*Photo: Scott Smith*

*Photo: Steve Spence*

# COVER CROPS AND SOIL HEALTH


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# Overview

- Soil Health overview
- Montana and Big Horn County
- Study 1: The Power of Peas
- Study 2: Cocktails Plot Study
- Study 3: Cocktails Farm Study
- Study 4: Long Term Study
- Conclusions and Resources

# The Summerfallow Challenge

*Photo: Susan Tallman*

PROS:
Soil moisture recharge
N benefit

CONS:
Loss of organic matter
Increased soil erosion
Decreased soil structure
Decreased water holding capacity
Increased saline seeps
Increased N leaching
Decreased soil biological activity

# Soil Quality vs Soil Health

Soil Quality

- Texture
- pH
- CEC

Soil Health

- Aggregation
- Microbial activity
- Tilth
- Nutrient availability
- Water holding capacity
- Compaction

# Increased Organic Matter = Healthier Soils

- Increased nutrient and water availability
- Support greater root and plant growth
- Increased microbial activity
- Provide resilience to uncontrollable factors such as weather and markets
- Problem: Hard to change much because amount is so large (~40,000 lb/ac in upper 6”)

# No-Till and Crop Intensification

*Photo: Susan Tallman*

- ↑ Soil aggregation
- ↑ Water holding capacity
- ↓ Erosion

## Legume Green Manure (LGM)

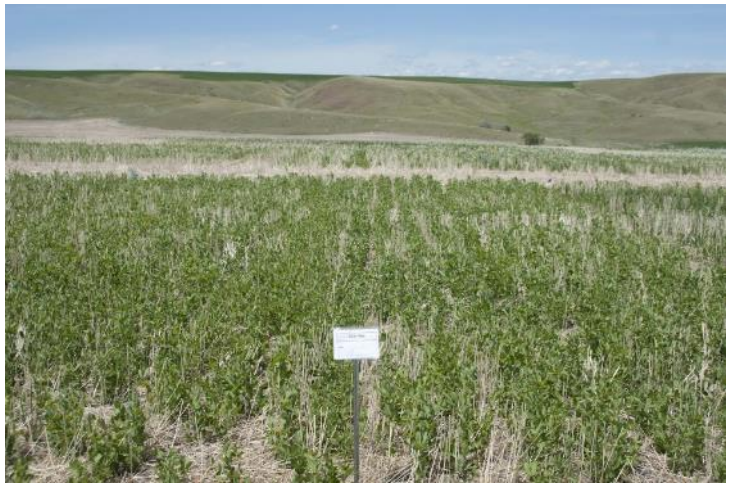


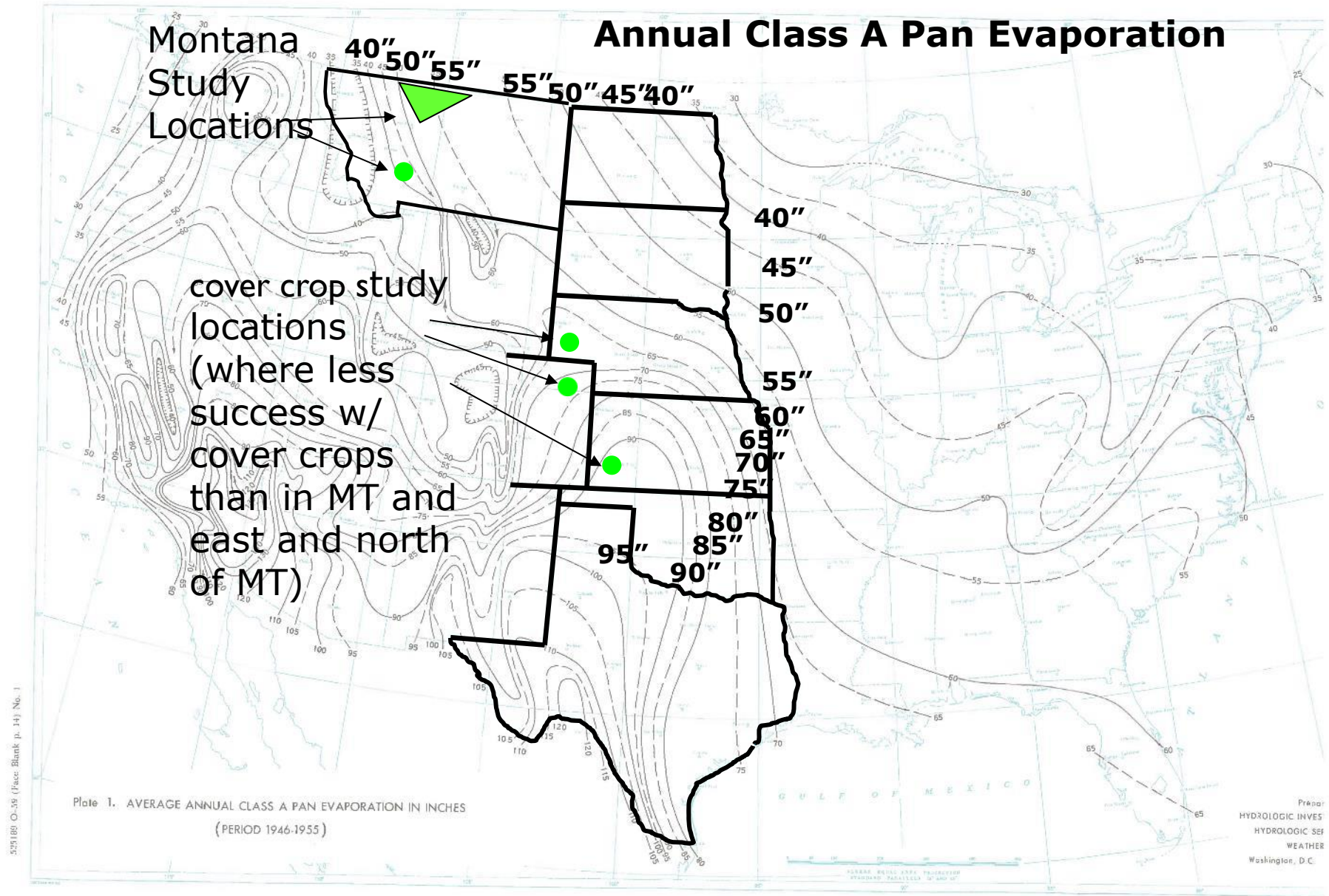
*Photo: Steve Spence*

- ↑ Organic matter
- ↑ N benefit

## Management Issues

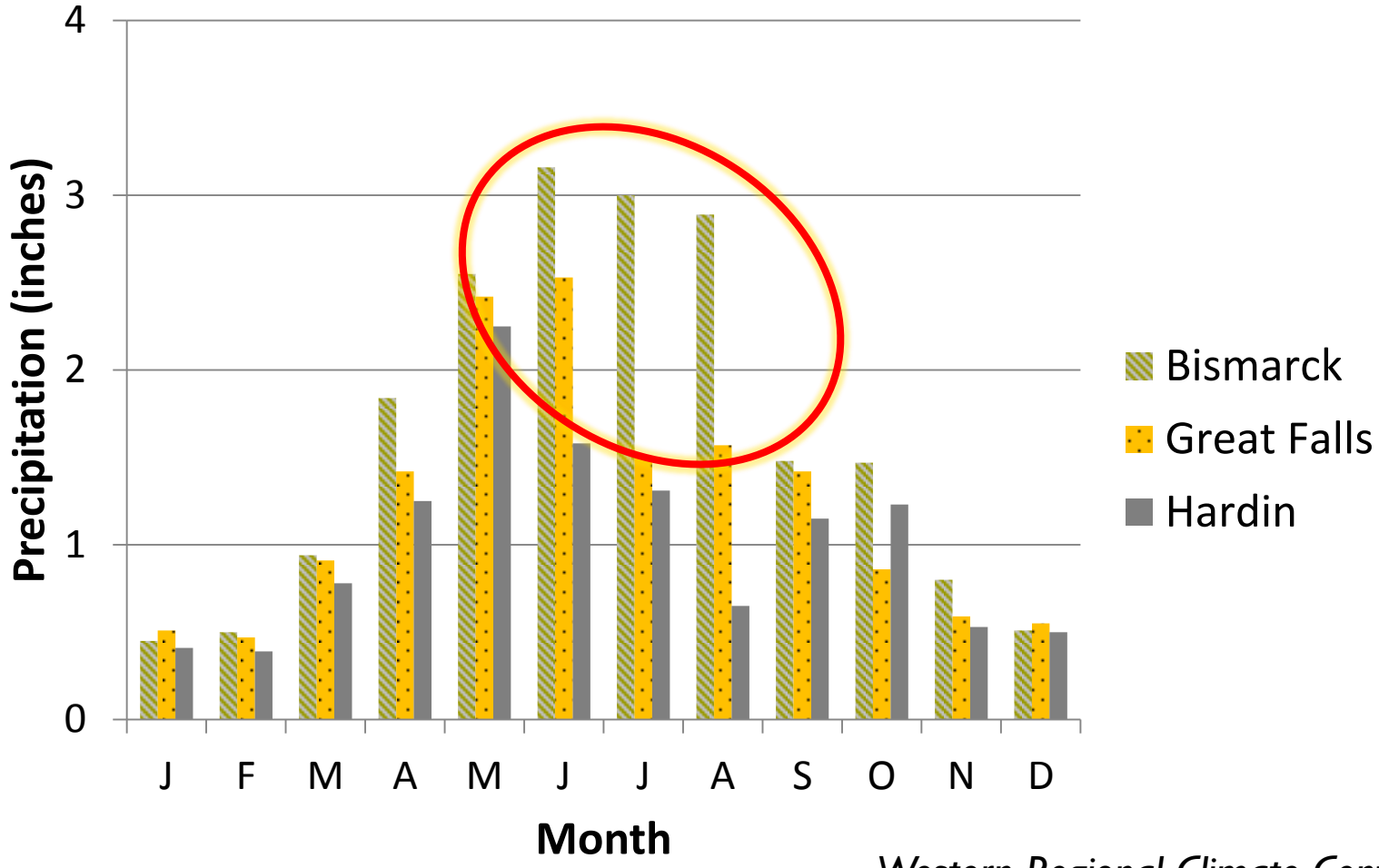
**WATER & N**

**TIME**




Provided by David Nielsen

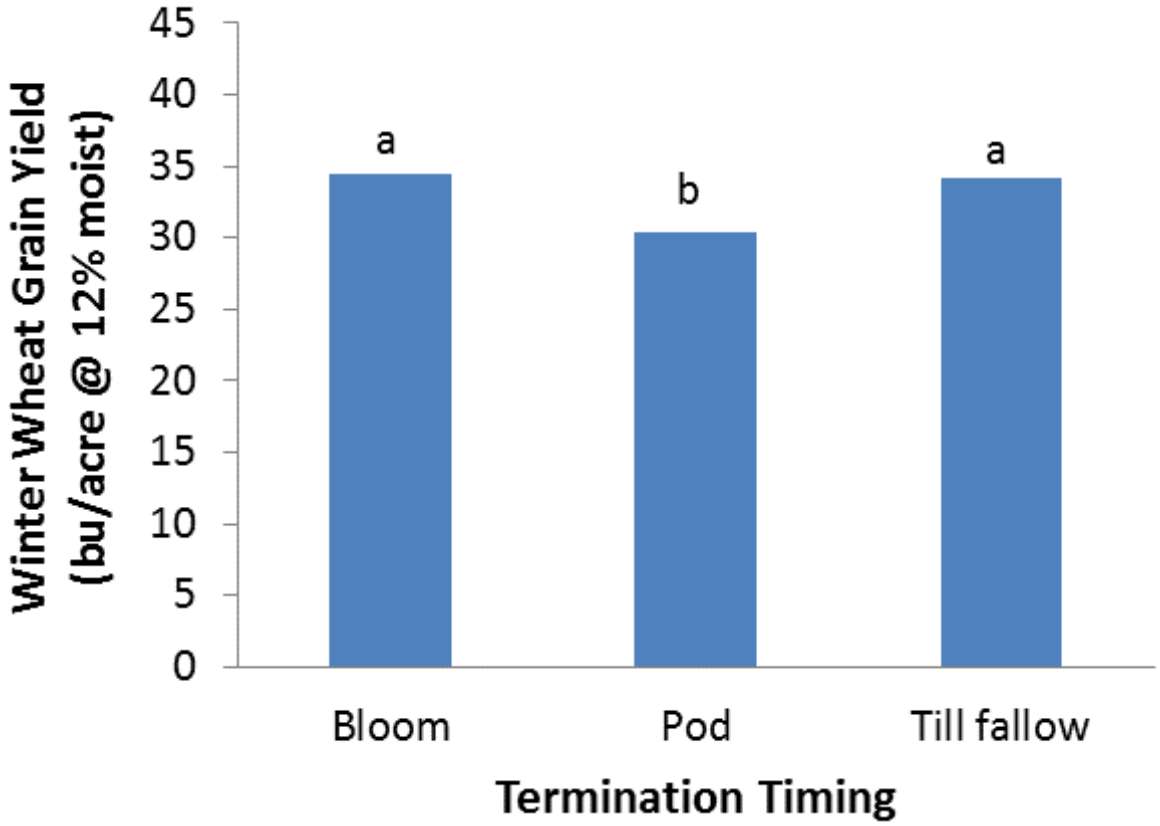
# Precipitation;1981-2010




*Western Regional Climate Center*
*High Plains Regional Climate Center*

# Our MT studies confirmed early Saskatchewan studies that termination timing is key

Terminating legume cover crop at early bloom produced higher organic wheat yields the following year than terminating at flat pod in 2006-2007 (Miller et al. 2011)




Similar results for advantage of bloom over pod in conventional systems

# Study 1: Three 2-year cycles, no-till and till, plot scale

- Objective: Determine effects of legume species and tillage on subsequent spring wheat.
- ~14 inch annual precip. (Gallatin Valley, MT)
- Field had been no-till for several years

# Study 1: Design

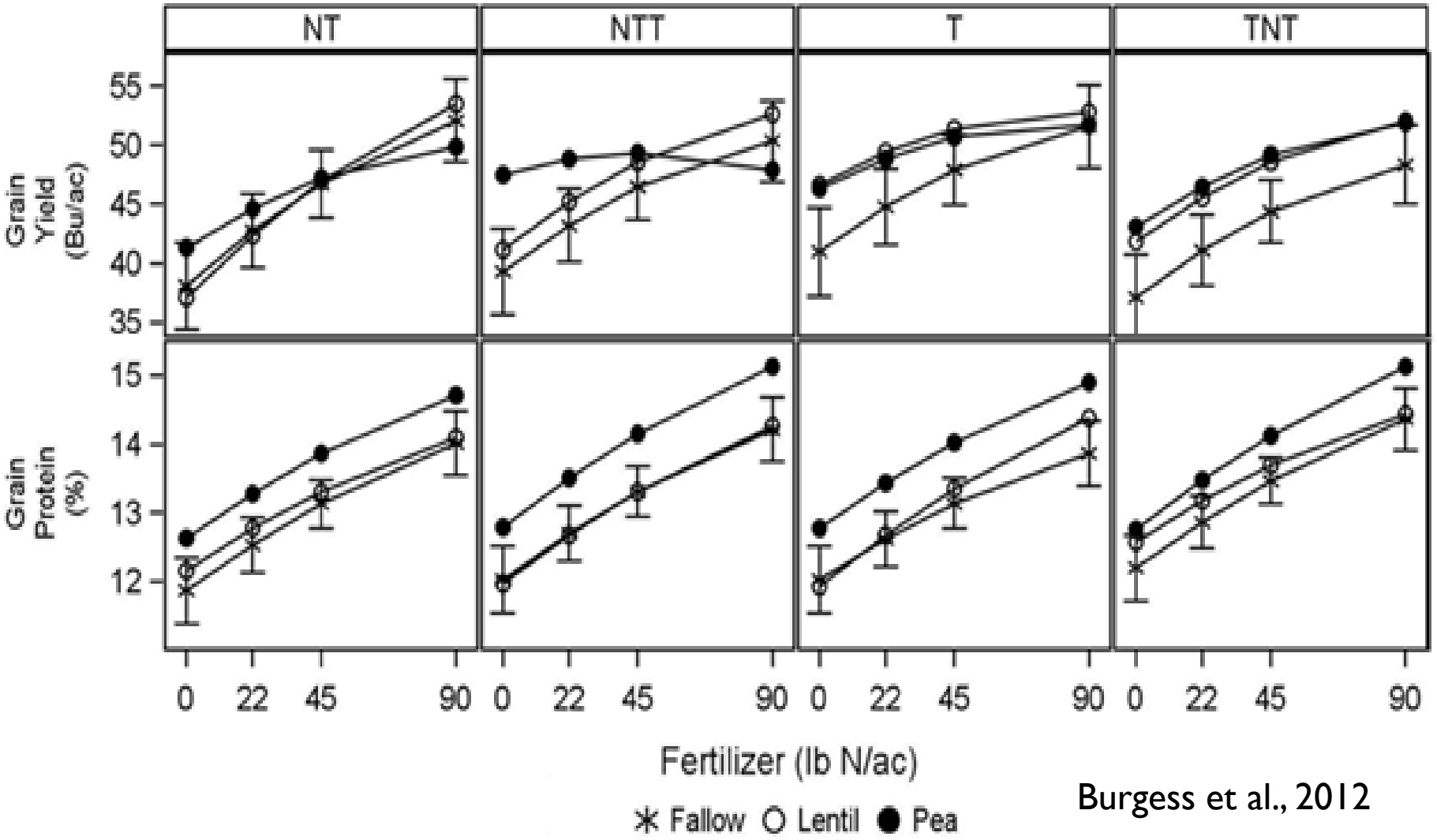
**3 Crop Treatments** X **4 Tillage Treatments**

- Spring Pea Manure
- Spring Lentil Manure
- Fallow

- No-Till (NT)
- No-Till, Till (NTT)
- Till (T)
- Till, No-Till (TNT)

- Green manures terminated at first flower
- Spring wheat planted at 4 N rates following year

# Study 1: (3-year plot scale) Results




Burgess et al., 2012

# Study 1: Take home messages

- Early-terminated spring cover crops did not hurt subsequent grain yield or protein compared to fallow.
- Higher N fixation by pea often produced higher subsequent spring wheat yield and/or protein than lentil especially in no-till at low N rates.

# QUESTIONS?

# Study 2: Cover Crop Cocktails Plot Study Objectives

1. Compare agronomic response variables of fallow, pea LGM, and multi-species cocktails

   Biomass
   Biomass quality
   Soil water and nitrate
   Wheat yield

2. Compare select soil biology parameters of fallow, pea LGM, and multi-species cocktails

   Microbial respiration rate
   Soil enzyme activity
   Soil temperature
   Potentially mineralizable nitrogen
   Mycorrhizal colonization

3. Determine the specific effects of 4 plant functional groups

# Plant Functional Groups & Species

## Nitrogen Fixers

Spring Pea
*Pisum sativum*

Common Vetch
*Vicia sativa*


Lentil
*Lens culinaris*

## Fibrous Root

Oats
*Avena sativa*

Italian Ryegrass
*Lolium multiflorum*


Proso millet
*Panicum miliaceum*

## Tap Root


Safflower
*Carthamus tinctorius*

Purple Top Turnip
*Brassica rapa*

## Brassica

Daikon radish
*Raphanus sativus*

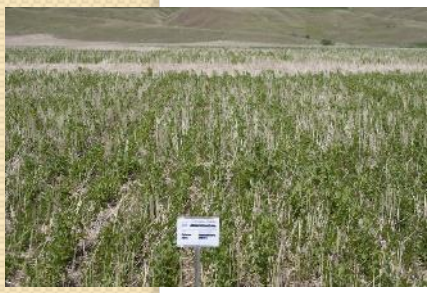
Camelina
*Camelina sativa*


Winter Canola
*Brassica napus*

Fallow

Pea

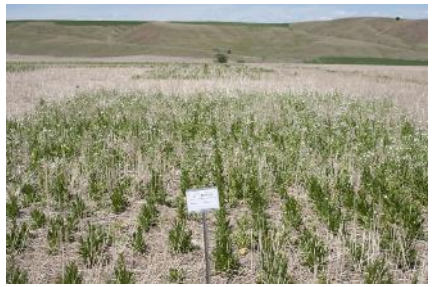
Full



Nitrogen Fixers

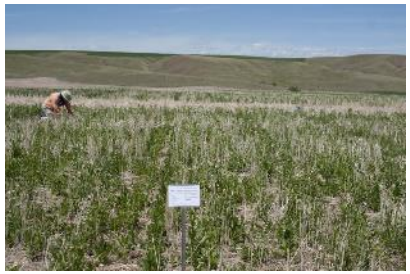
Fibrous Roots

Tap Roots



Brassicas

Minus Nitrogen Fixers



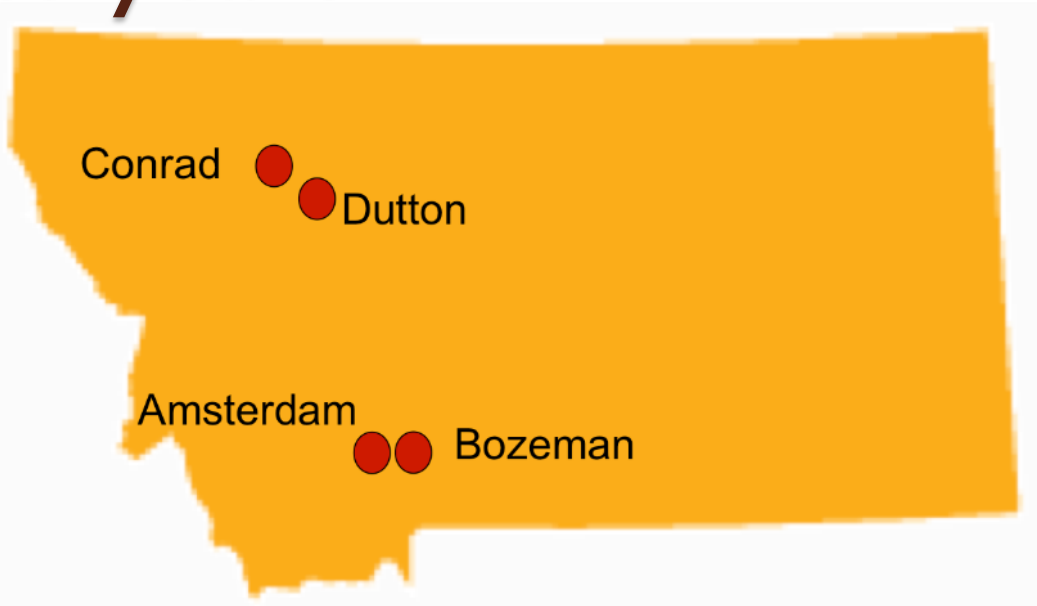
Minus Fibrous Roots

Minus Tap Roots

Minus Brassicas
*(no turnip)*

*All photos: Steve Spence; Amsterdam, 14 June 2012*

# Four Site-years




| | 2012 | 2013 | 2014 |
|---|---|---|---|
| Amsterdam | Cover crop | Spring wheat | Cover crop |
| Conrad | Cover crop | Spring wheat | Cover crop |
| Bozeman | -- | Cover crop | Spring wheat |
| Dutton | -- | Cover crop | Spring wheat |

# 2012 Cover Crop Biomass

*Photo: Steve Spence*

Amsterdam 2012

0.9 Mg $ha^{-1}$

= 0.4 ton $acre^{-1}$

*Photo: Evette Allison*

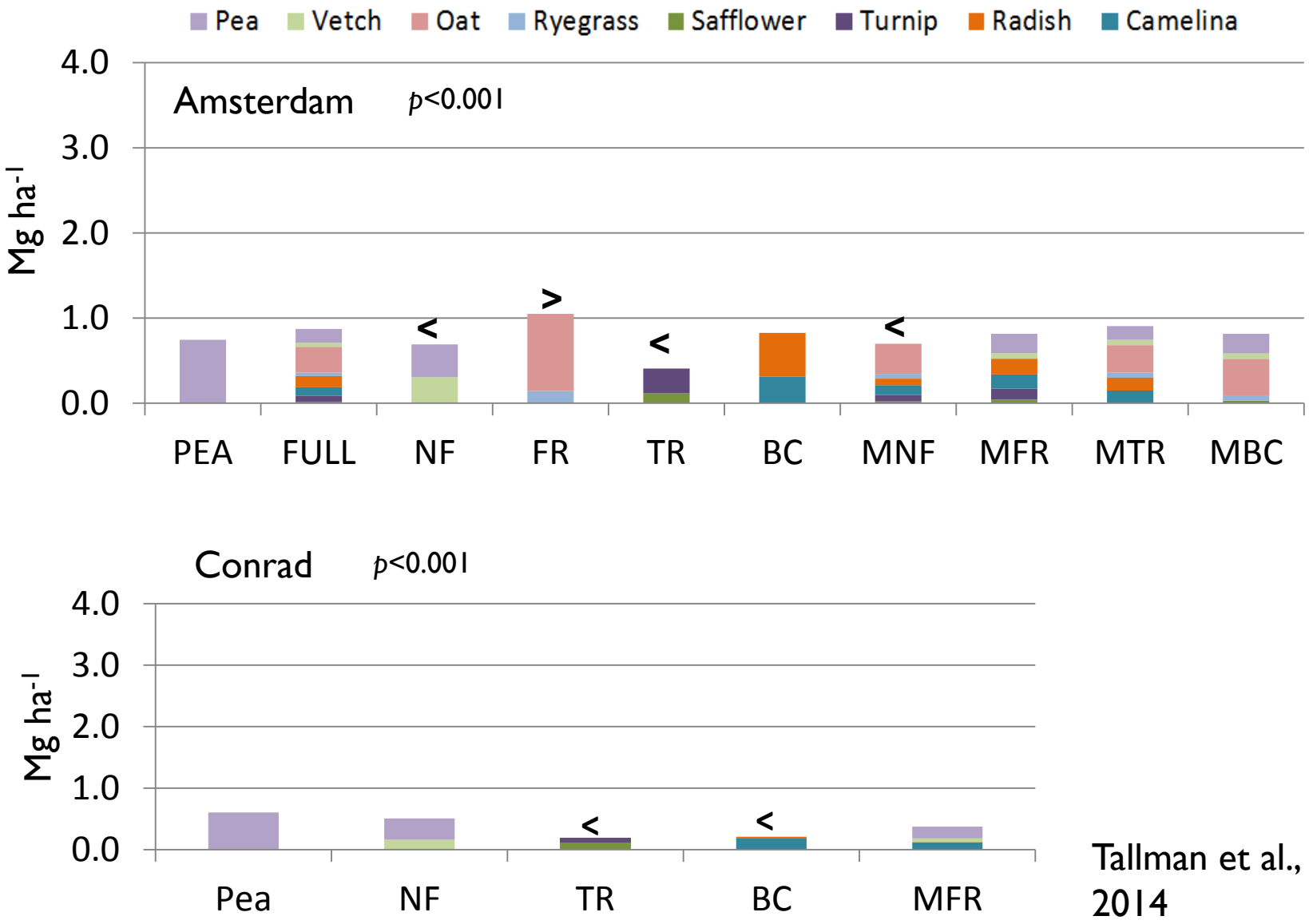
Conrad 2012

0.4 Mg $ha^{-1}$

= 0.2 ton $acre^{-1}$

*Photo: Steve Spence*

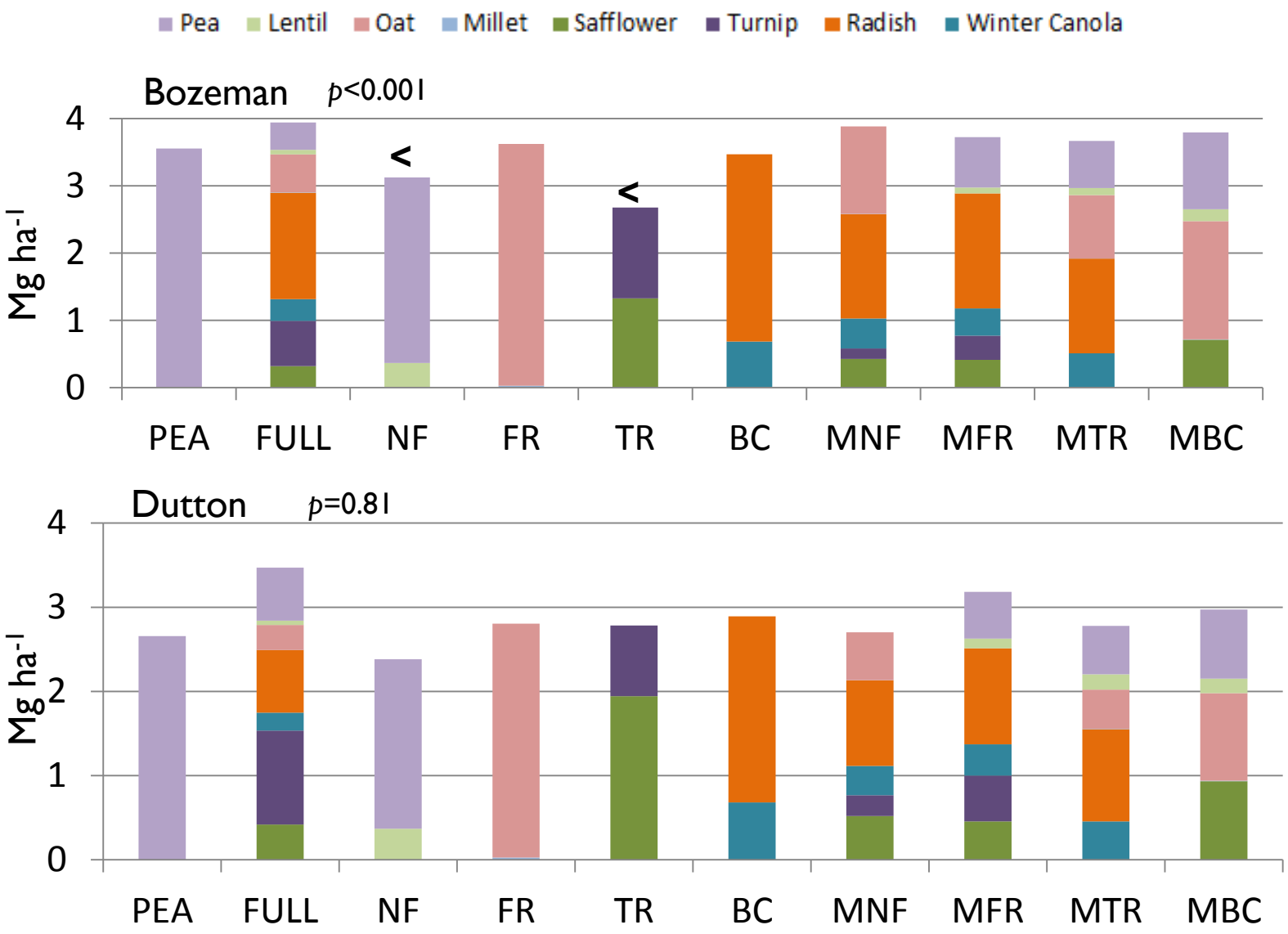
# 2012 Cover Crop Biomass




Tallman et al., 2014

# 2013 Cover Crop Biomass

# 2013 Cover Crop Biomass




Tallman et al., 2014

# Lessons Learned

*Photo: Susan Tallman*

- Early weed control is essential
- Common vetch difficult to terminate
- Camelina, Italian ryegrass, and lentil not competitive
- Radish bolts in late spring
- Millet not competitive in spring mix
- Possible biological control benefits of wheat-stem sawfly with oat and radish

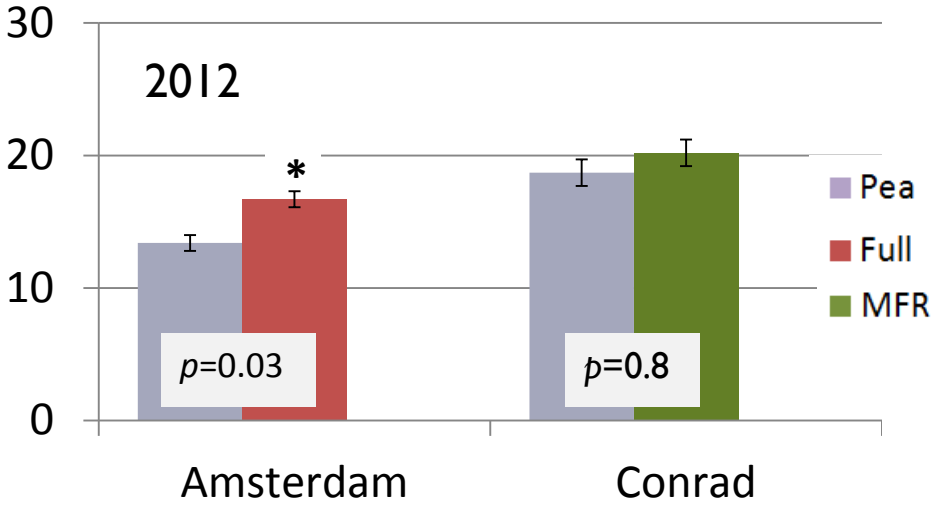
# Lessons from the Literature

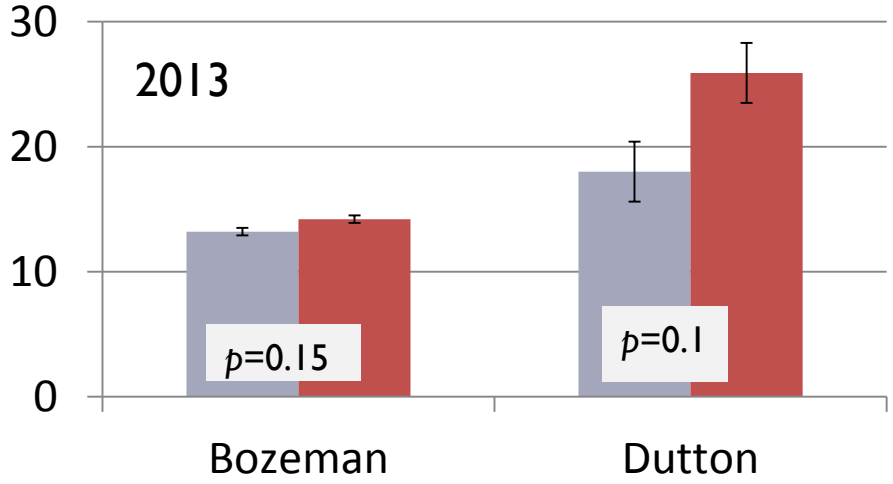
Many studies in native, perennial systems indicate a positive effect of plant diversity on total biomass.

However, over 30 studies have shown that plant species **identity** matters more than plant species **number** in driving belowground processes.

**Which plant species affect which soil processes in which ecosystems?**

# Cover Crop C:N



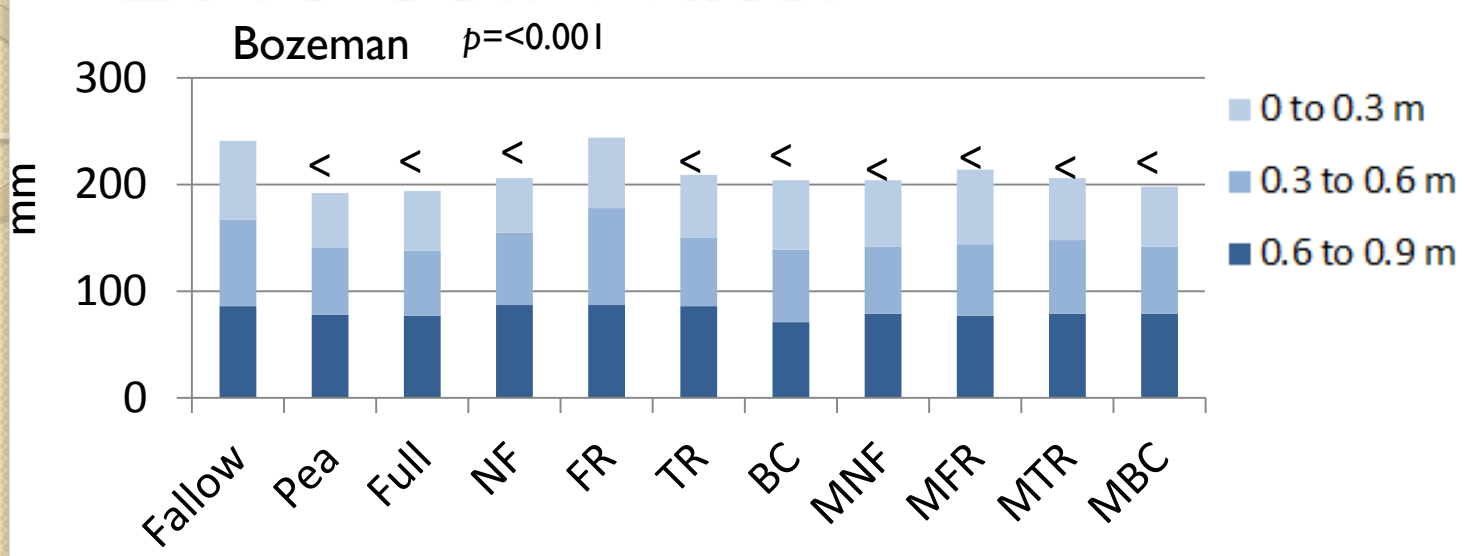



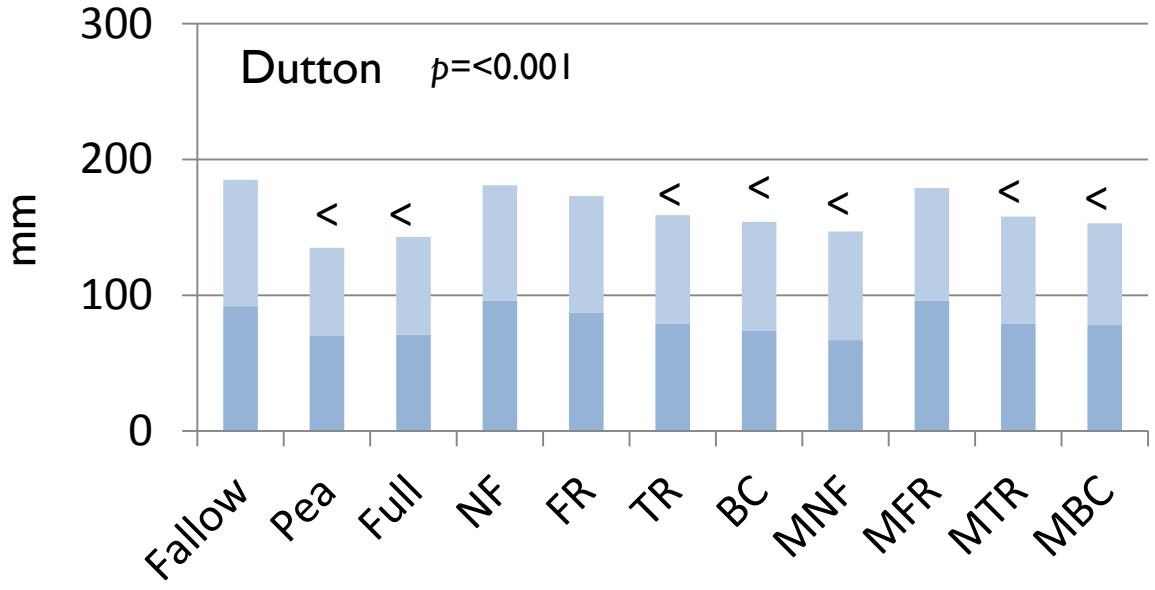

Statistically different only at one site year.

Practical significance?

Tallman et al., 2014

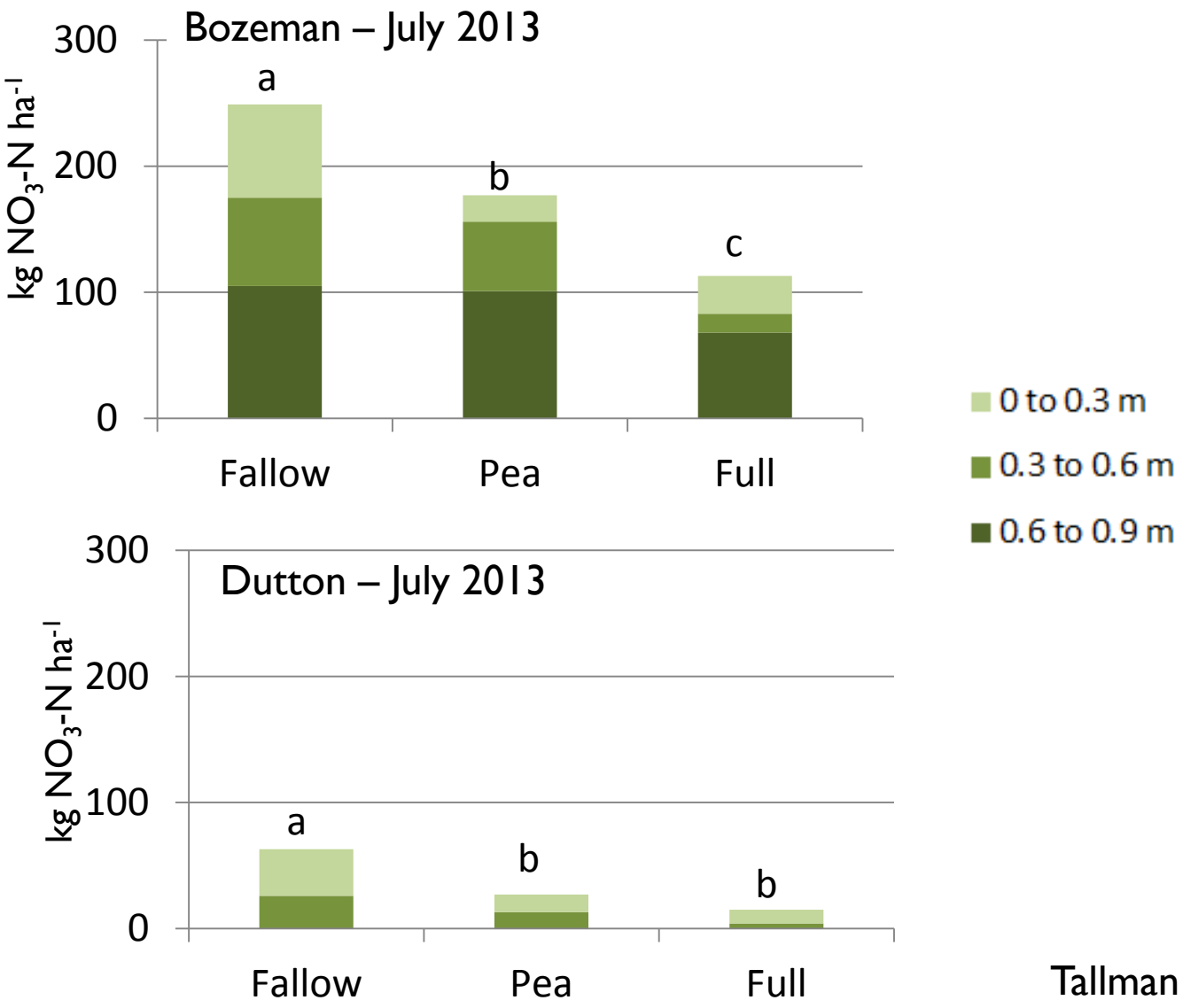
# 2013 Soil Water



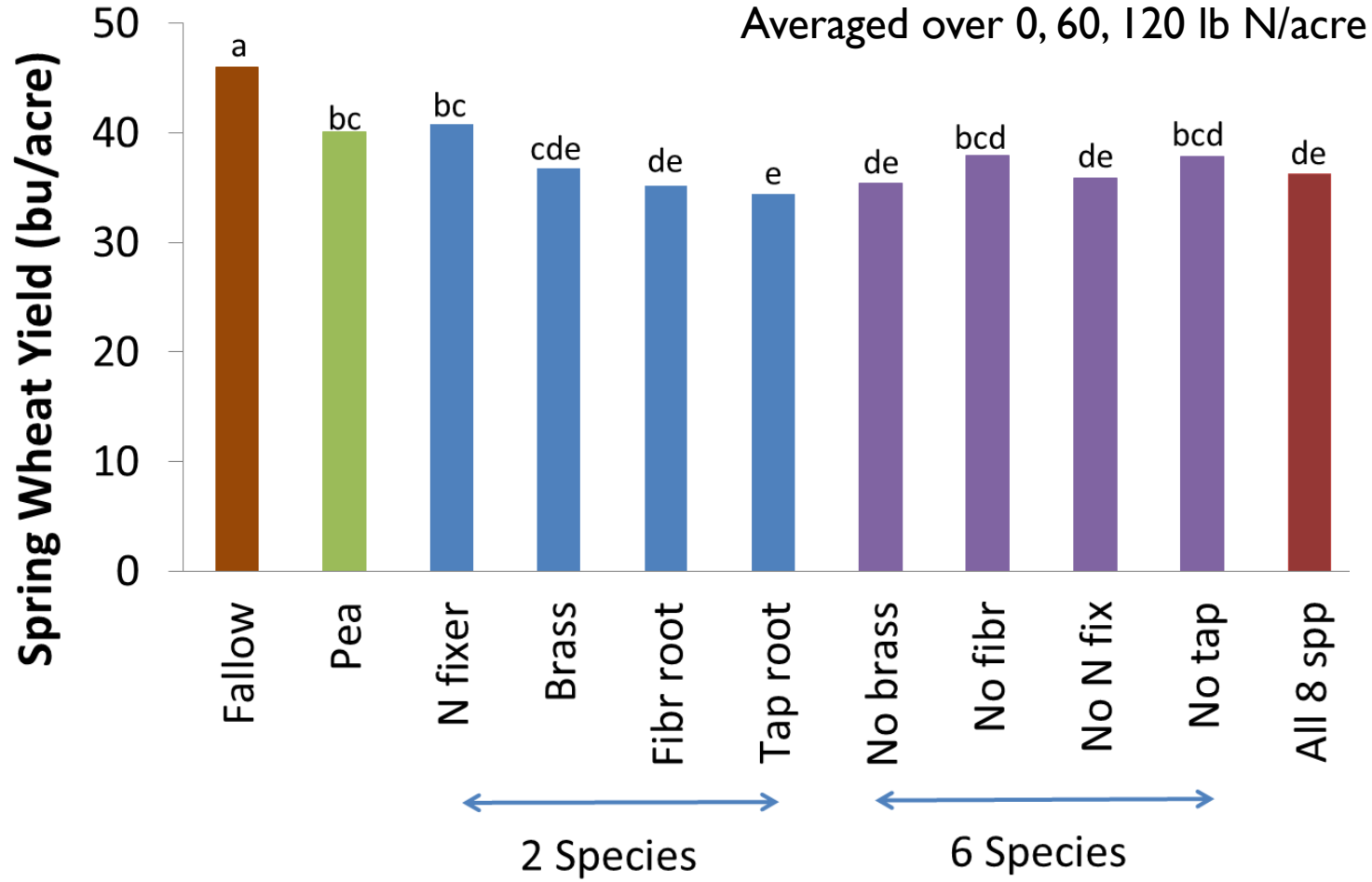

Tallman et al., 2014

# 2013 Soil Nitrate



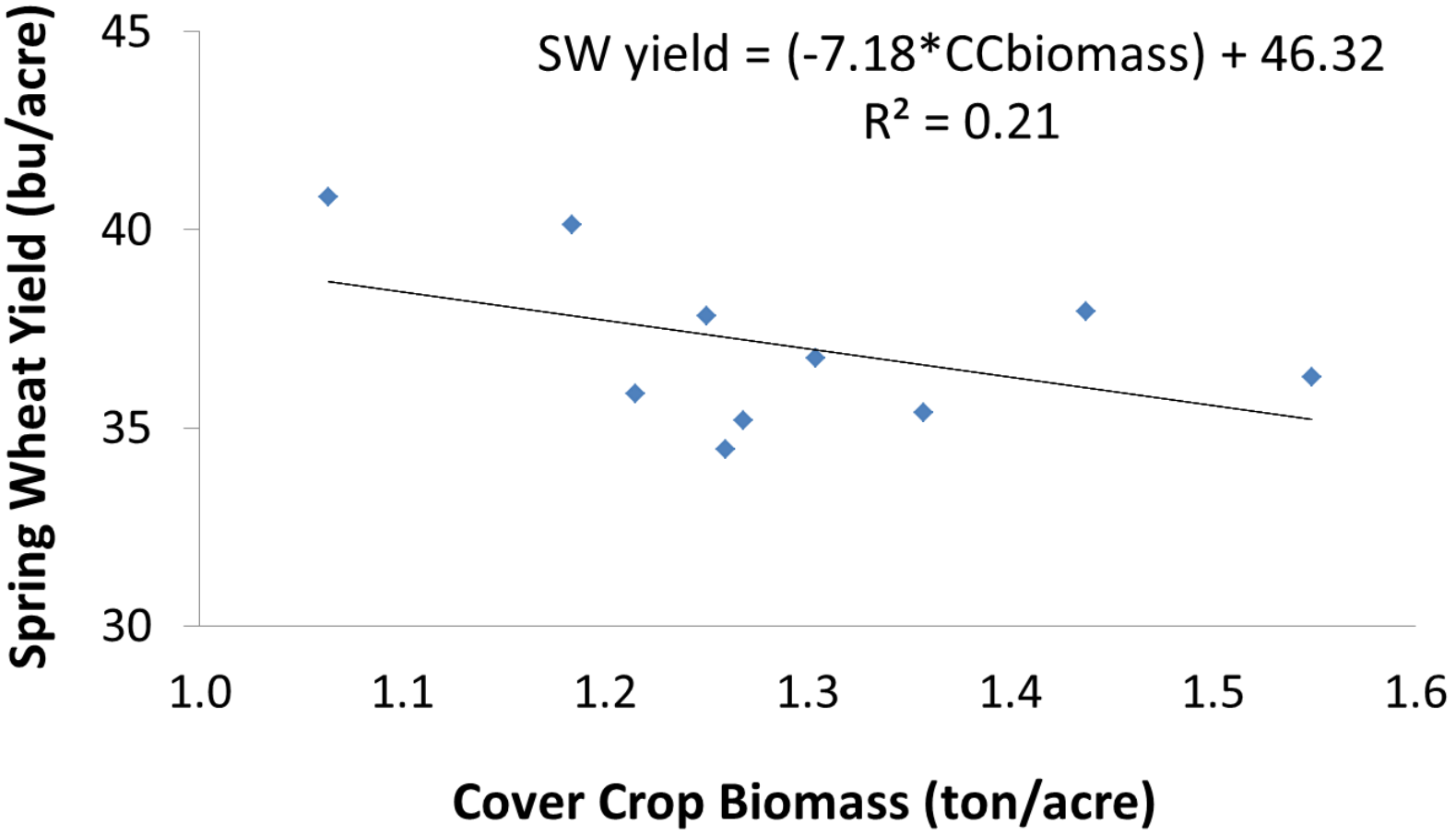

Tallman et al., 2014

# Effect of cover crop treatment on spring wheat grain yield at Dutton (2014)



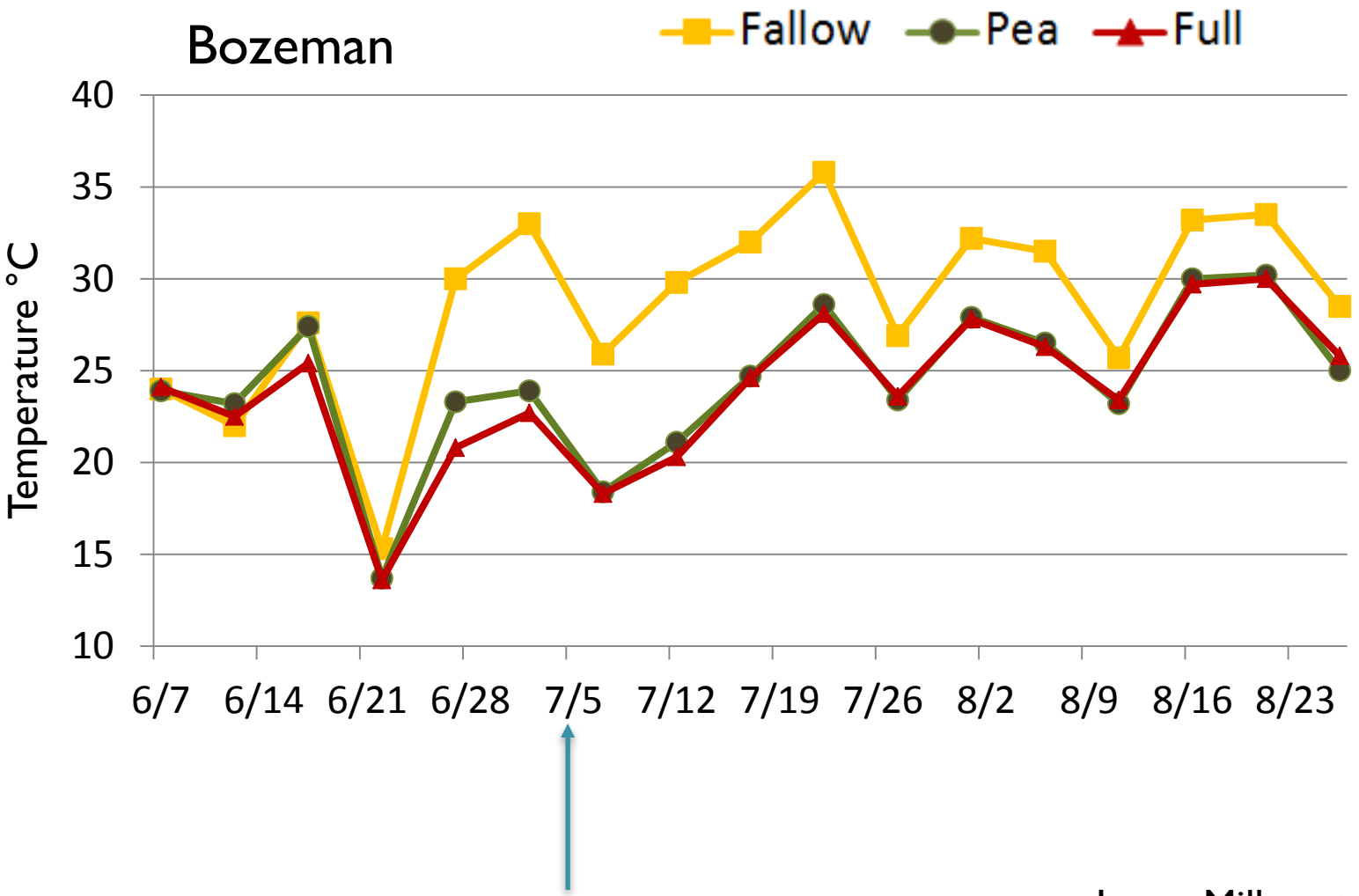

Housman et al., unpub. data, Dutton

# Spring wheat yield at Dutton vs previous year cover crop biomass




Housman, Tallman, et al., unpub data, Dutton

# 2013 Soil Temperature study

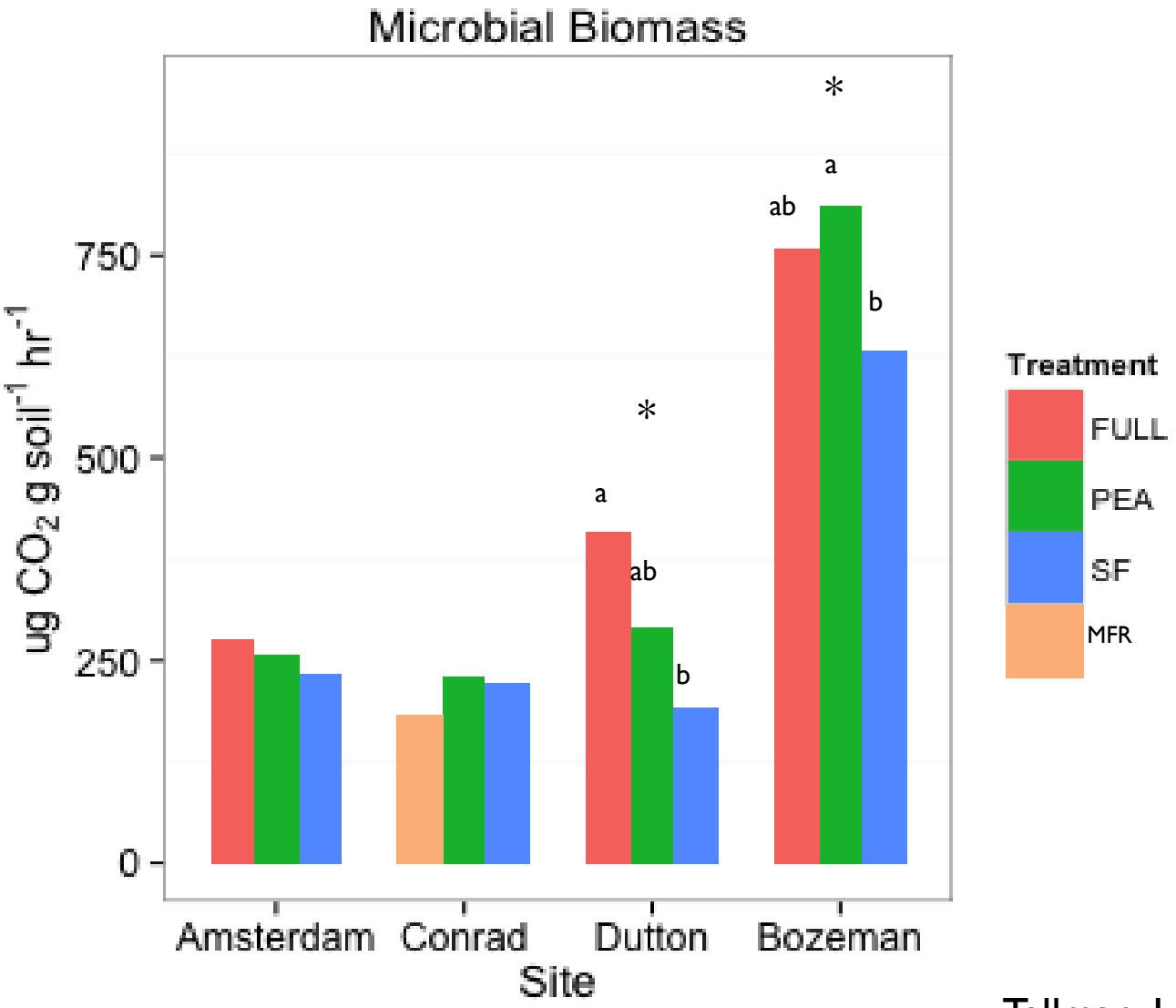



Cover crops terminated on 5 July

Jones, Miller, et al. unpublished

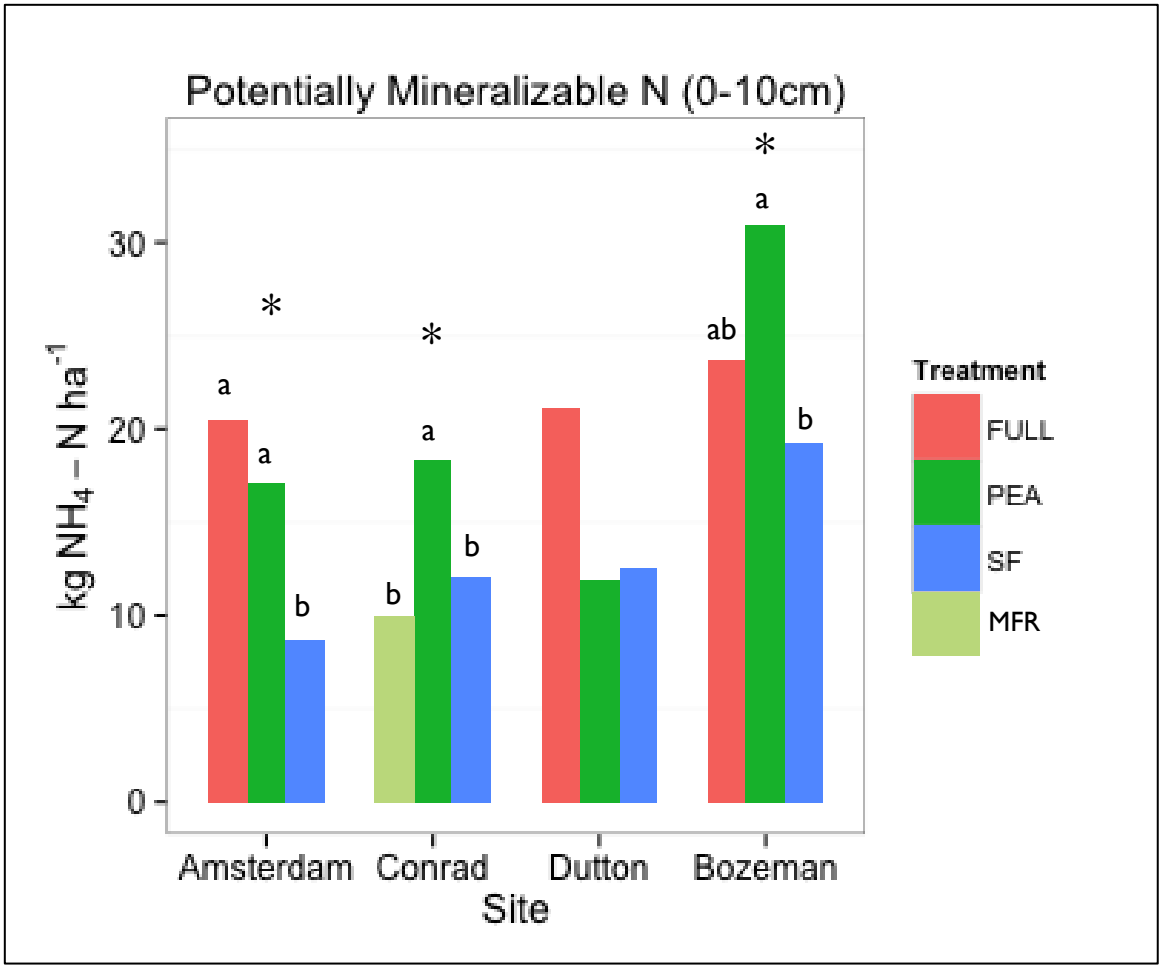
Preliminary Results

# Microbial Biomass




Tallman, Housman, et al., 2014

# Potentially Mineralizable Nitrogen




Tallman, Housman, et al., 2014

# Mycorrhizal Colonization

*Photo: Susan Tallman*

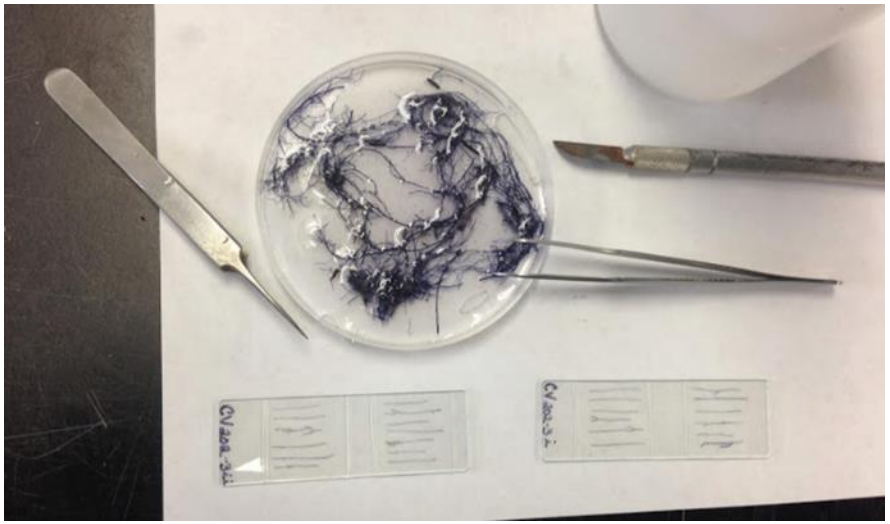
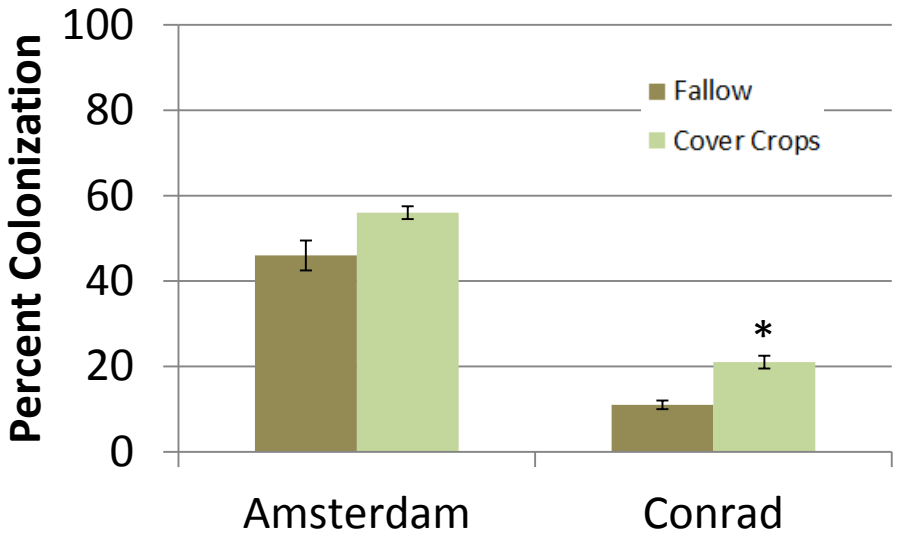


*Photo: Susan Tallman*

*Photo: Susan Tallman* 100x




Tallman et al., 2014

# Study 2 : Take home messages on yield and soil quality

- After one cycle, spring wheat grain yields higher after pea and N fixers than most other mixes.
- Higher cover crop biomass correlated with lower spring wheat yield, likely b/c of water and N use.
- Relatively few soil health differences; not unexpected given only one cycle.

# QUESTIONS?

# Study 3: Cover Crop Cocktail Farm Study, (2012 – 2013)

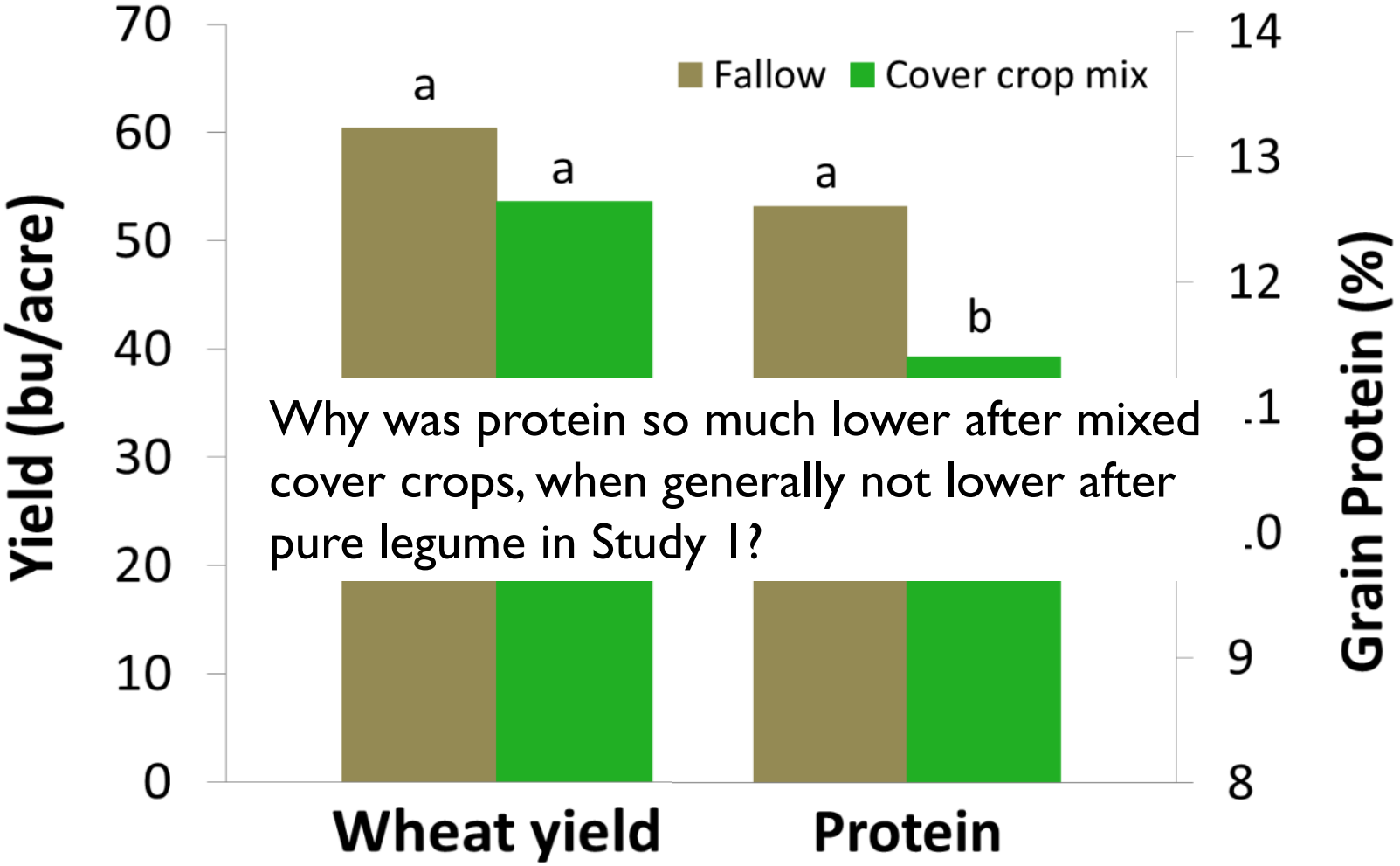
- 3 sites (Gallatin Valley and two in Triangle)
- Cover crops selected by growers and/or NRCS
- Growing season length somewhat on long side:

  Site 1 (Gallatin Valley): May 29 – Aug 29

  Site 2 (Triangle): Apr 12 – July 1

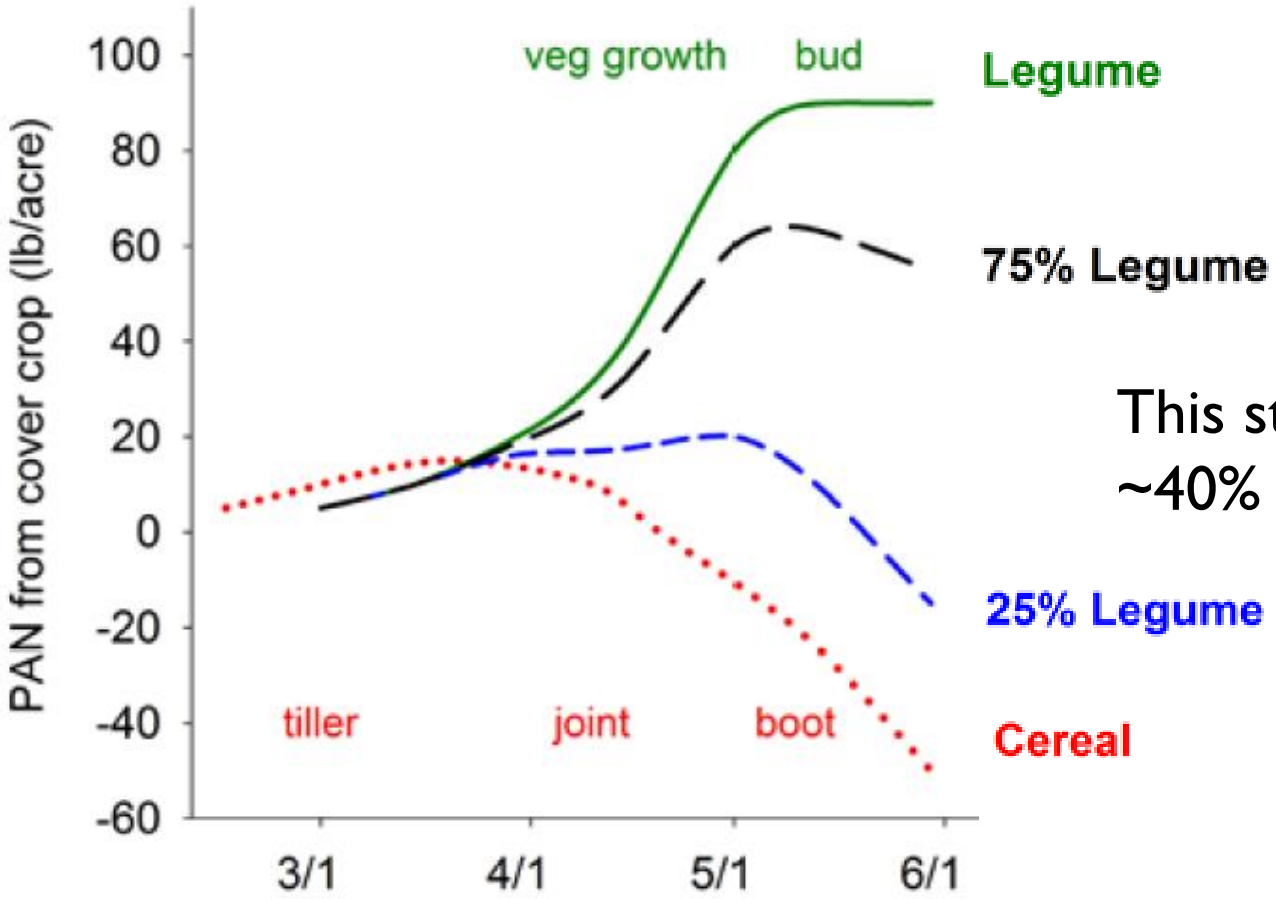
  Site 3 (Triangle): May 5 – July 20

# Study 3: Wheat Results (after mixed CC, farm-scale, Gallatin Valley)




Why was protein so much lower after mixed cover crops, when generally not lower after pure legume in Study 1?

# Percent legume and termination timing affects plant available N (PAN)




This study:
~40% Legume.

**Take home**: Legume % less than 50 can result in low available N esp if terminated late

Willamette Valley, Oregon
Sullivan and Andrews, 2012

# Study 3: Wheat Results (after mixed CC, farm-scale, Golden Triangle)

| Crop | Grain Yield (bu/ac) | | Grain Protein (%) | |
|---|---|---|---|---|
| | After fallow | After mixed cc | After fallow | After mixed cc |
| Barley | 83 a | 65 b | | |
| Spring Wheat | 46 a | 38 b | | |

# Study 3: Wheat Results (after mixed CC, farm-scale, Golden Triangle)

| Crop | Grain Yield (bu/ac) | | Grain Protein (%) | |
|---|---|---|---|---|
| | After fallow | After mixed cc | After fallow | After mixed cc |
| Barley | 83 a | 65 b | 12.1 a | 9.5 b |
| Spring Wheat | 46 a | 38 b | 14.5 a | 14.0 b |

Yield and protein less after mixed cover crops on farmers' fields, likely due to late termination and high water & N use

# Study 3: Take home messages on yield and protein

- Spring wheat grain yield was lower after CC than fallow in two of three field-scale studies
- Spring wheat grain protein was lower after CC than after fallow in all 3 studies.
- High water use from late termination was likely cause of yield differences.
- Low N availability from late termination & low legume % was likely cause of protein differences.

# QUESTIONS?

# Study 4: Eight-year, plot study

- Objective: Determine long-term effects of legume-containing rotations vs. fallow on subsequent wheat mainly in no-till.
- ~16 inch annual precip. (4 miles west of Bozeman)

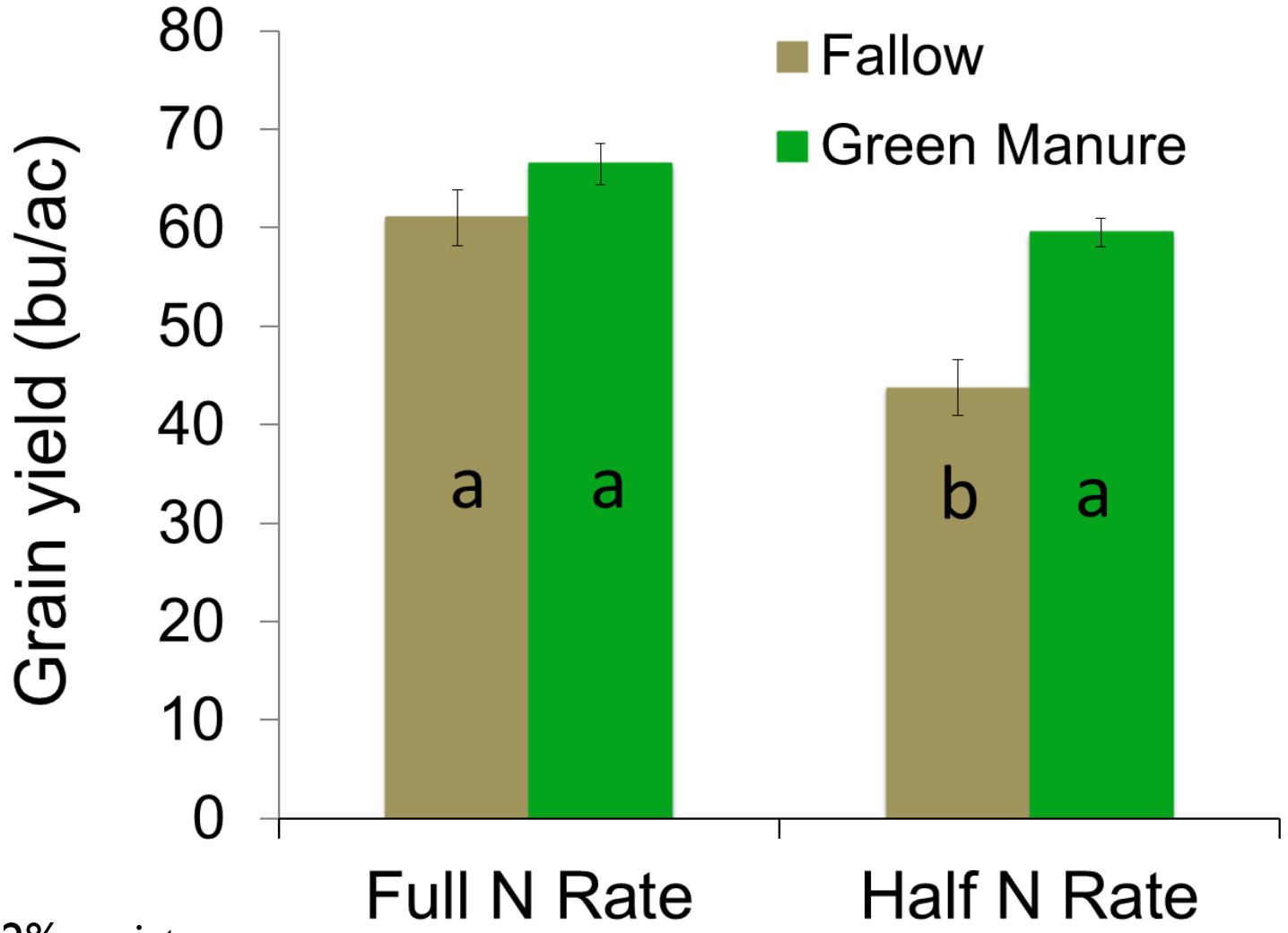
# Study 4: Experimental Design

- Unique feature is deep, uniform silt loam soil and relatively abundant winter precip. to recharge soils
- Focus here on no-till pea forage/legume cover crop-wheat vs. fallow-wheat
- Pea forage grown in 2003, 05, 07 and pea CC grown in 2009, terminated at full pod
- Spring or winter wheat planted in even years. 2010 was wettest of wheat years, 2012 record drought.
- 2 N rates: Full (3 lb available N/bu) and ½ N


Pea and Fallow Year

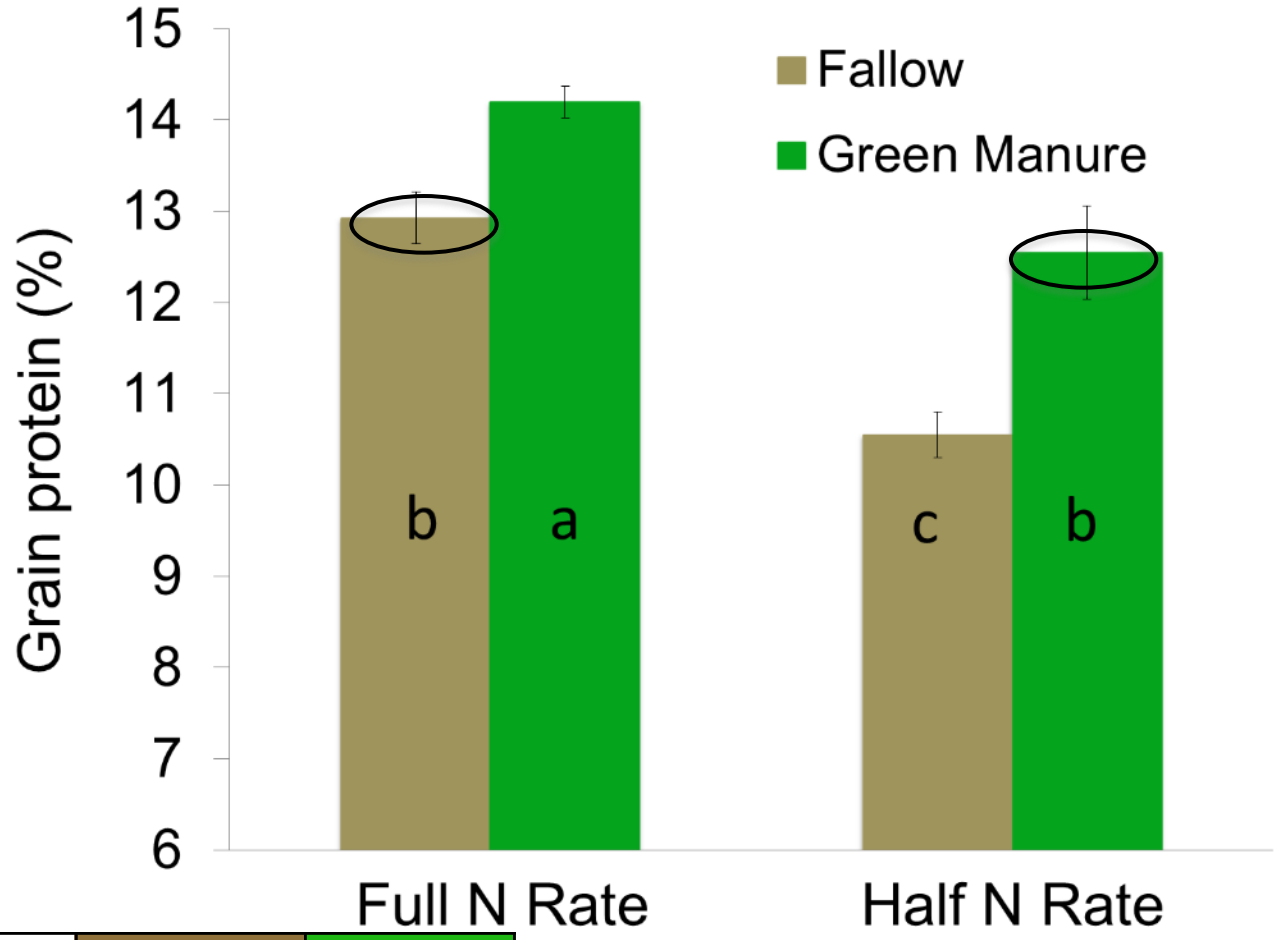

Wheat Year

# Study 4: Grain yield in 8th year




@ 12% moist

# Study 4: Grain protein in 8th year




| * N fertilizer rates | *Fallow-Wheat* | *LGM-Wheat* |
|---|---|---|
| Full N rate (lbs/ac) | 124.00 | 83.00 |
| Half N rate (lbs/ac) | 39.00 | 0.00 |

Pea cover crop after 4 CC-wheat rotations saved **124 lb N/ac** compared to fallow.

# Study 4: Soil Biology Results after 8 years

**Potentially Mineralizable Nitrogen**

Pea-W = LGM-W > W-W = F-W

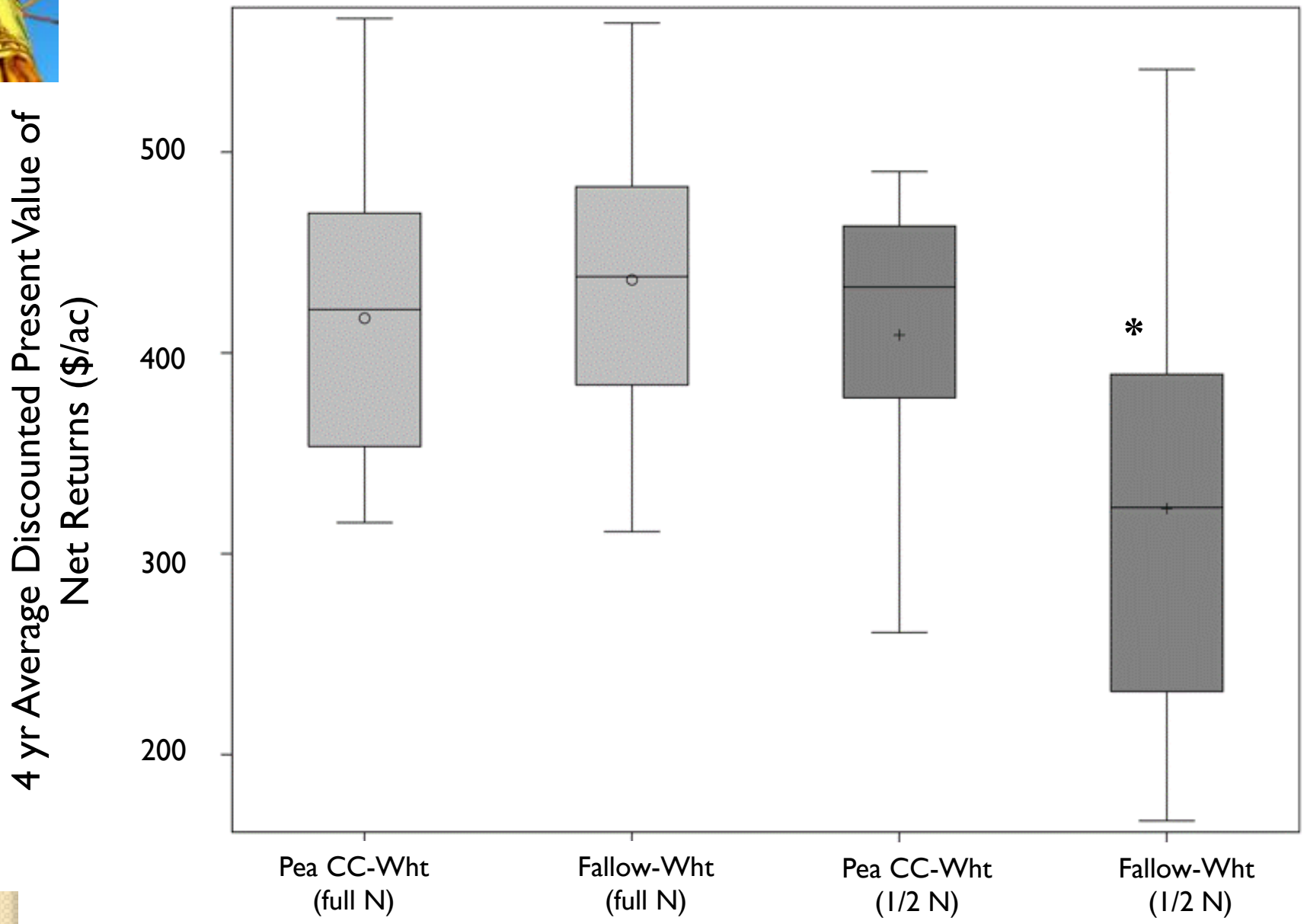
**Microbial biomass**

Pea-W> W-W > F-W

**Aggregate Stability**

No treatment differences

# Study 4: Economics (2009 – 2012)



# Conclusions


*Image: Roy Lichtenstein*

- In short term (1 CC-cycle studies), grain yield and protein are generally equal or less than after fallow.
- Early termination (by ~ first pea bloom) is key to preventing yield and protein losses.
- In cover crop mixtures, the presence of a dominant legume affects available N to following cash crop
- In long term (4+ cycles), yield, protein, and net revenue can be higher after cover crops than fallow, likely from more available N.
- Cover crop value to soil health and subsequent crops is expected to increase over time.

# Additional Resources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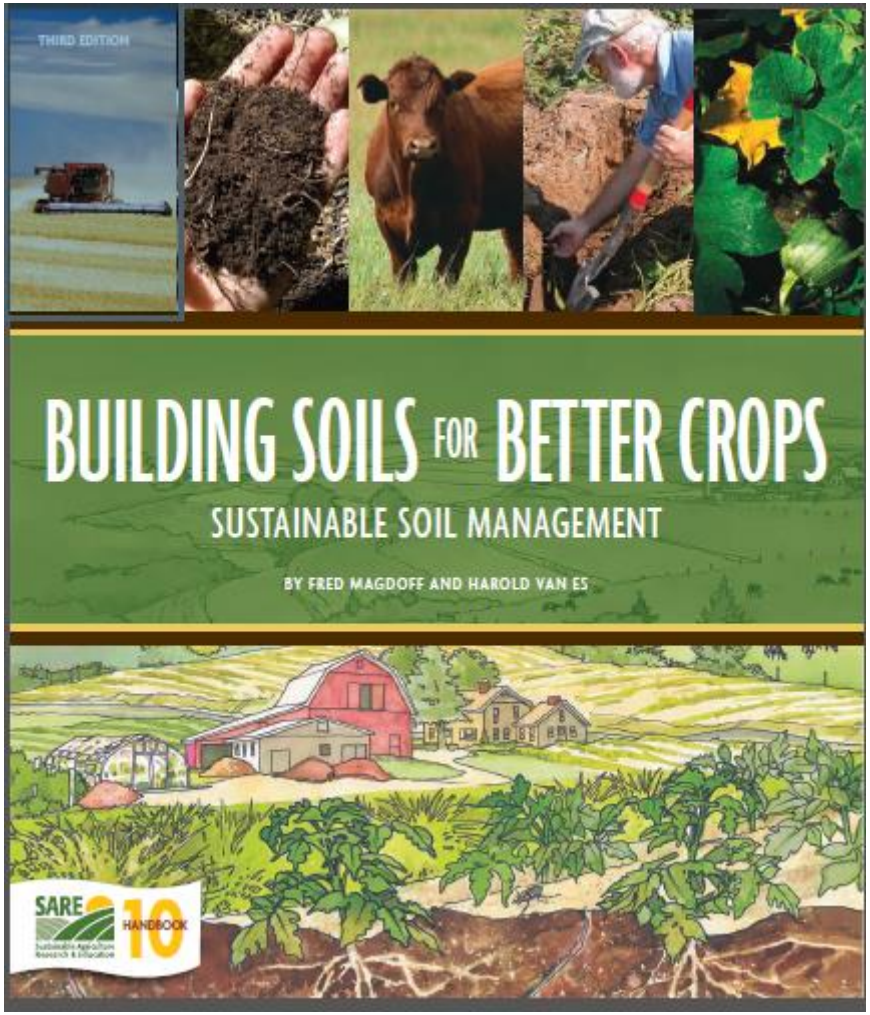
Dr. Clain Jones
Soil Fertility Extension Specialist
406-994-6076
clainj@montana.edu

MSU
landresources.montana.edu/soilfertility/covercrops.html

NRCS
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/




http://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition

## Active Organic Matter Test
## Hardin NRCS Office

*Photo: David Wolfe*

## Cornell Soil Health Test

http://soilhealth.cals.cornell.edu/

- Active organic matter
- Soil respiration
- Standard fertility
- More

# Thank You


- USDA – AFRI
- USDA – WSARE
- NRCS – CIG
- USDA-ARS, Mandan, ND
- Montana Fertilizer Advisory Committee
- Montana Wheat and Barley Committee
- Numerous landowners
- Ann McCauley
- Jeff Holmes
- Ann Fischer – USDA, NRCS
- Stacey Eneboe – USDA, NRCS
- Jane Holzer - Montana Salinity Control Assoc.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