass (but not as accurate!)

1. Use height and density of the cover crop to determine biomass
2. At 100% ground cover and 6 inch height, most legumes contain 2000 lbs /acre of dry matter
3. For each additional inch, add 150 lbs

You have a cover crop that is 18 inches tall and has 100% coverage. How much biomass do you have?

ANSWER: 3,800 lbs

First 6 inches = 2000 lbs
Additional 12 inches =
(150 lbs)(12 inches) = 1800
1800 + 2000 = 3,800 lbs!

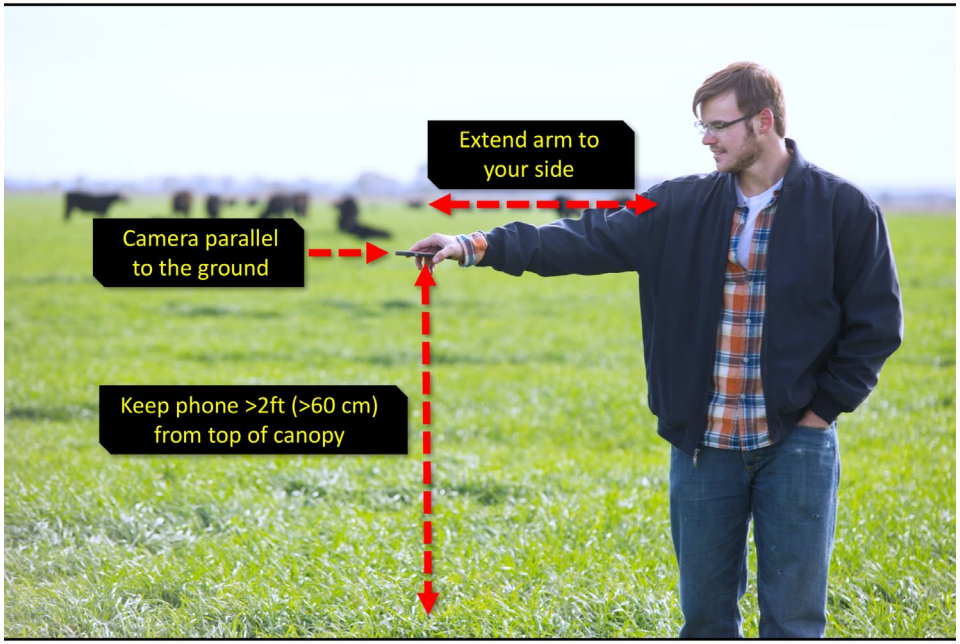
Less than 100% cover? Multiply by the percent cover you have. 60% cover?

(3800 lbs) (.60) = 2,280 lbs

(Adapted from Sarrantonio, 1998)

New tools for these estimates:

- Canopeo App
  - http://canopeoapp.com/#/login
- Can assess % cover



Second step: determine the nitrogen in your biomass

- Use tissue tests or a % nitrogen number from another source
- Multiply the dry biomass yield times the percentage of nitrogen.
- Multiple the N content (lbs/ac) by the percentage of nitrogen that came from the atmosphere (% N from fixation)

If your hairy vetch cover crop in the last example (3,800 lbs of biomass) has 3% N at kill, and 85% of the vetch N came from atmospheric N_2 fixation, how much N are you applying to your field?

ANSWER: 97 lbs of total N

(3,800 lbs/acre)(.03)(.85) =

96.9 lbs of N

How much N is in my cover crop?

Which cover crop?	Examples	How much N?
Legumes	Hairy vetch, crimson clover, Austrian winter pea	3-4% at flowering; less if plant has maturing seeds
Non-legume grasses	Rye, sudex	2-3% at flowering, less if plant has maturing seeds

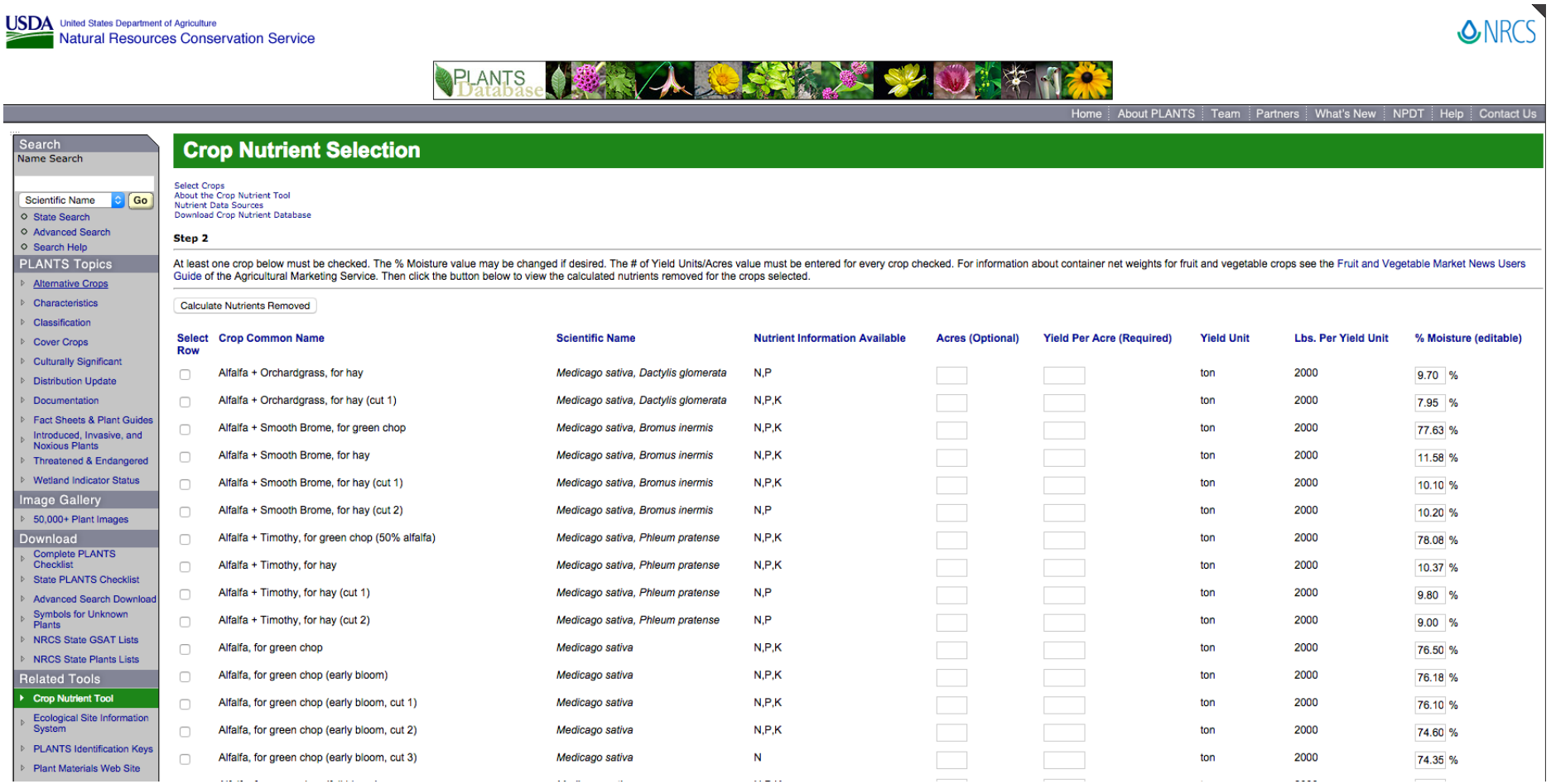
How do I find out how much N is in my cover crop biomass?

Lab	website
AgVise	http://www.agvise.com/
A & L labs	http://www.al-labs-plains.com/
Midwest labs	https://www.midwestlabs.com/

OK, now what do I do with all of this stuff?

USDA Crop Nutrient Tool

Website:
plants.usda.gov/npk/main



Select Row	Crop Common Name	Scientific Name	Nutrient Information Available	Acres (Optional)	Yield Per Acre (Required)	Yield Unit	Lbs. Per Yield Unit	% Moisture (editable)
☐	Alfalfa + Orchardgrass, for hay	*Medicago sativa, Dactylis glomerata*	N,P			ton	2000	9.70 %
☐	Alfalfa + Orchardgrass, for hay (cut 1)	*Medicago sativa, Dactylis glomerata*	N,P,K			ton	2000	7.95 %
☐	Alfalfa + Smooth Brome, for green chop	*Medicago sativa, Bromus inermis*	N,P,K			ton	2000	77.63 %
☐	Alfalfa + Smooth Brome, for hay	*Medicago sativa, Bromus inermis*	N,P,K			ton	2000	11.58 %
☐	Alfalfa + Smooth Brome, for hay (cut 1)	*Medicago sativa, Bromus inermis*	N,P,K			ton	2000	10.10 %
☐	Alfalfa + Smooth Brome, for hay (cut 2)	*Medicago sativa, Bromus inermis*	N,P			ton	2000	10.20 %
☐	Alfalfa + Timothy, for green chop (50% alfalfa)	*Medicago sativa, Phleum pratense*	N,P,K			ton	2000	78.08 %
☐	Alfalfa + Timothy, for hay	*Medicago sativa, Phleum pratense*	N,P,K			ton	2000	10.37 %
☐	Alfalfa + Timothy, for hay (cut 1)	*Medicago sativa, Phleum pratense*	N,P			ton	2000	9.80 %
☐	Alfalfa + Timothy, for hay (cut 2)	*Medicago sativa, Phleum pratense*	N,P			ton	2000	9.00 %
☐	Alfalfa, for green chop	*Medicago sativa*	N,P,K			ton	2000	76.50 %
☐	Alfalfa, for green chop (early bloom)	*Medicago sativa*	N,P,K			ton	2000	76.18 %
☐	Alfalfa, for green chop (early bloom, cut 1)	*Medicago sativa*	N,P,K			ton	2000	76.10 %
☐	Alfalfa, for green chop (early bloom, cut 2)	*Medicago sativa*	N,P,K			ton	2000	74.60 %
☐	Alfalfa, for green chop (early bloom, cut 3)	*Medicago sativa*	N			ton	2000	74.35 %

Third step: How much N will be available to my crop?

- To conservatively estimate how much N is made available to your crop over the entire growing season, multiply legume biomass nitrogen:
  - by 0.50 if the cover crop residue will be incorporated
  - by 0.40 if the residue will be left on the soil surface.

- If your hairy vetch is incorporated in the soil in early may in a normal spring, how much N will be available to your crop?

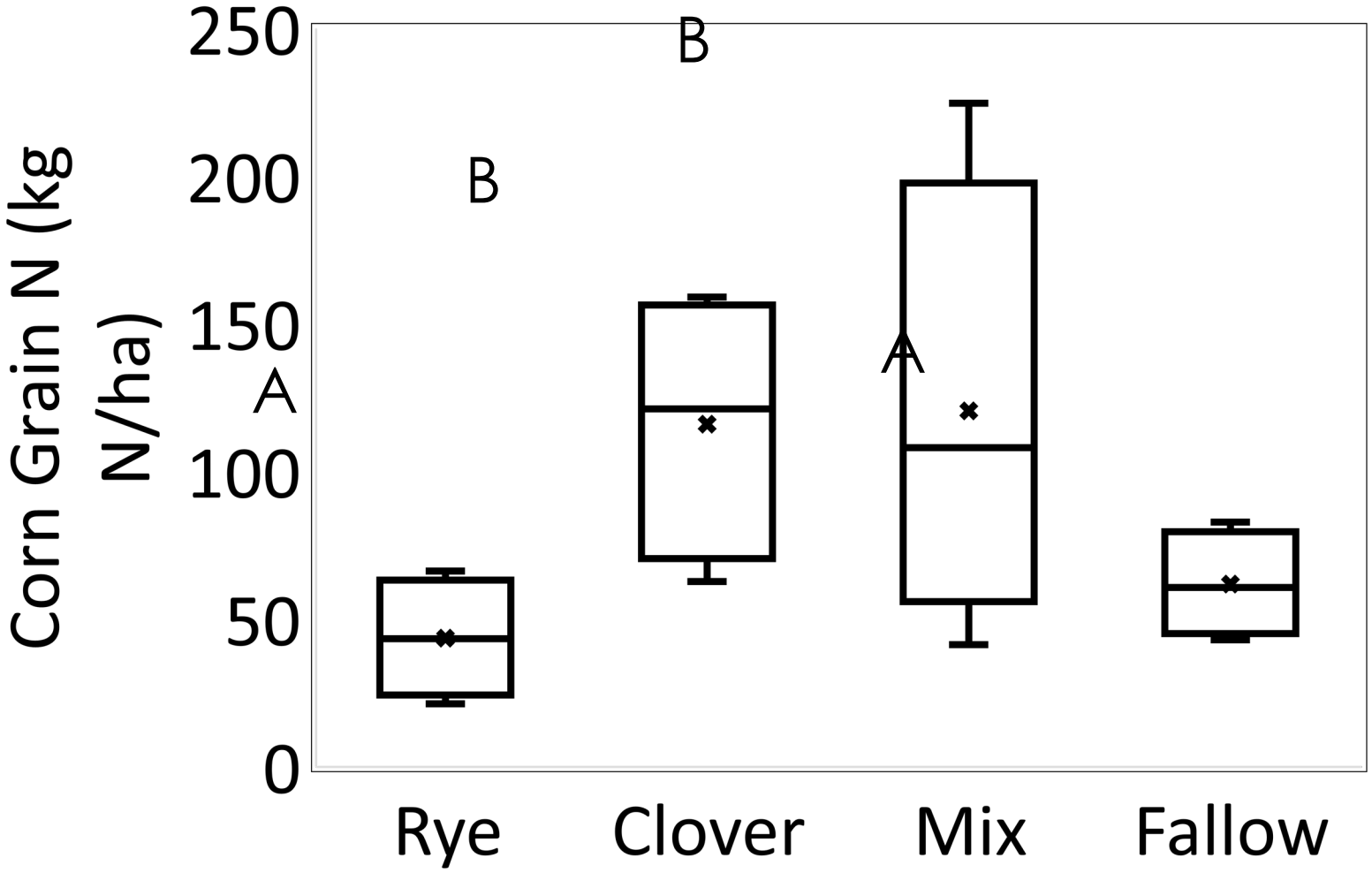
(152 lbs of N)(.50) =

Understanding timing of N release with legume-grass mixes

- Companion study on UM Campus Farm
- Crimson clover-cereal rye mixture planted August 16, 2017
- Measured N mineralization rates following incorporation by tillage on May 23, 2018 and N uptake by corn
- Clover supplied 76 lbs/ac alone and 50 lbs/ac in mix

Bressler and Blesh, In Review

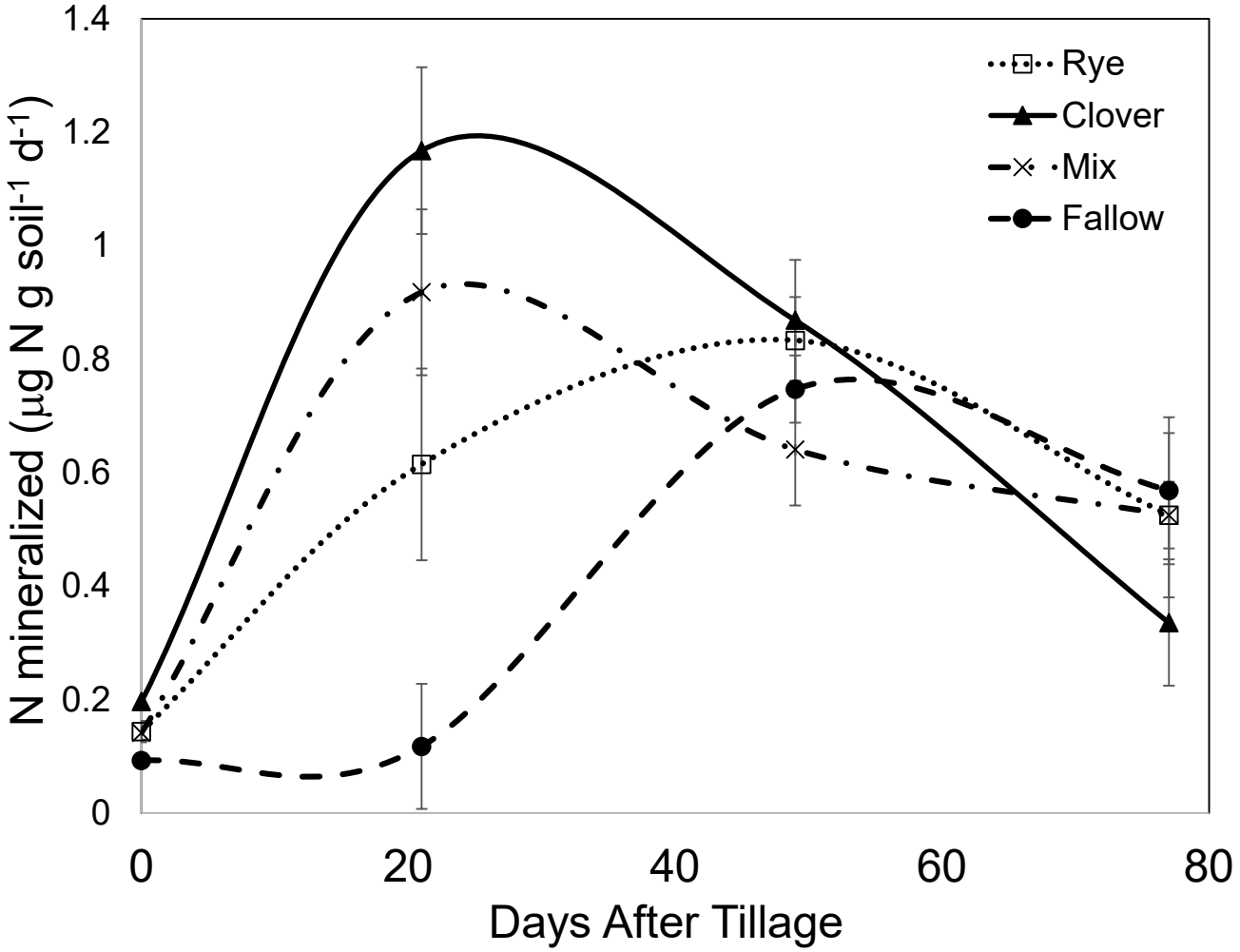
N uptake by following corn crop



p = 0.016

Bressler and Blesh, In Review

N release following tillage from litter and soil combined: field incubation



Rate on day 21 (lbs N/acre/day):

Clover:	30
Rye:	16
Clover/Rye:	24

Rate on day 49:

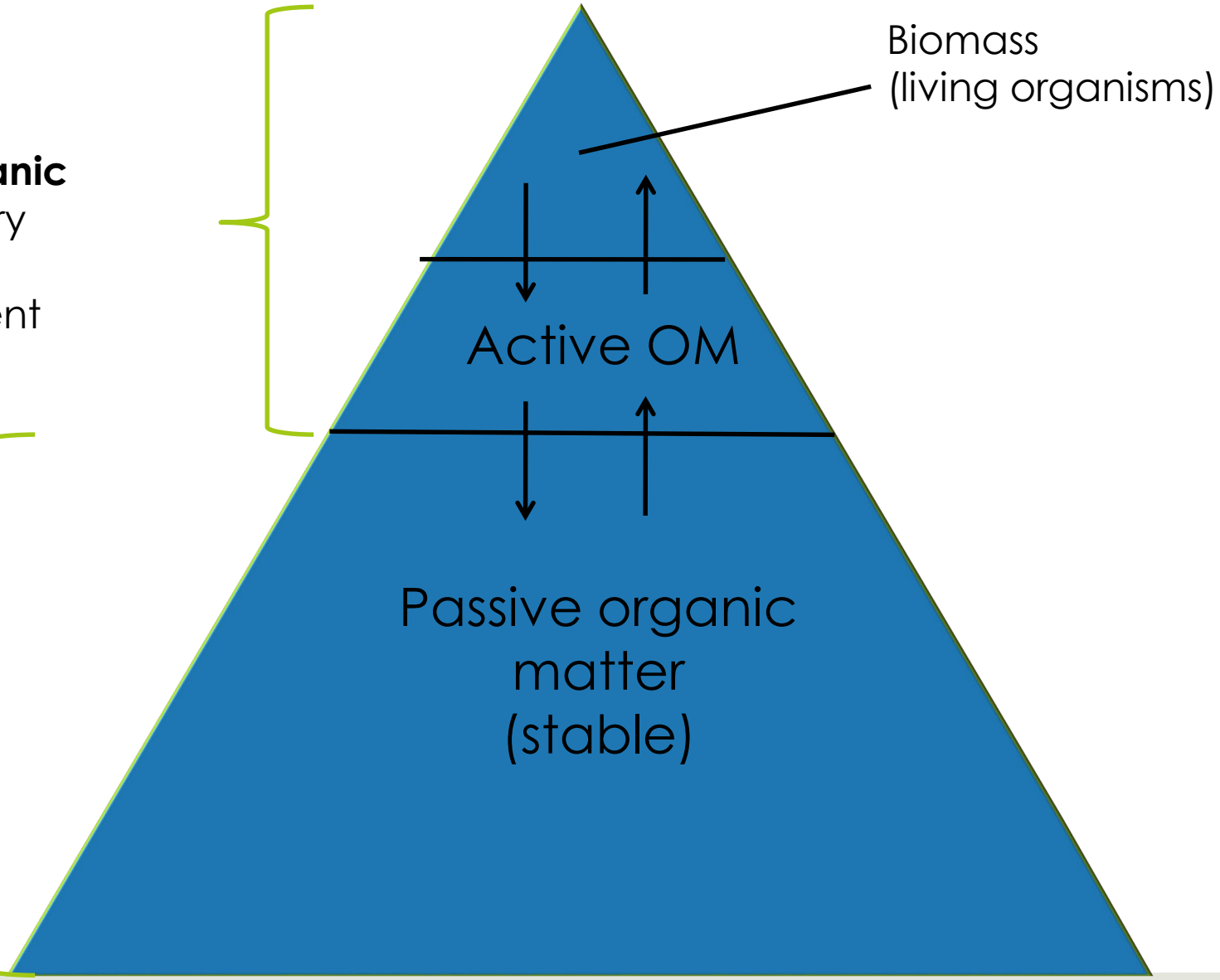
Clover:	23
Rye:	22
Clover/Rye:	17

Rate on day 77:

Clover:	9
Rye:	13
Clover/Rye:	13

Bressler and Blesh, In Review

Soil organic matter

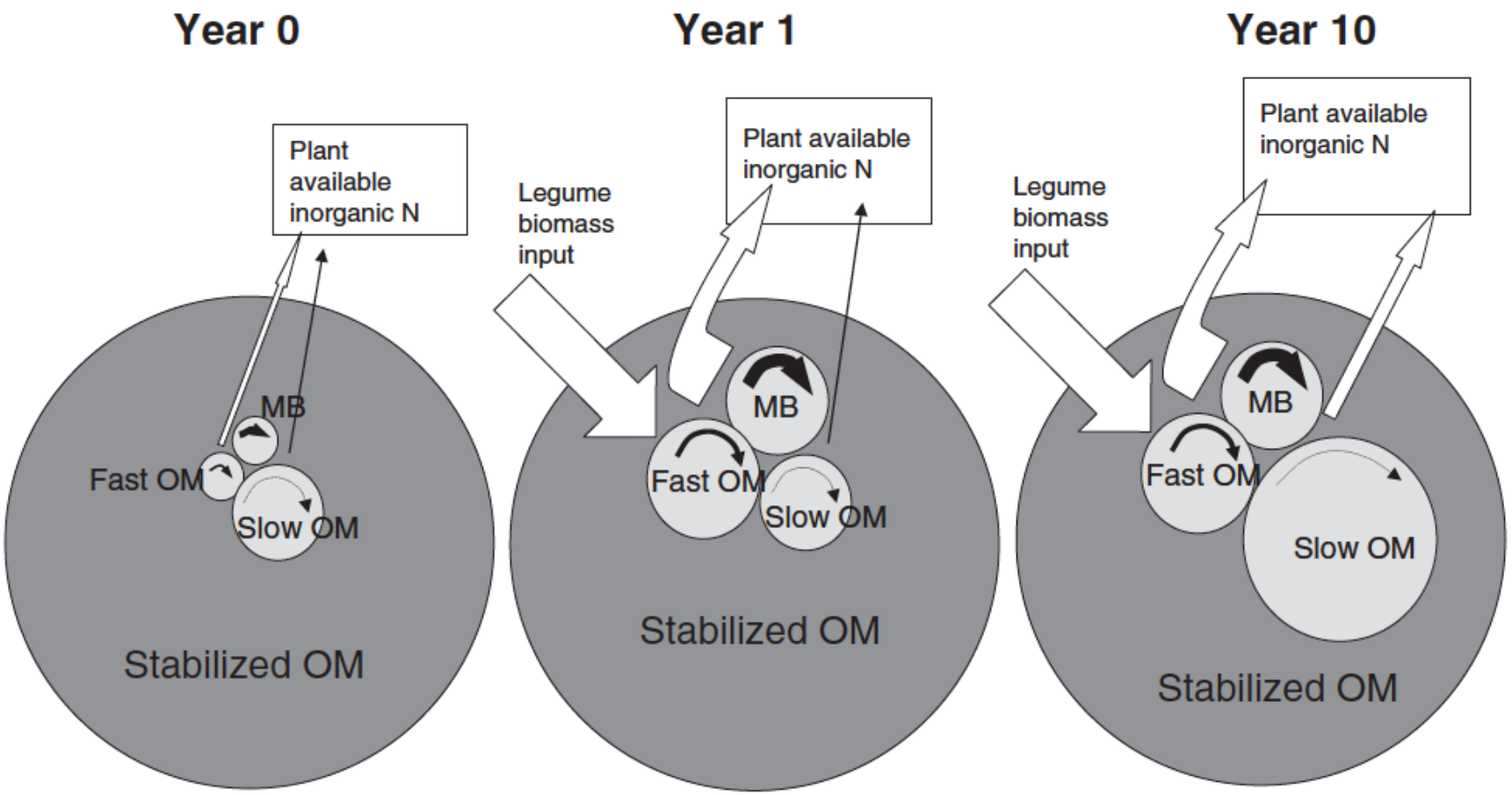


Active, organic matter – Very sensitive to management changes

Passive organic matter – Half life measured in centuries

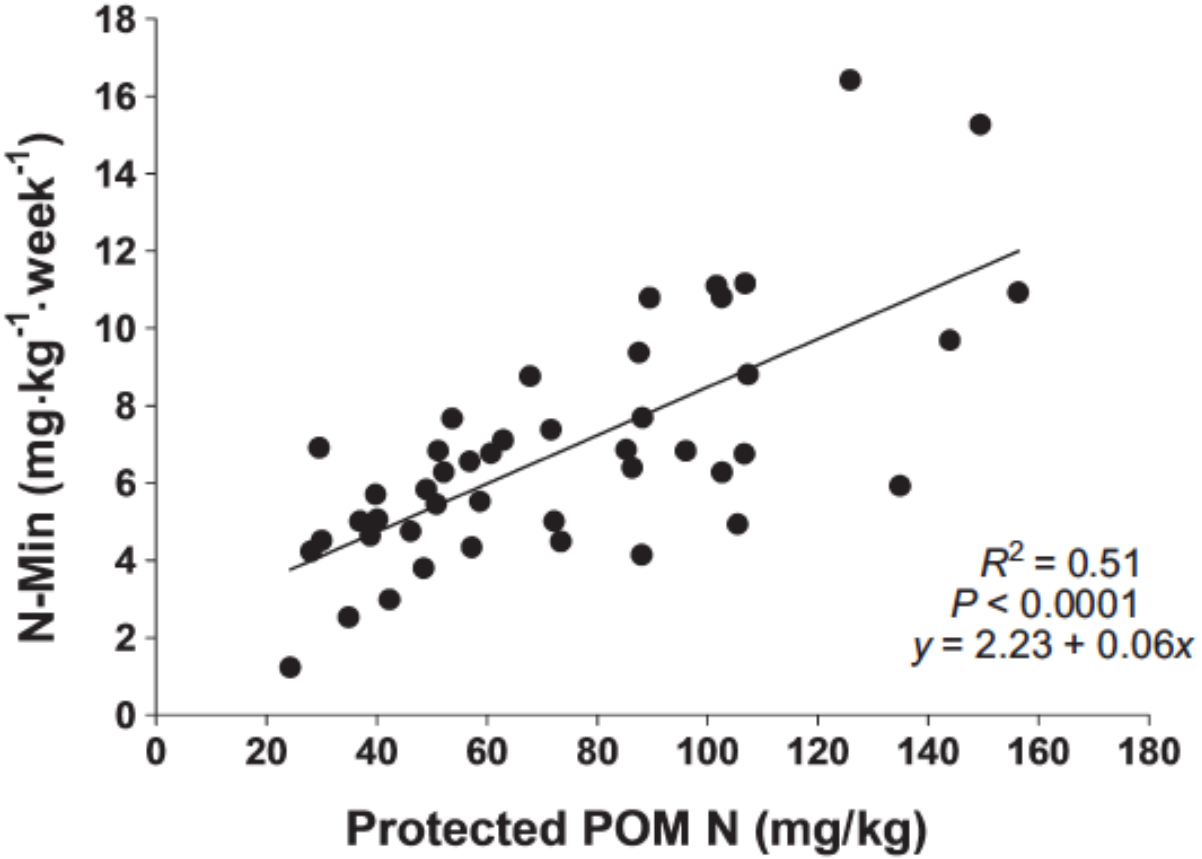
Magdoff and Weil, Fig 1.18 *Soil organic matter in sustainable agriculture*

Effect of legumes on organic matter over time



Drinkwater et al. 2008; Ecologically-based nutrient management

More particulate organic matter means more nitrogen mineralization



Blesh 2019, Ecological Applications

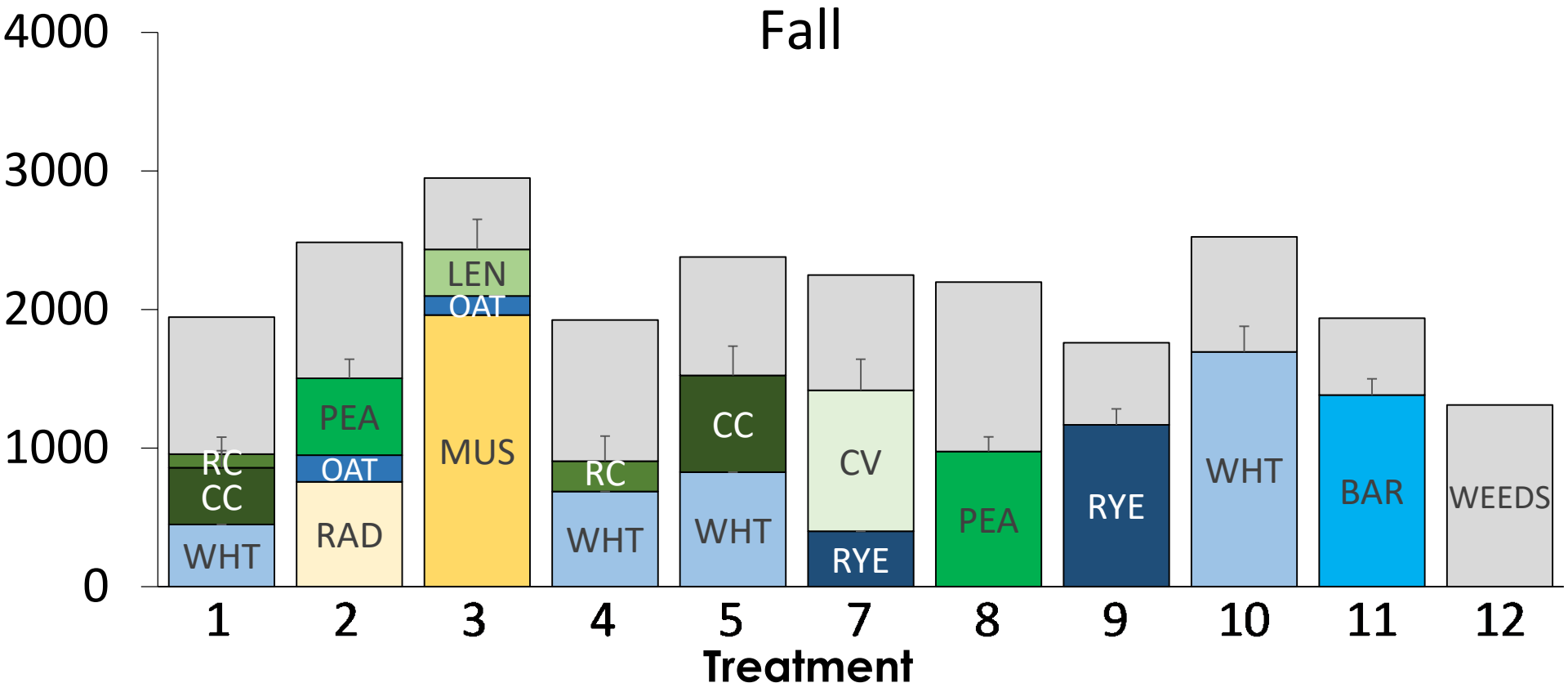
Legume cover crop mixtures

- Multiple benefits from different species with different traits
  - Nitrogen source from legume nitrogen fixation AND
  - Weed, pest, or soil-borne disease control; reduce compaction; build macropores and aerate soil; attract pollinators or other beneficial insects; scavenge/retain soil nutrients; reduce erosion; increase resilience to drought and flooding
- Increasing research attention on quantifying the benefits of different species mixes, and developing farmer decision tools

Field 2: Screen different cover crops

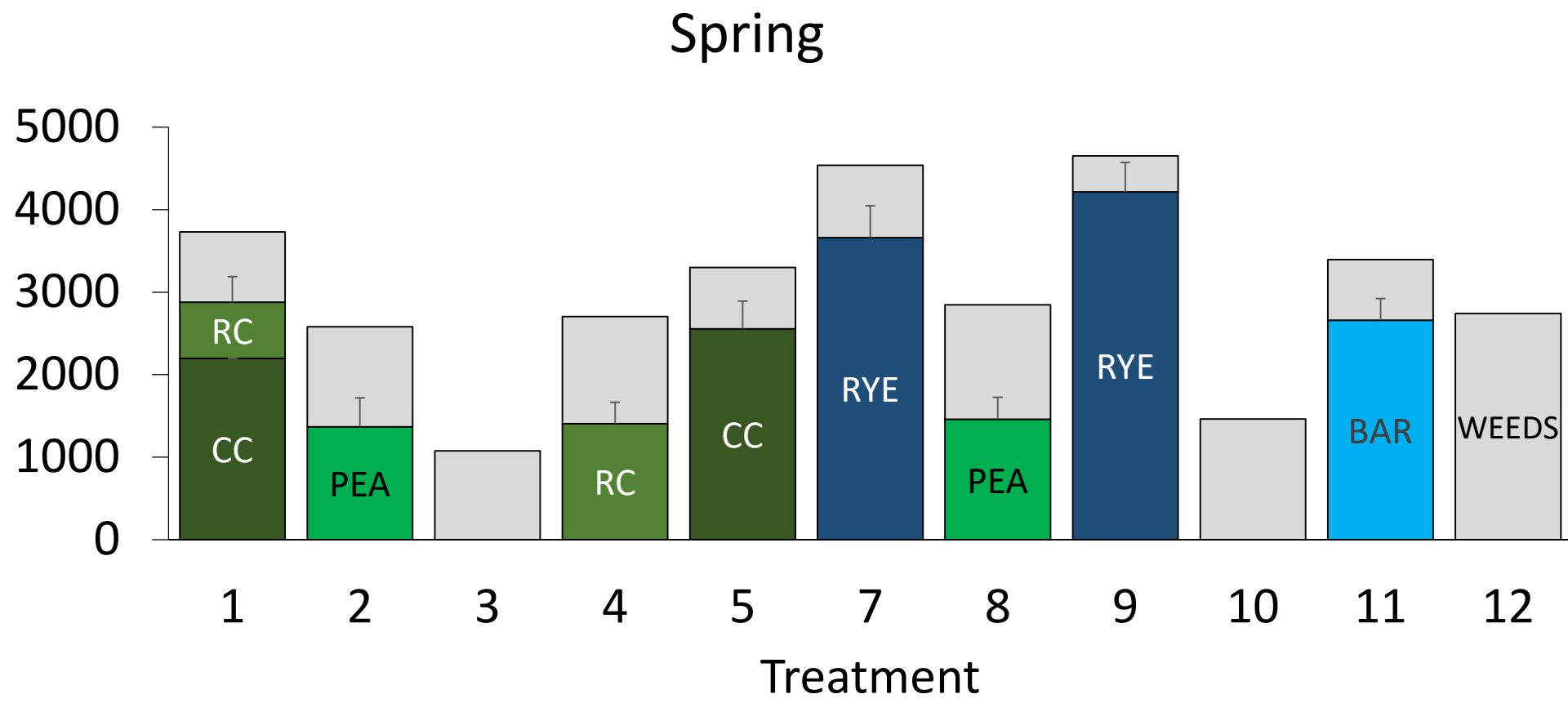
- Replicated different cover crops in 4 blocks in a field (all broadcast and lightly incorporated):
  - **Crimson clover (17)/red clover (6)/spring wheat (45)**
  - **Winter pea (50)/oat (40) /daikon radish (3)**
  - **Lentil (30)/yellow mustard (8)/oat (40)**
  - **Red clover (8)/spring wheat (50)**
  - **Crimson clover (22)/spring wheat (50)**
  - **Cereal rye (50)/chickling vetch (105)**
  - **Sole pea (100)**
  - **Sole rye (155)**
  - **Sole winter barley (155)**
- Tested for functions:
  - Biomass production (e.g., erosion control), Nitrogen scavenging, Legume nitrogen fixation, Weed control

Average fall biomass (all farms)



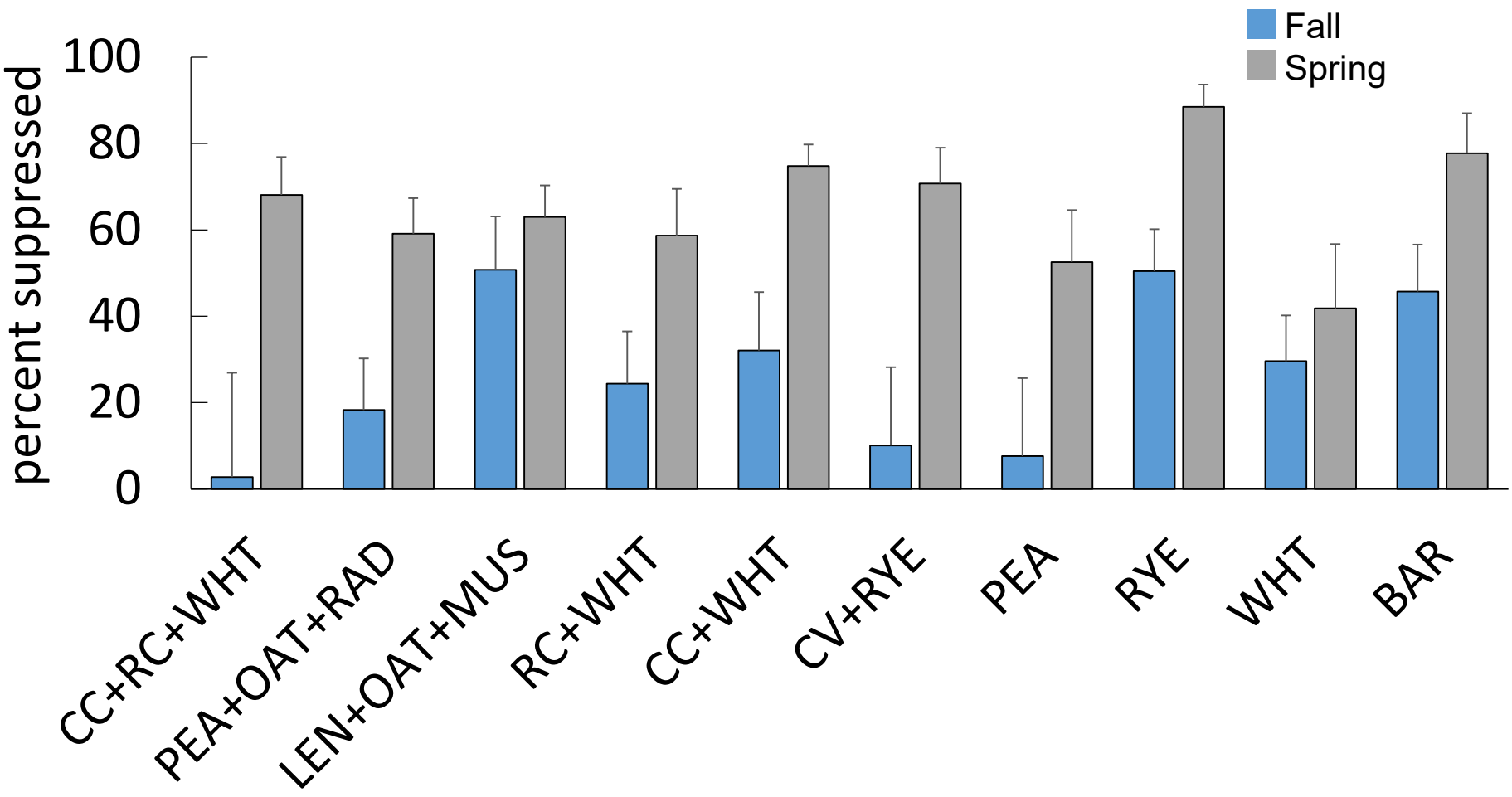
Biomass units are kg/ha (which is similar to lbs/ac);
Across farms, biomass ranged from 600 lbs/acre to 3550 lbs/acre

Average spring biomass (all farms)



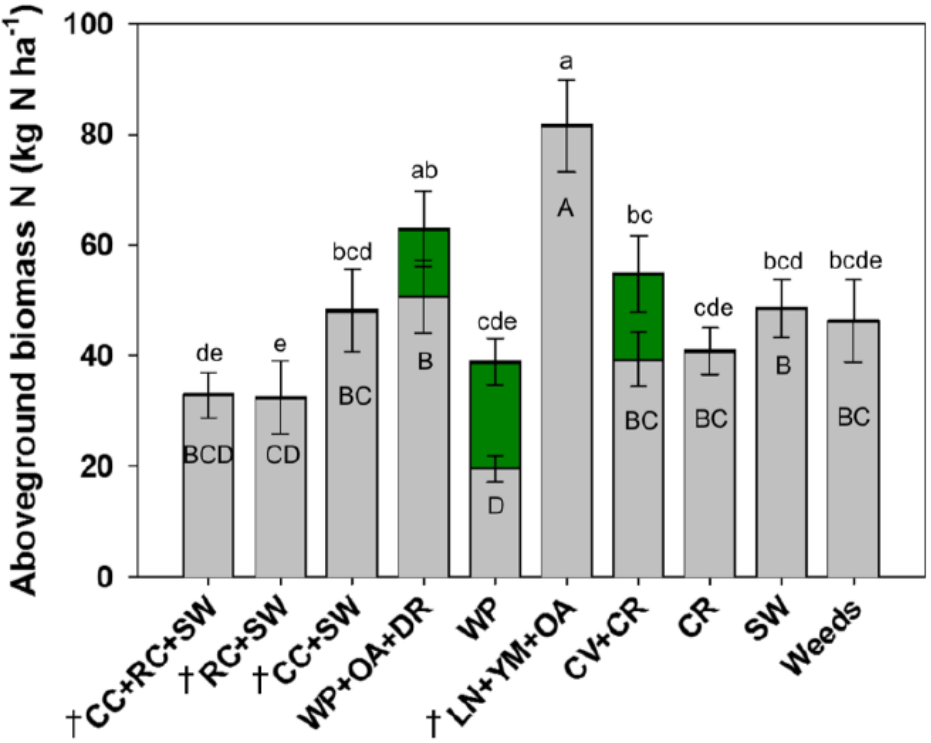
Biomass units are kg/ha (which is similar to lbs/ac);
Across farms, biomass ranged from 1000 lbs/acre to 7000 lbs/acre

Average weed suppression (all farms)

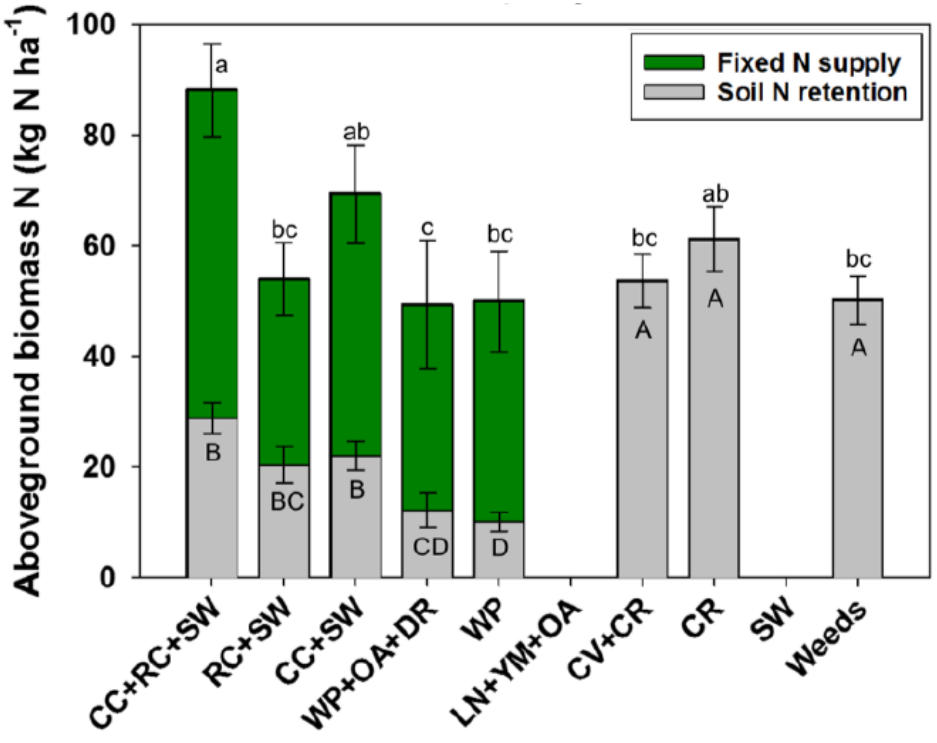


Legume N fixation (average by treatment)

Fall

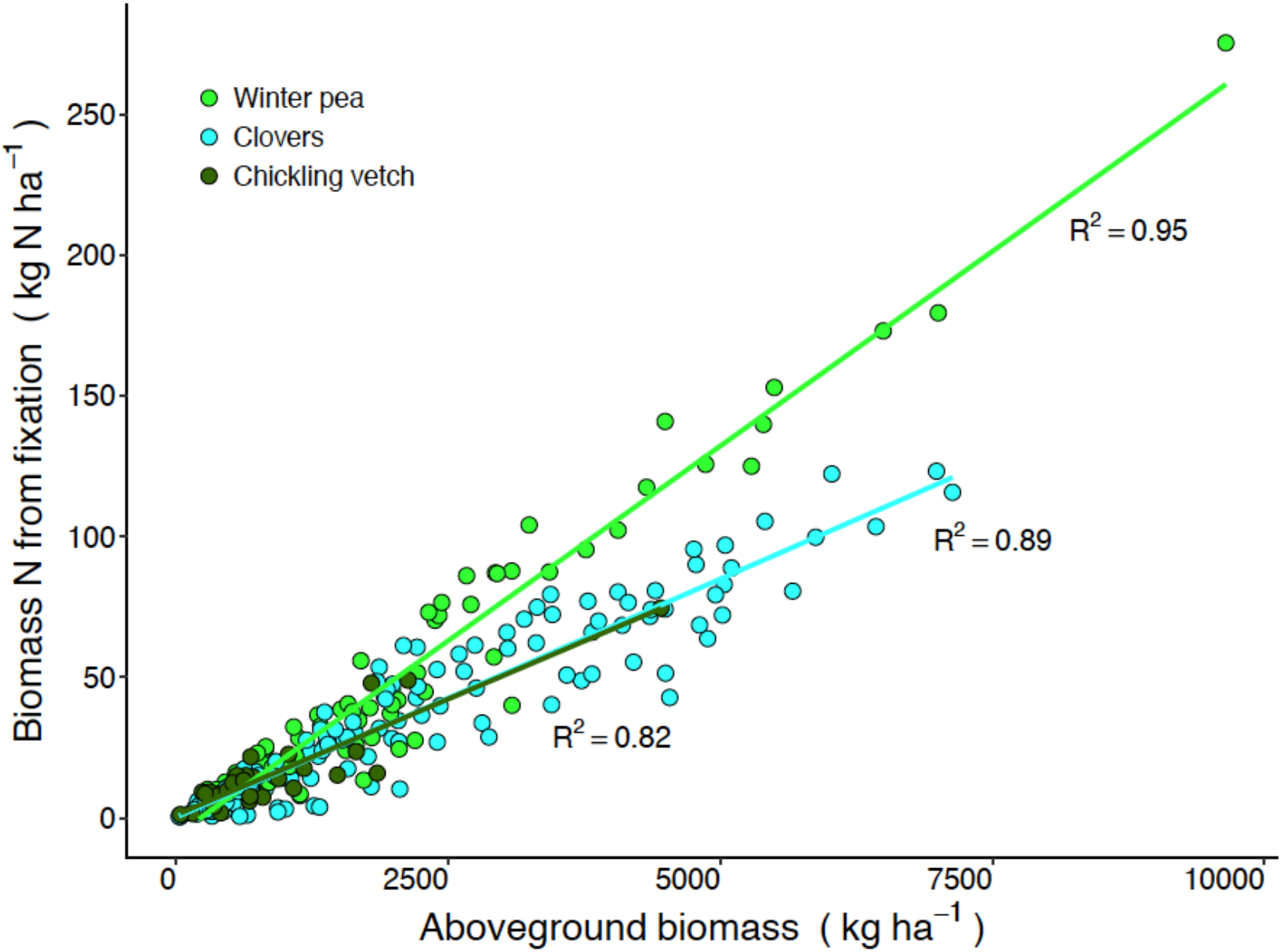


Spring



Treatments with different letters are significantly different (for N from fixation; green part of the bar)

Variation in N fixation across farms



What explained this variability?

- Winter pea and crimson clover biomass was higher in soils with lower N availability from SOM (i.e., smaller active OM pools)
  - Because the process of N fixation takes energy
  - N fixation was also higher in sandier soils
- Legume biomass increased with plant-available P
- Grasses were also positively correlated with P, and with higher N concentration in soil

Summary: key findings from the cover crop mixture trial

- Cereal rye performed the best in terms of weed suppression and soil N scavenging
- No clear benefit of mixes for weed suppression, but several mixes were not different from rye
- Overwintering cover crops (with more biomass) provided more overall benefits to farms
- Rye cannot supply a NEW source of N (it recycles soil N), whereas legumes can fix N
- N fixation rates were consistently higher in mixtures, and there was some transfer of new N to other species in the mix→ N supply and N retention
- If your primary goal is N fertility, then maximize the legume biomass
- Results variable across years and farms

Considerations for on-farm research

- Places logistical demands on both farmers and researchers
- Takes some compromise
- More realistic/more variable than research on experiment stations
- Important to control for as many variables as possible
- Findings can be more exciting because they reflect the real-world: more relevant to policy and management

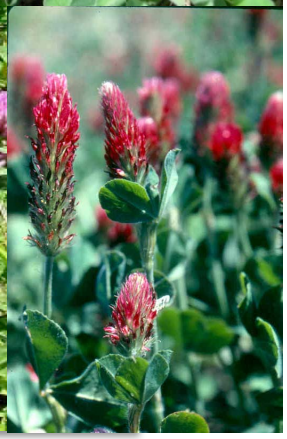
Take away points

Rye – Vetch Mixture

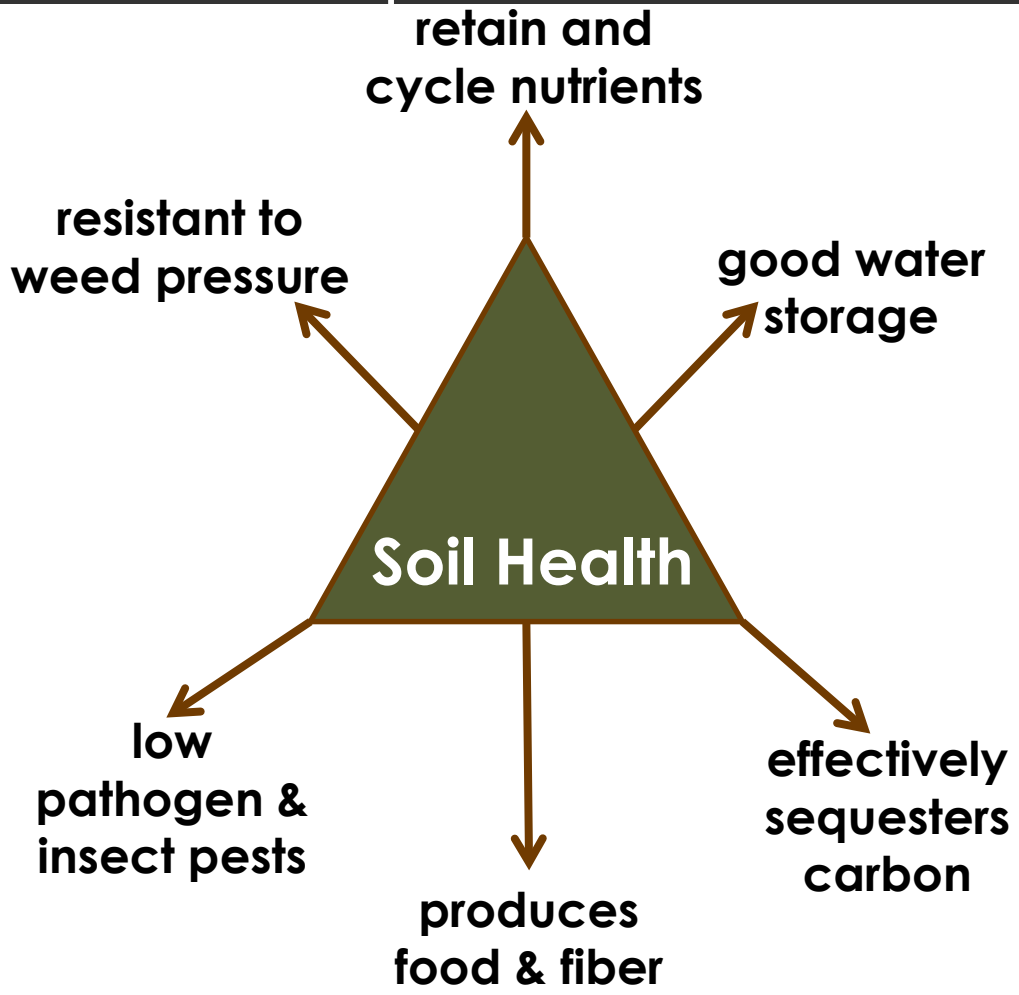
- If your primary goal is N fertility, then you should maximize legume biomass
- You can estimate N inputs from legumes on your farm to reduce uncertainty in N supply
- Inoculation is usually a good idea; actively-fixing nodules is your goal
- Mixtures can reduce some of the trade-offs of legume covers and provide multiple benefits at once on farms

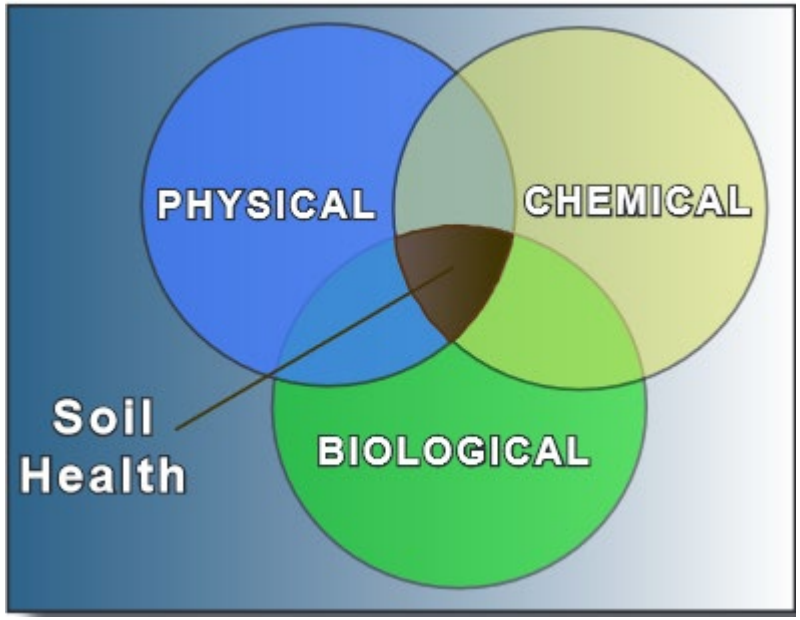
Photo credit: Danielle Treadwell, University of Florida.

Questions/Discussion



Back to the farms: How did the cover crops affect the soil?



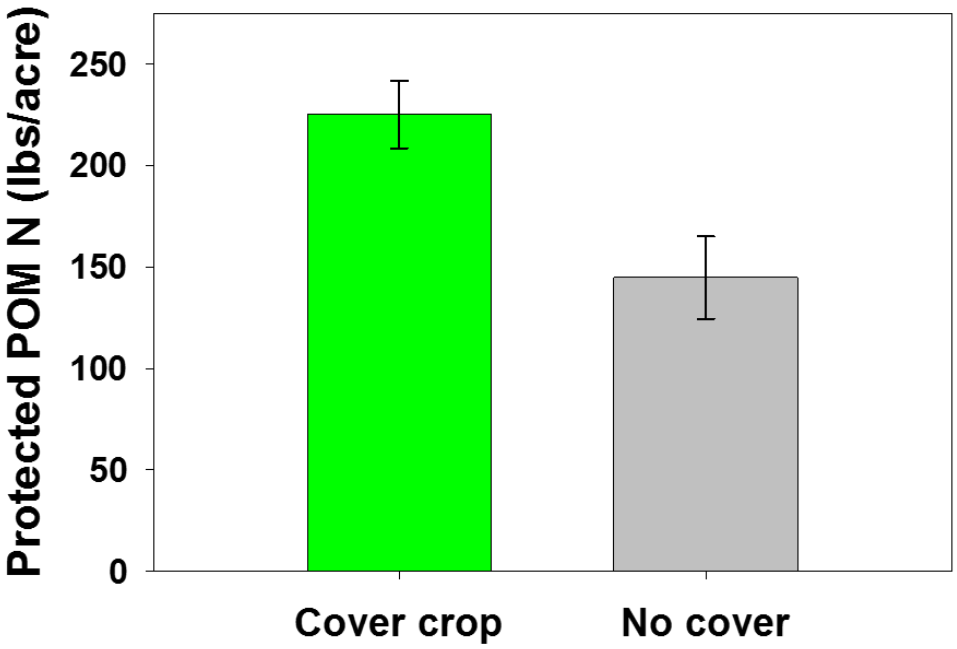


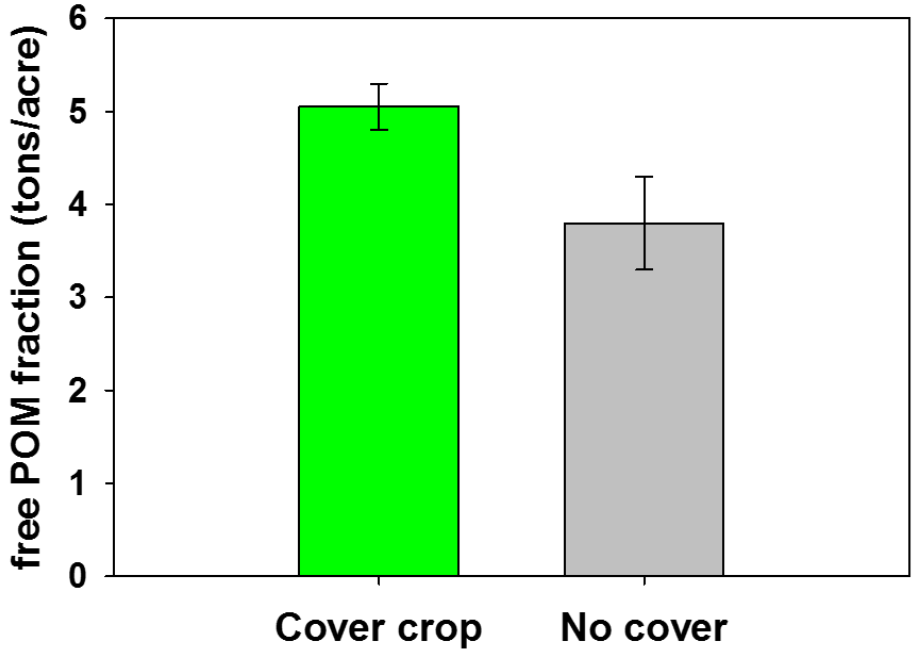
Courtesy of Cornell soil health manual

"Active SOM": Particulate organic matter

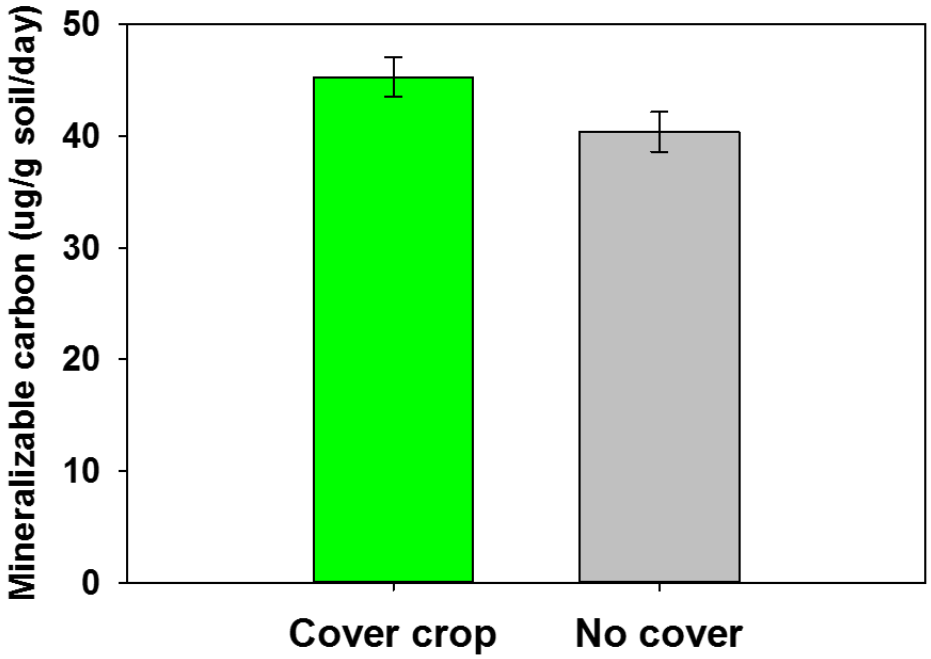
- Density fractionation
- Collect floating material (free POM)
- Size fractionation
- Obtain physically protected material (intra-aggregate POM)
- Weigh and analyze for C and N

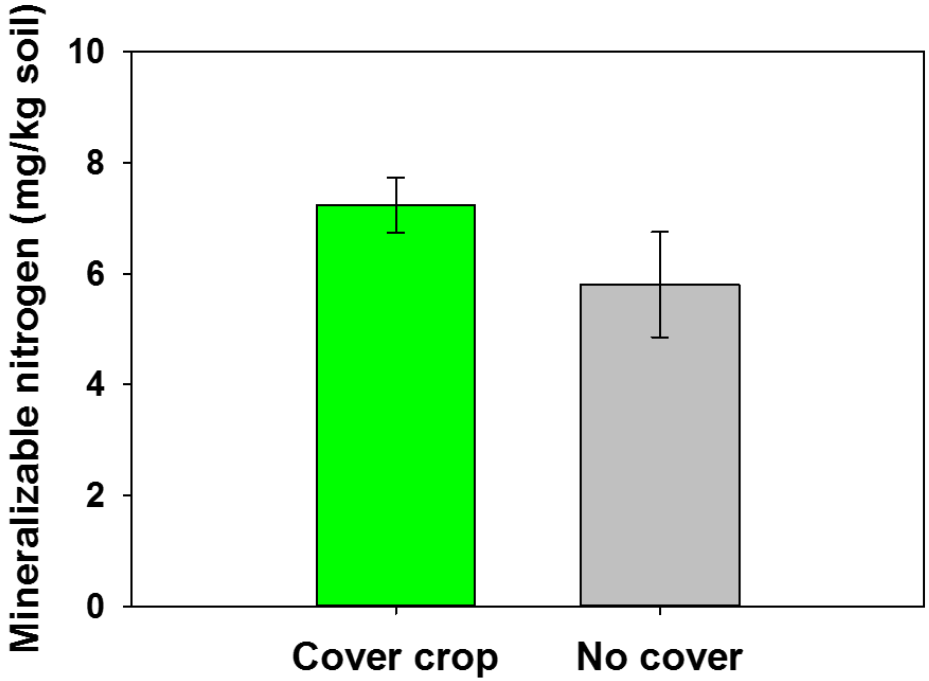
POM increased on farms with cover



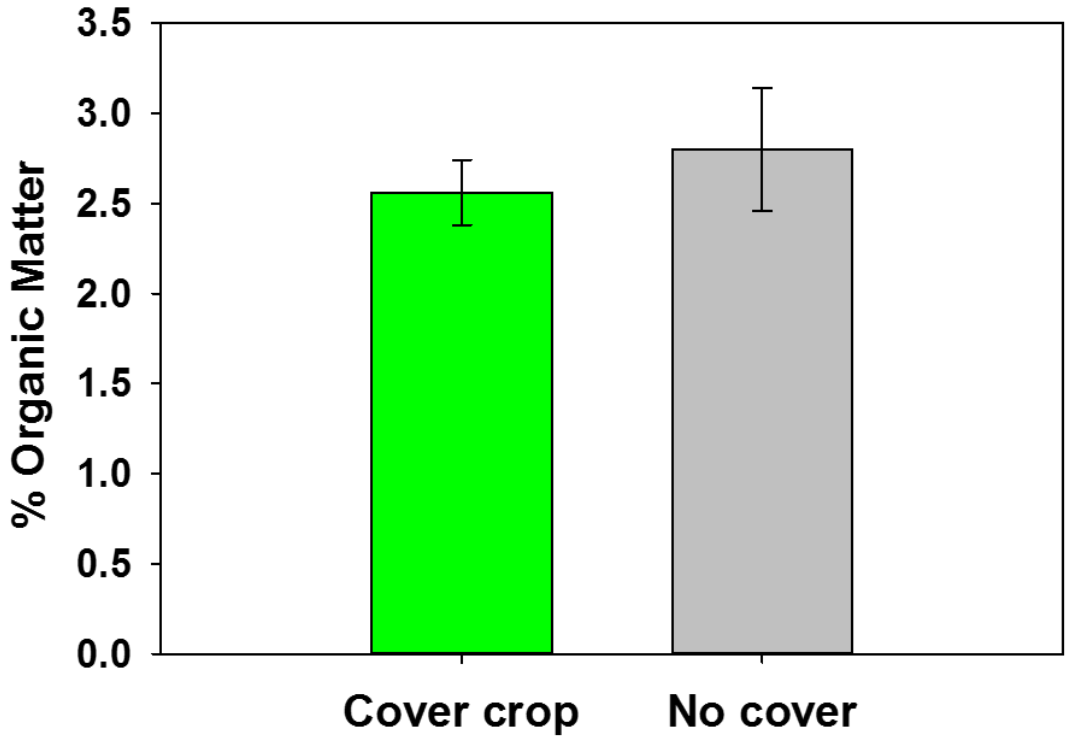


So did other biological indicators of soil health…

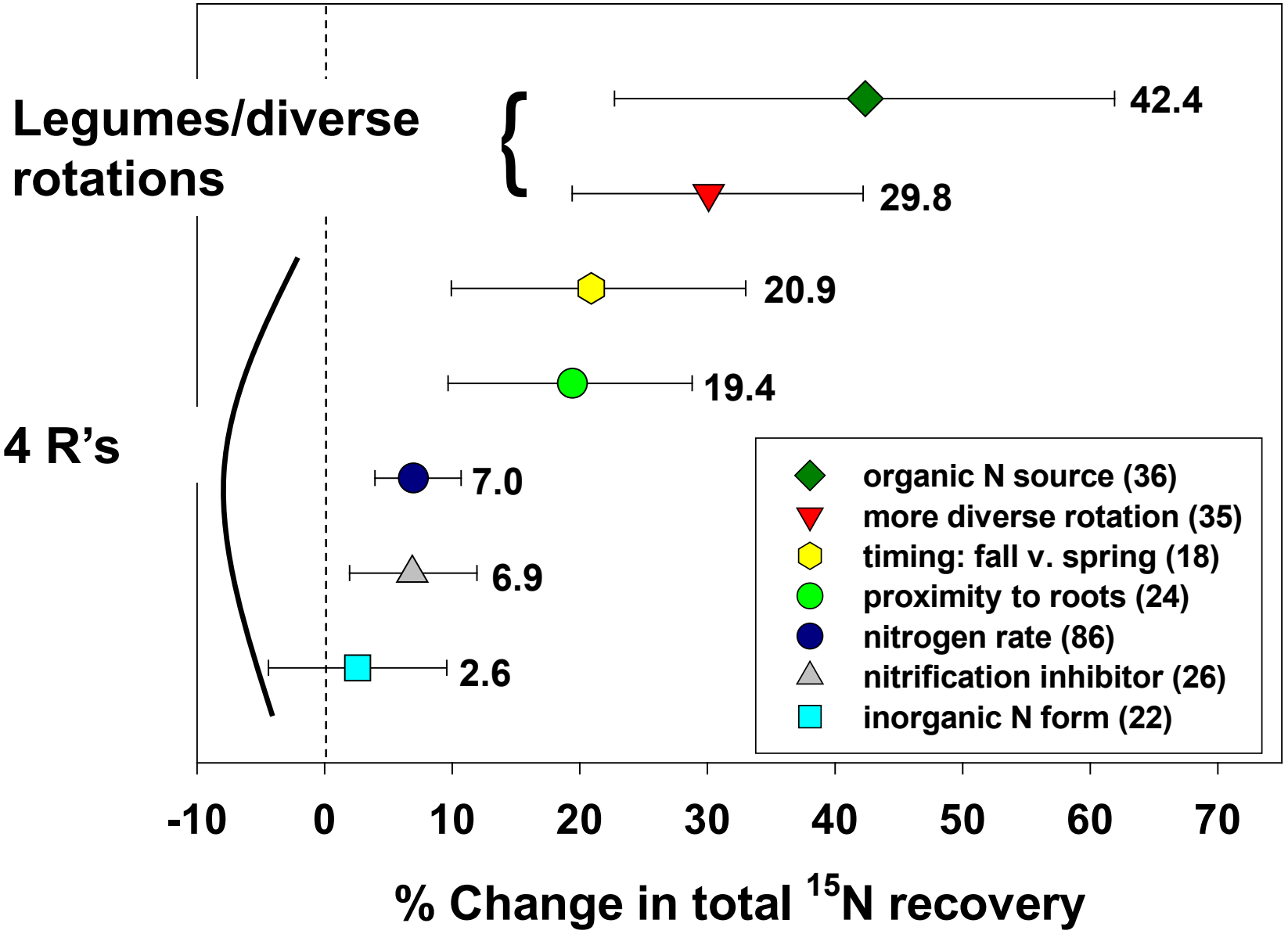




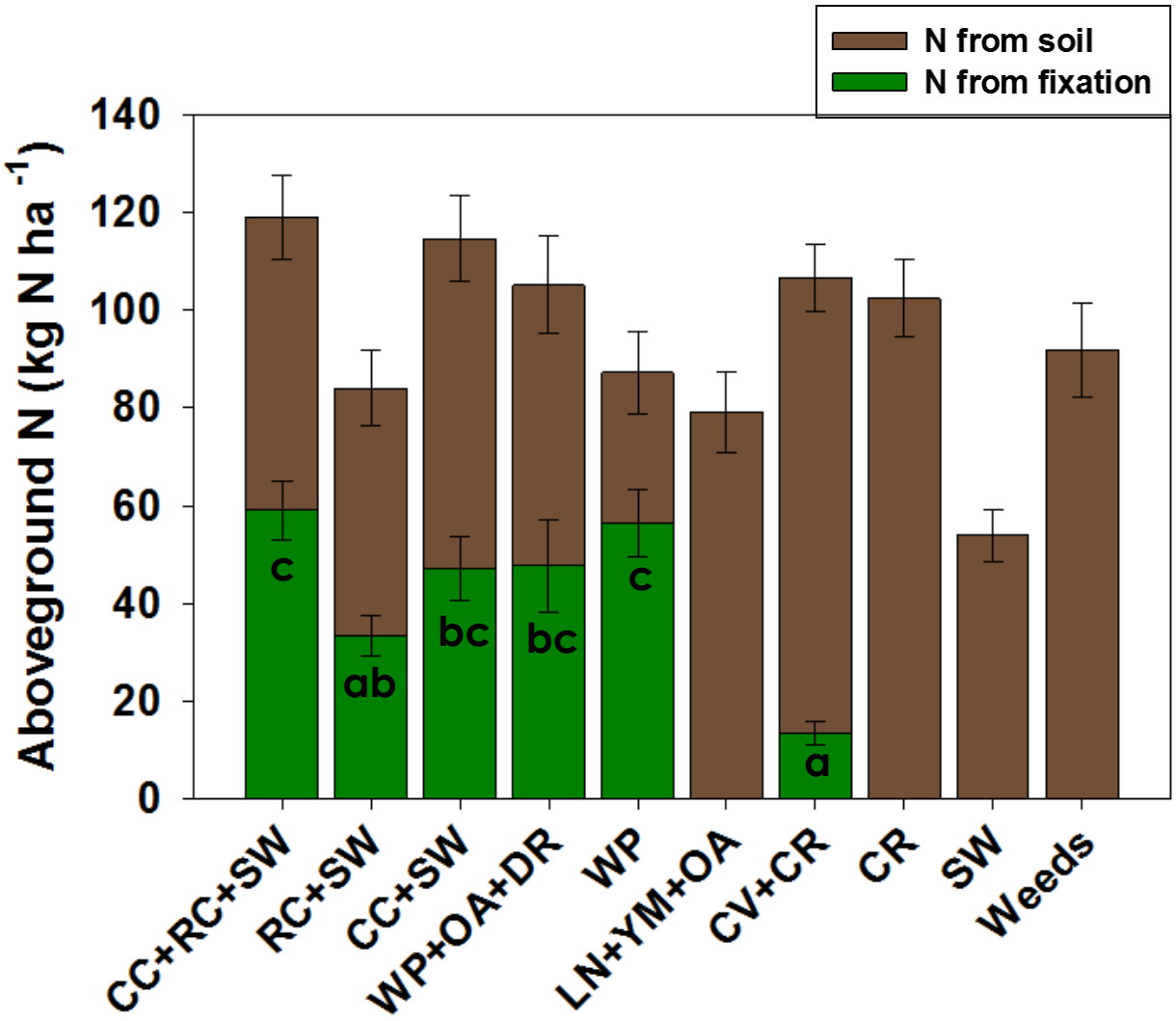
Total OM did not change



More N from legumes remains in soil than N from inorganic fertilizer



Fall + Spring biomass N and N supply from legume N fixation



Ecology of intercropping/mixtures

<u>"Complementarity" reduces competition and can increase total yield compared to monoculture</u>

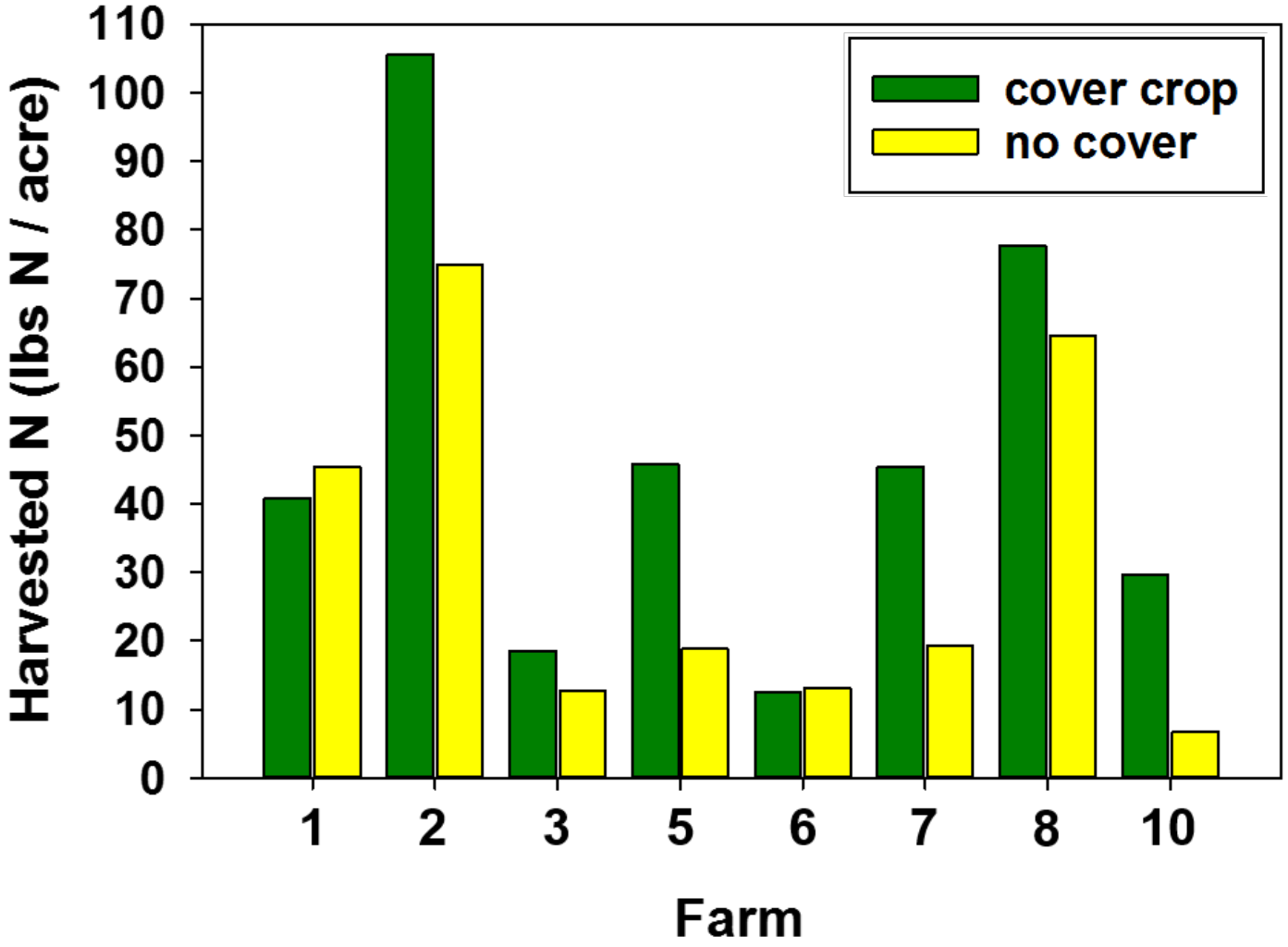
Niche differentiation: Plant species use different resources (e.g., water, light, nutrients)

Facilitation: One species improves the growth or survival of another species by improving its environment

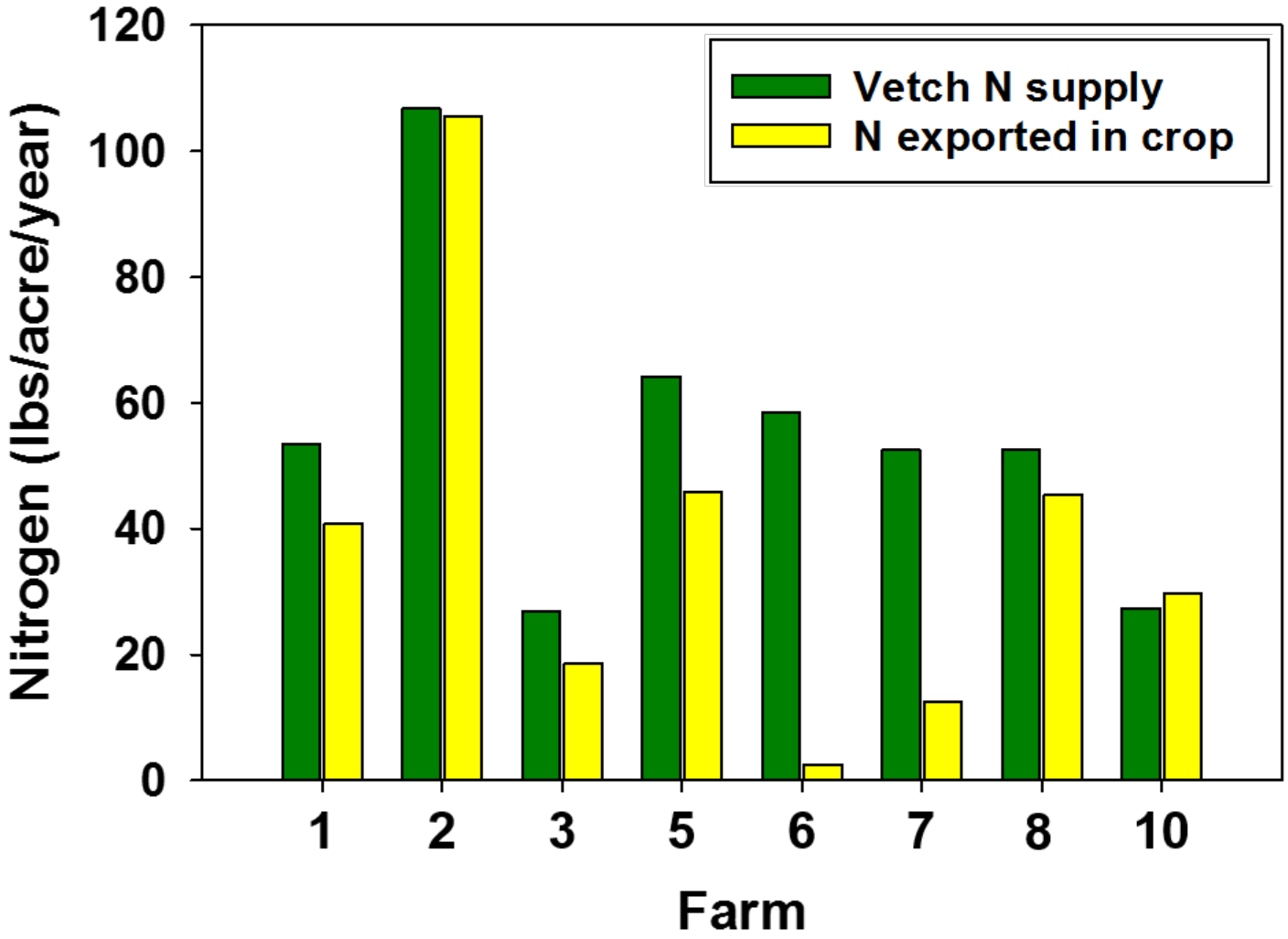
Biology is not only about competition!

Farmer meeting 2018

Harvested N greater following cover crop on most farms



N budget: Vetch N supply vs. harvested N



Fall + Spring aboveground biomass