Nutrient Management on Organic Grain Farms

MT Organic Association

Bozeman

November 30, 2021

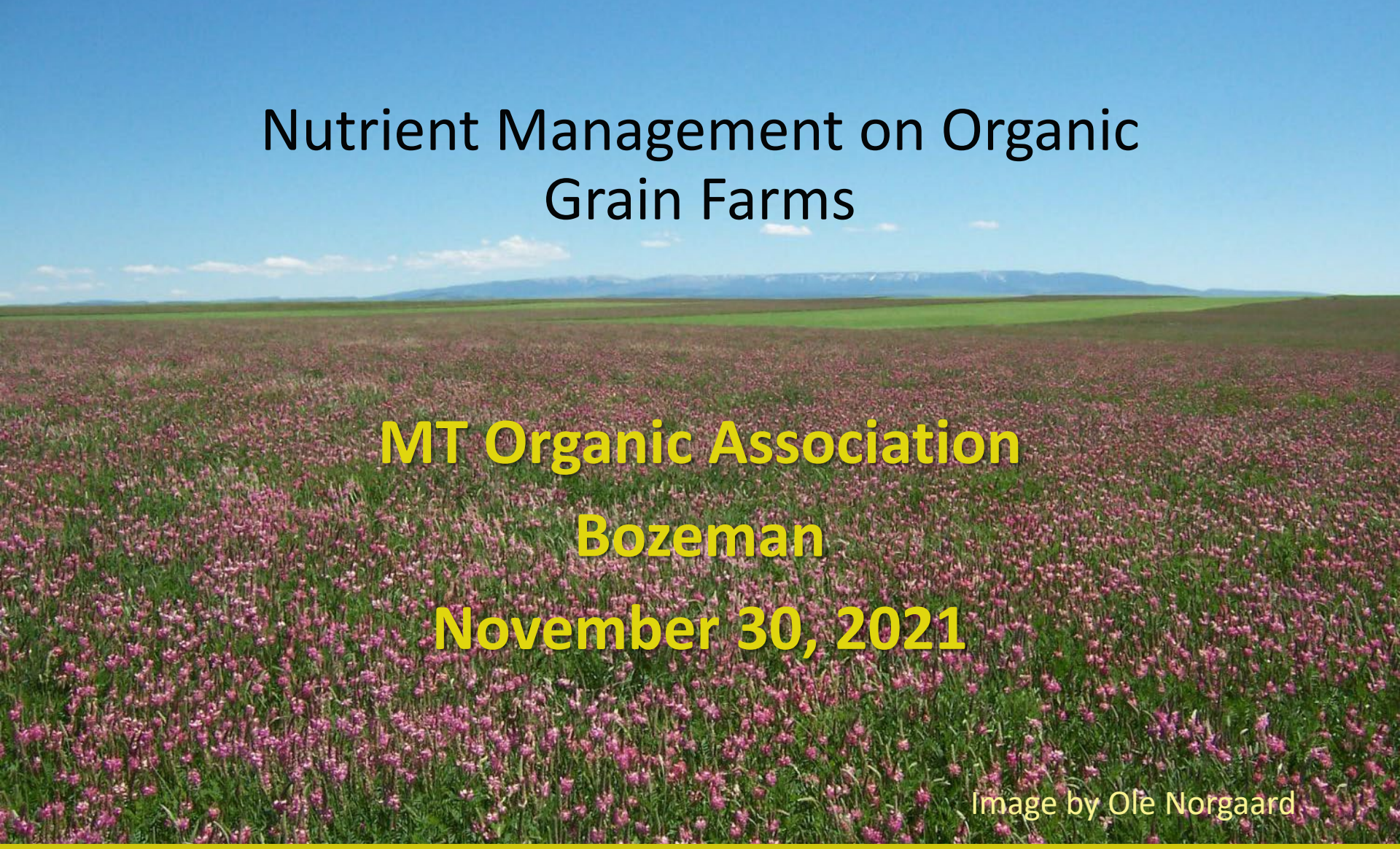

Image by Ole Norgaard

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MONTANA STATE UNIVERSITY

MSU Soil Fertility Extension

Objectives

- Present nutrient losses from croplands
- Discuss N supply from covers and manure
- Show options and benefits with adding S
- Discuss the challenges of P fertility in organic fields

These 14 mineral nutrients are known to be essential for growth of most plants:

Macronutrients	Micronutrients
Nitrogen (N)	**Boron (B)**
Phosphorus (P)	**Chloride (Cl)**
Potassium (K)	**Copper (Cu)**
Sulfur (S)	**Iron (Fe)**
Calcium (Ca)	**Manganese (Mn)**
Magnesium (Mg)	Molybdenum (Mo)
	Nickel (Ni)
	Zinc (Zn)

How many of these can be 'grown'?

Bolded nutrients: deficiencies have been observed in Montana

Crop nutrient removal rates (lb) Table 21 EB0161

Crop	Unit	N	P_2O_5	K_2O	S
Barley grain	40 bu	35	14	10	3
Oat grain	40 bu	24	10	7	2
Wheat grain	30 bu	37	25	15	2
Canola, mustard	10 bu	19	12	6	3
Pulse grain	15 bu	18	10	13	2
Sunflower	27 bu	29	9	7	2
Wheat straw	1.5 ton	22	5	37	6
Alfalfa	2 ton	96	22	106	11
Grass	2 ton	50	20	76	4

Is N limiting yield?

- Protein levels that suggest N limitation:
  - < 12.5% for WW (Ffact 34)
  - < 13.2% for SW (Ffact 21)
- Nutrient deficiency symptoms

Image from Univ. ID Extension

N options

Spring wheat @ 14% protein needs 3.3 lb N/bu
e.g., 30 bu/ac crop needs ~100 lb N/ac

Legumes are likely best N source on MT organic farms

Source	# ton for 100 lb N/ac
Manure solids	> 15*
Manure compost	> 35*
Poultry manure	5
	N credit (lb N/ac)
1-2 x pulse grain	10
3+ x pulse grain	20
1-2 x pulse cover	20 - 30
3+ x pulse cover	30 - 50
Perennial legume 3 yrs	35 - 100

* Depending on source, N may be tied up and no N supplied the first year, e.g., dairy solids or horse manure

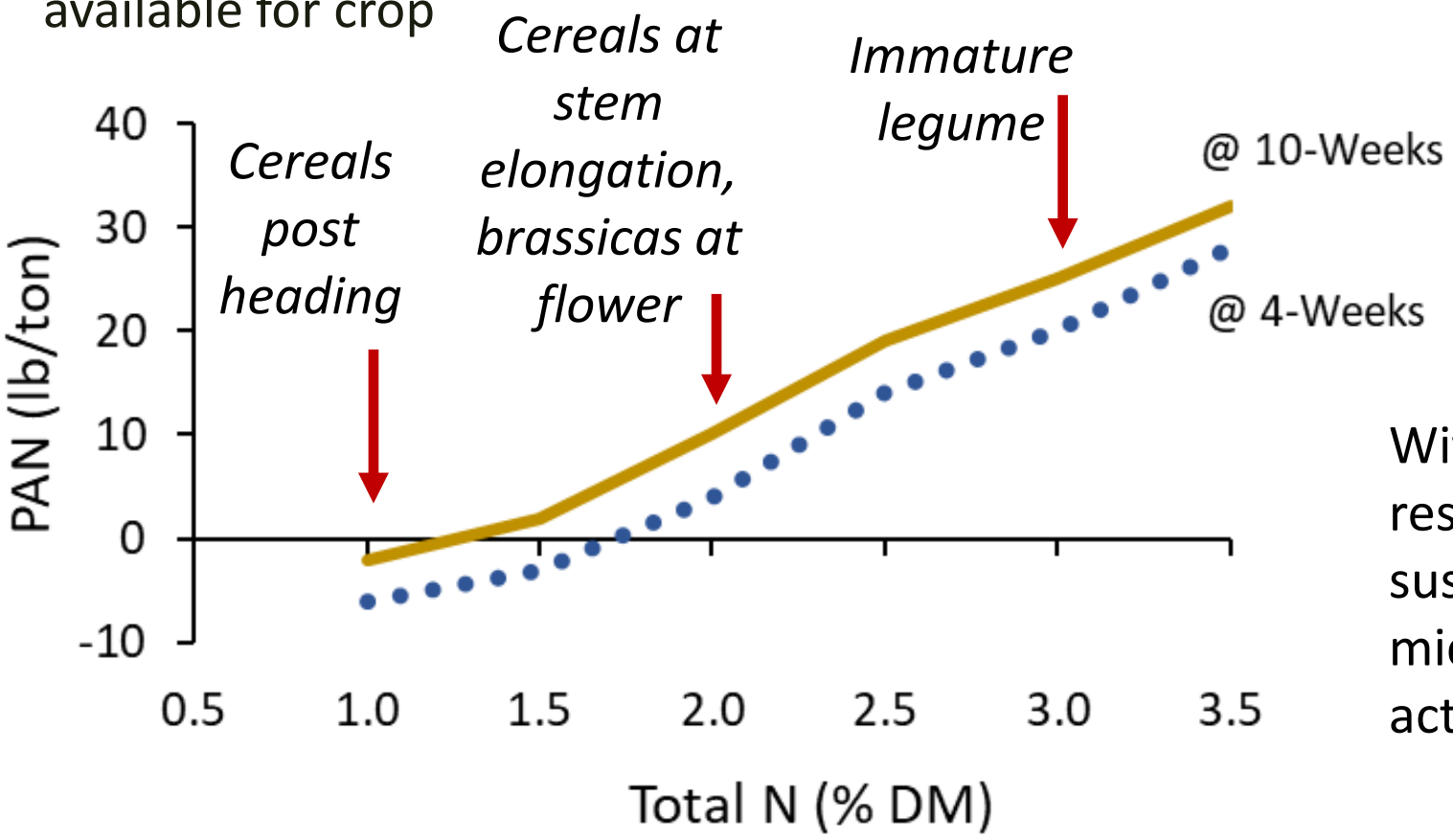
N release from plant residue

- Most release for the first year in 7-10 weeks once conditions suitable for decomposition, depends on N content, freshness, structure (lignin, phytochemicals)
- Release slow but steady for years after that
  - 15% pea cover N used by Sp-wheat following yr
  - 55% pea cover N used by crops over 3 following yrs
  - Rest in soil as SOM (Janzen et al. 1990, Jensen et al. 1994)

Plant available N **AMOUNT** from plant residue

Depends on residue N concentration

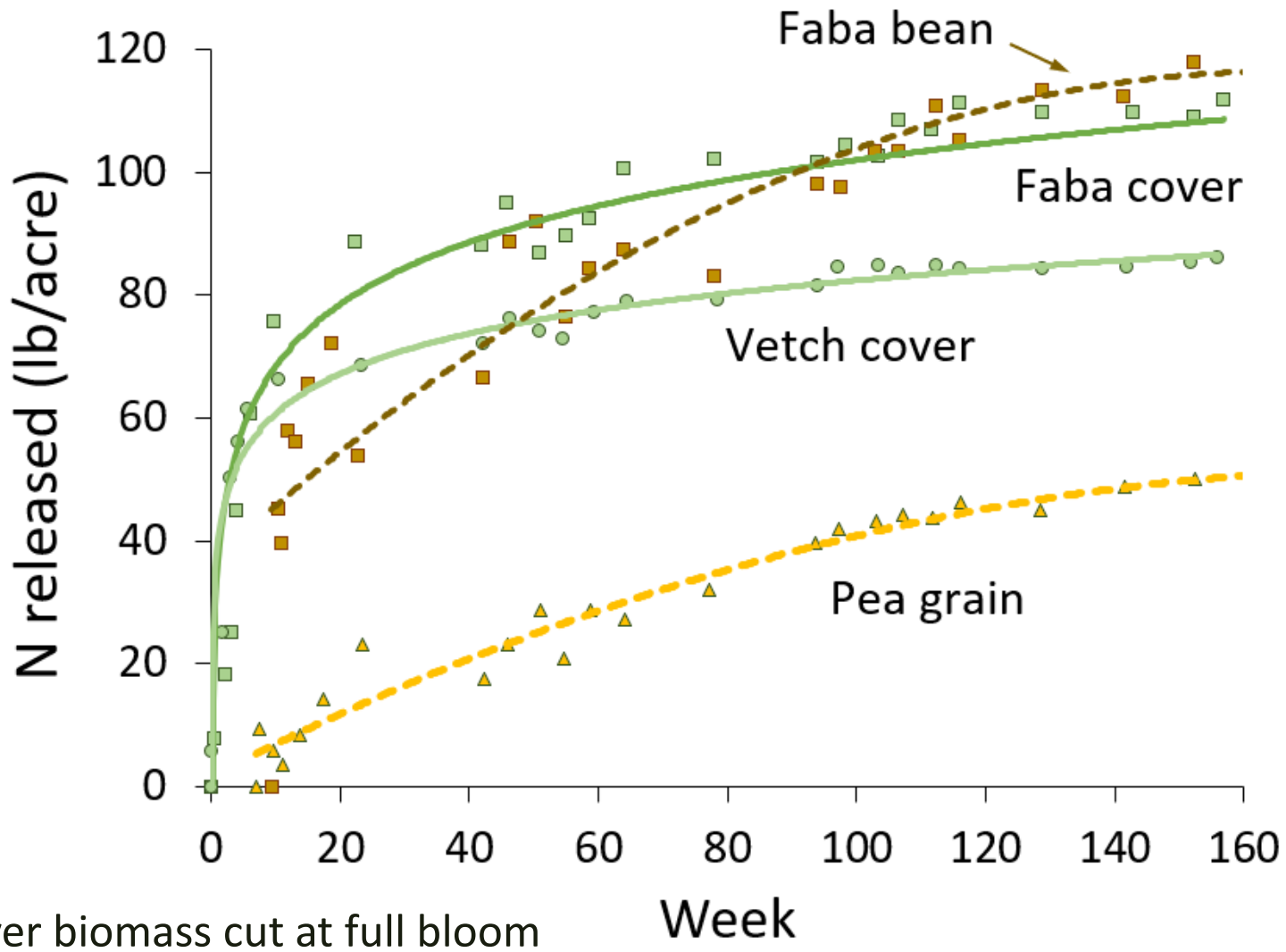
- Leafy green: high N concentration = more PAN
- Mature plant: lower N concentration, N used by microbes and not available for crop



With tilled residue and sustained microbial activity

Oregon State University Extension Predicting Plant Available N EM9235
Estimating Plant-available Nitrogen Release from Cover Crops PNW636

N release from above ground plant material for many years



Cover biomass cut at full bloom
Lupwayi and Soon 2015, AB

Questions?

Cover termination timing

Questions to ask:

- H_2O or N more limiting
- Decomposition in fall
- Over-winter leaching
- Early demand for spring crop

To increase N in cover

- Plant all legume
- Grow to pod stage IF N more limiting than H_2O. Bud otherwise.

To speed up release

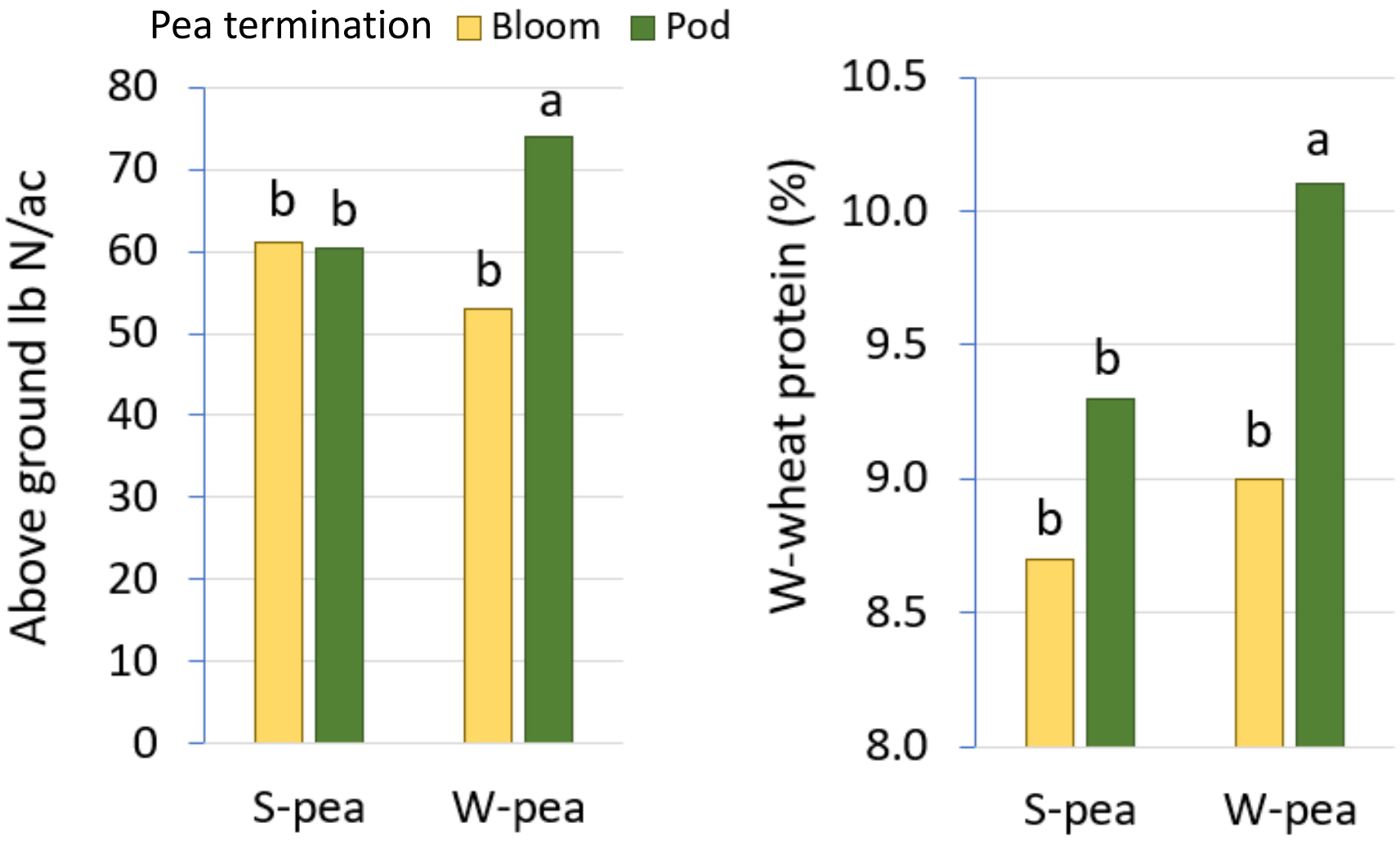
- Terminate when plant tissue is 'young'
- Allow more time for decomposition – at risk of over-winter leaching loss

If N is not needed early in spring

- Till shortly before ground freezes or early following spring (challenge with getting into wet fields)
- Include grass in mix

Plan rotations to catch N, e.g., high protein wheat

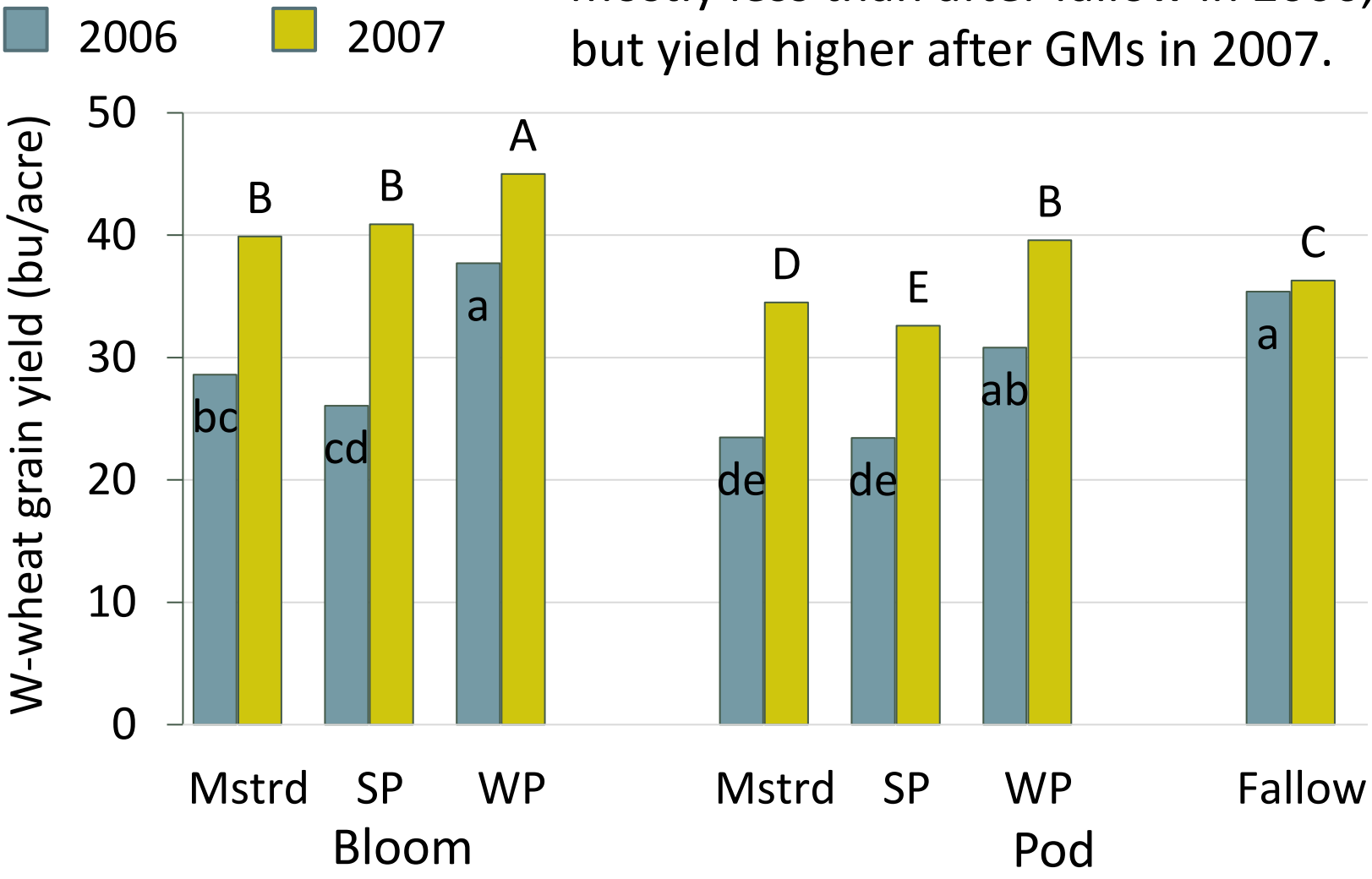
Successful late terminated winter pea produced the most above ground N residue and wheat grain protein



Izard 2007, Miller et al. 2011, Big Sandy, MT, organic system

Winter wheat grain yield after early and late terminated cover

Why was yield after green manure mostly less than after fallow in 2006, but yield higher after GMs in 2007.



Izard 2007, Miller unpub. data, Big Sandy, MT, organic system

Practices to increase N fixed

- Perennials, but also use more water
- Winter vs. spring annuals, challenges with establishment and overwintering
- Grow longer, but risk water use, let go to legume pod in wet years, terminate early in dry?
- Adequate P, K, S, micronutrients (especially iron)
- Inoculation – are there organic sources?

Organic, not fertilized

Fertilized w/ P, K, and S

Winter Pea, Bozeman, 5/17/07, photo by C. Jones

Winter Pea Roots

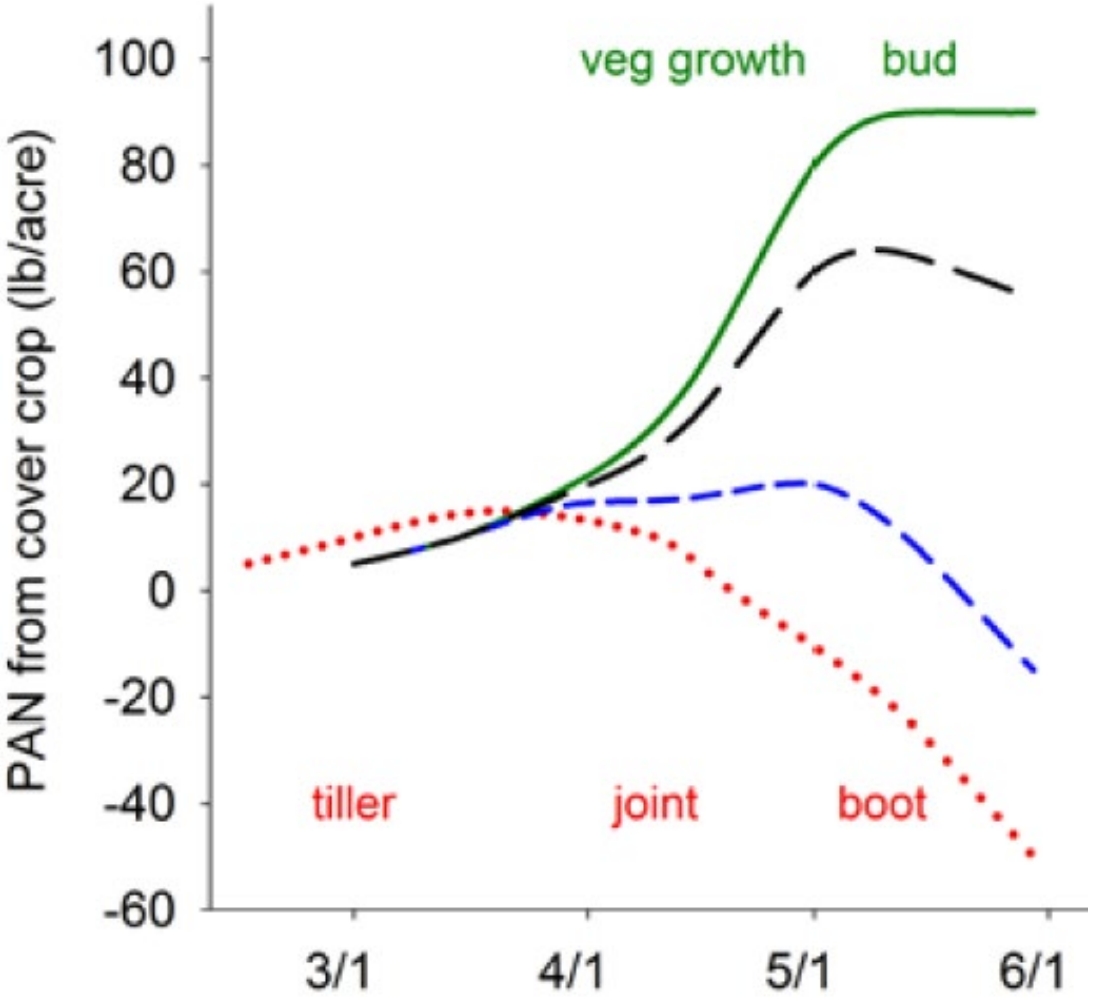
Organic, not fertilized

Fertilized with P, K, and S

Winter pea, Bozeman 5/17/07, photo by C. Jones

What looks different?

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



Legume

75% Legume

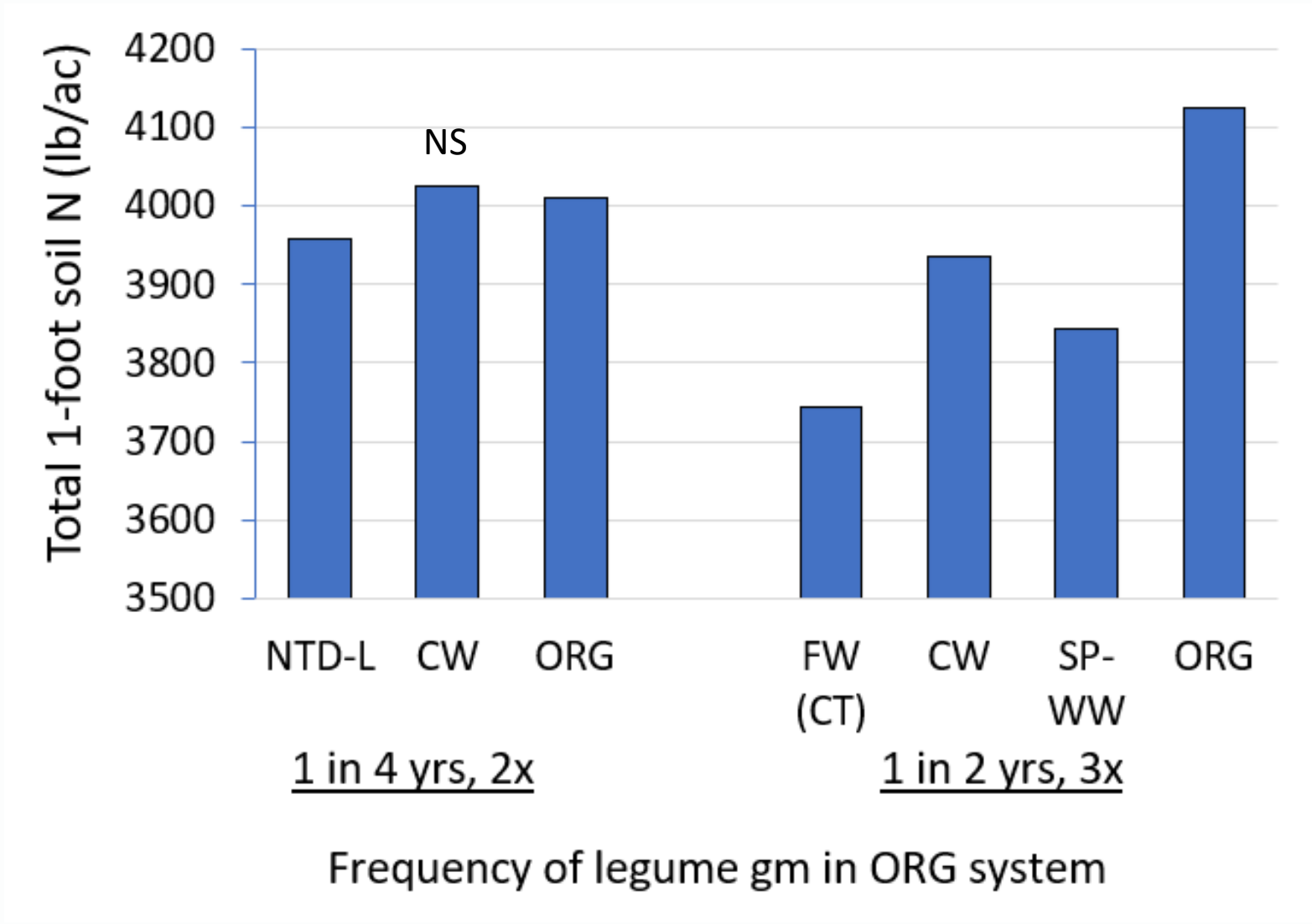
25% Legume

Cereal

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

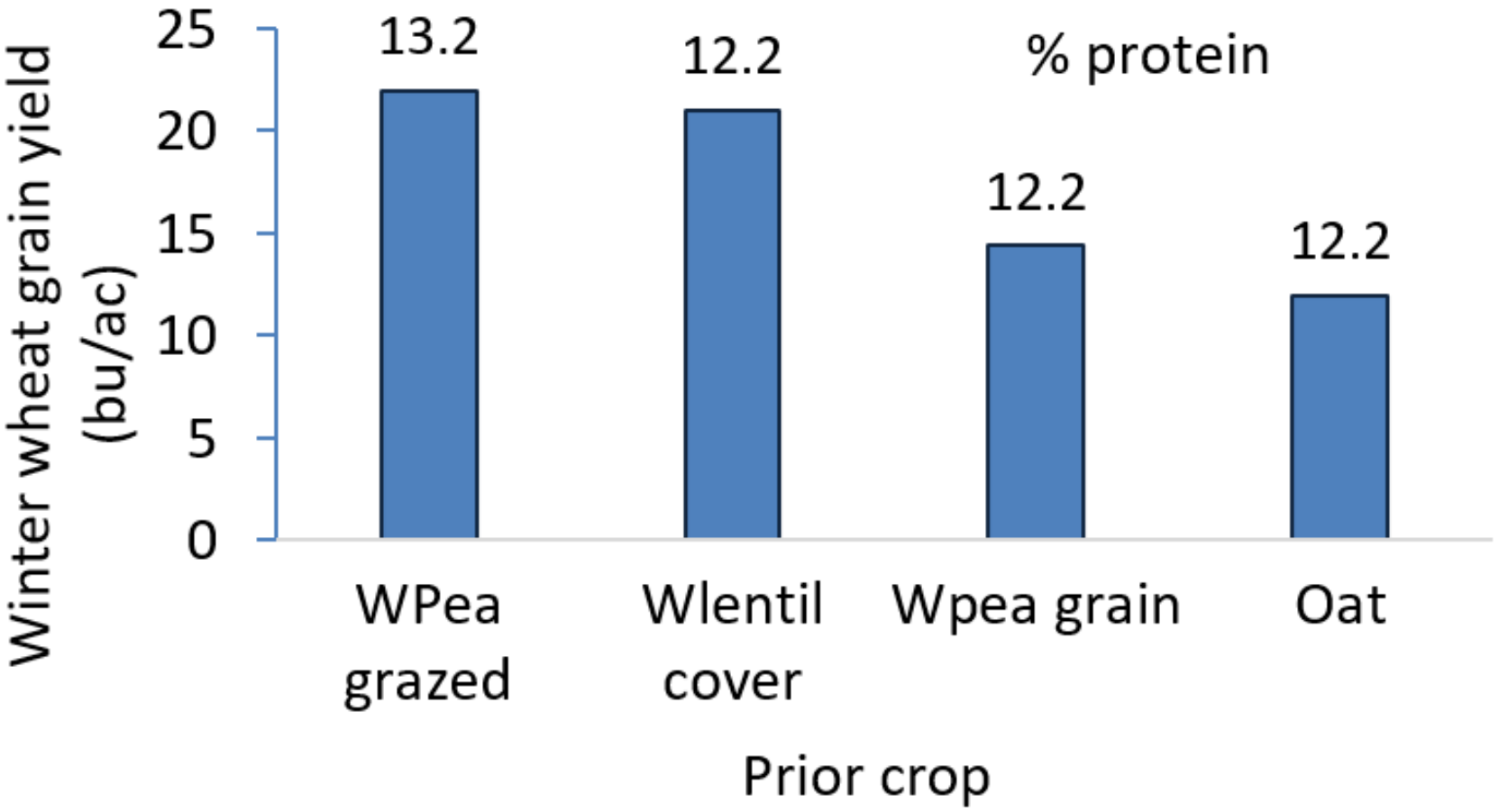
Willamette Valley, Oregon
Sullivan and Andrews, 2012

Frequent legumes needed to supply N



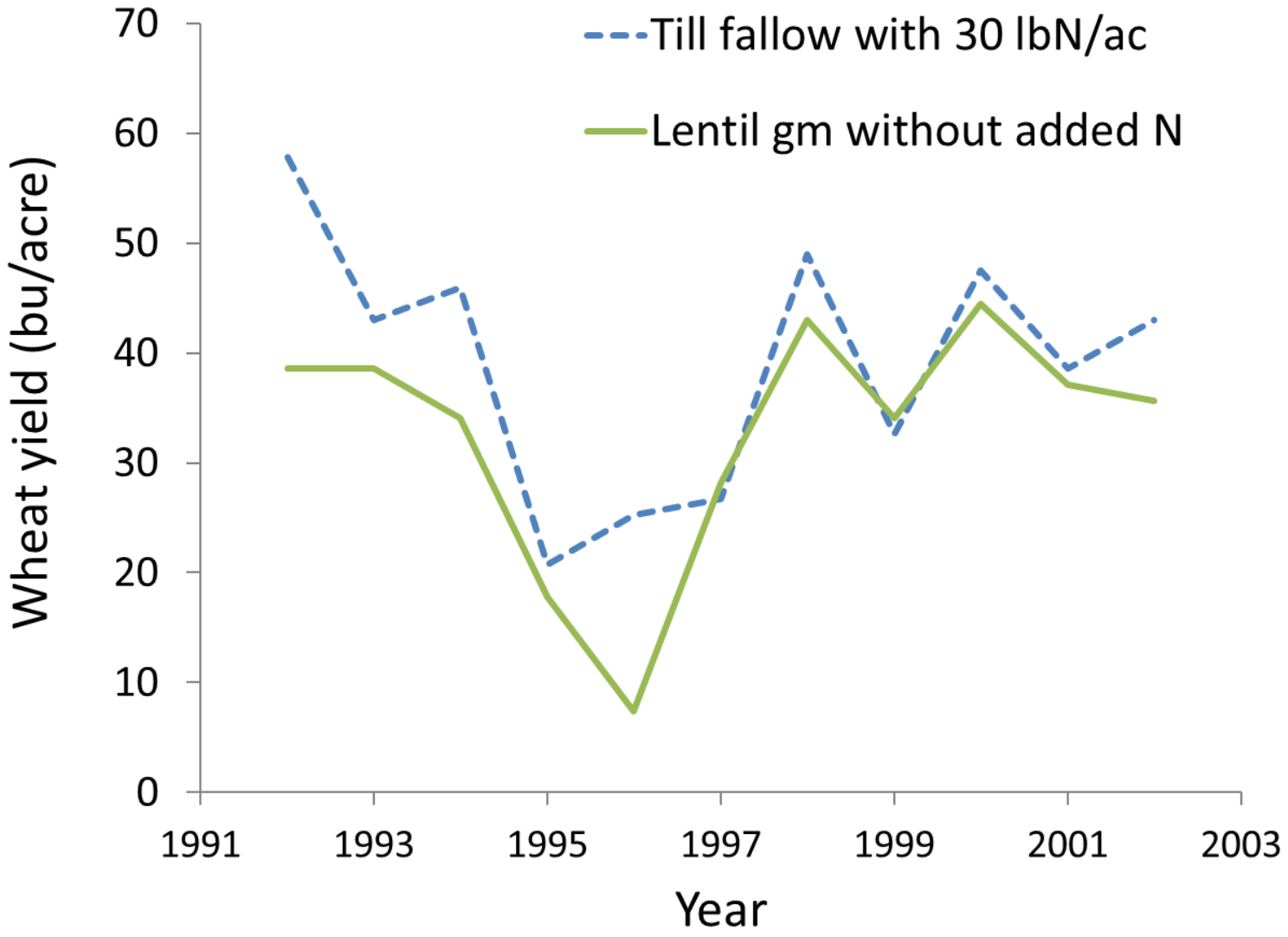
Miller et al. 2008, MT

Previous crop effect on ww yield and protein



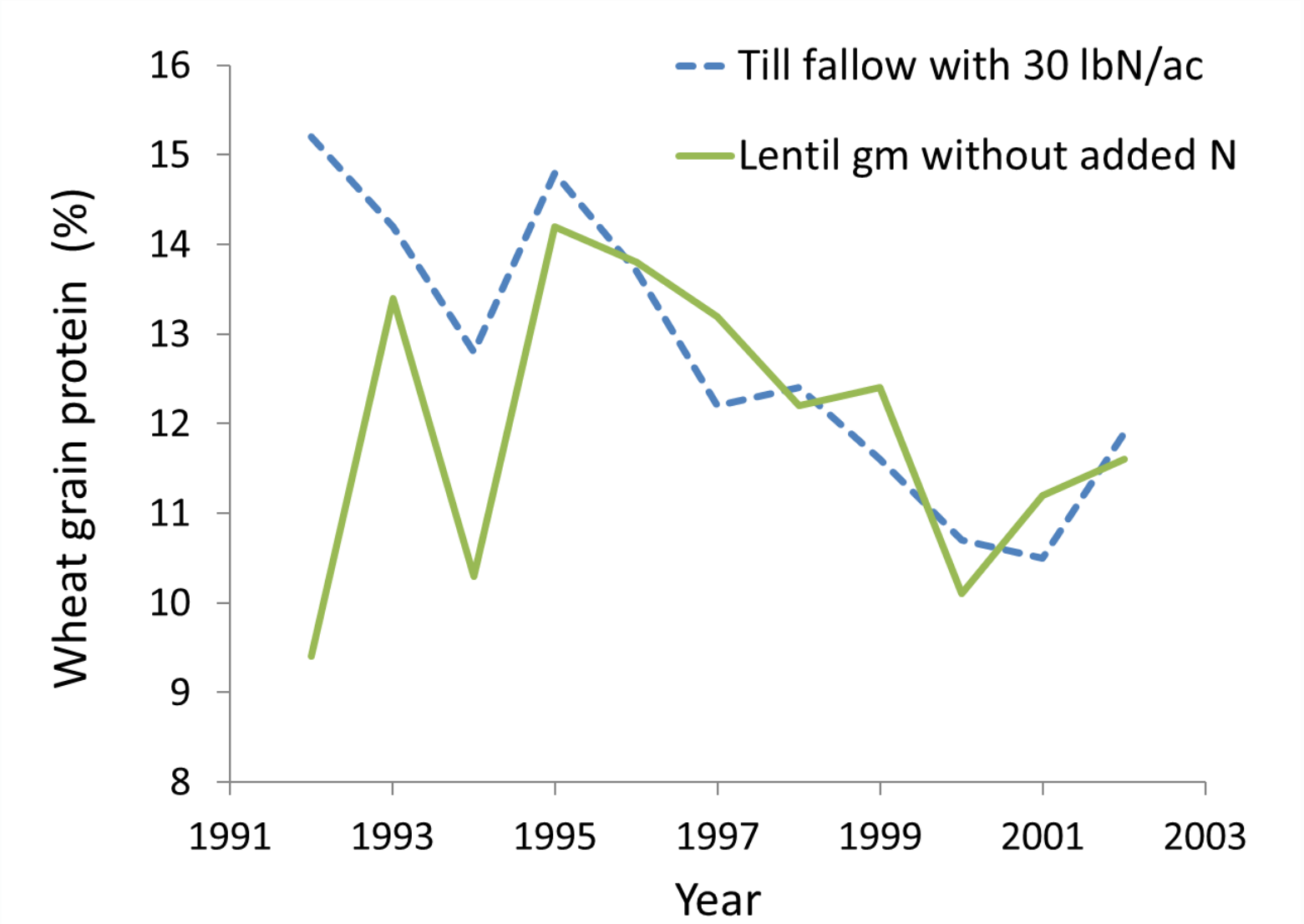
Chen et al. 2010, Stanford, MT, organic

Legume cover crops take time to influence subsequent wheat yield



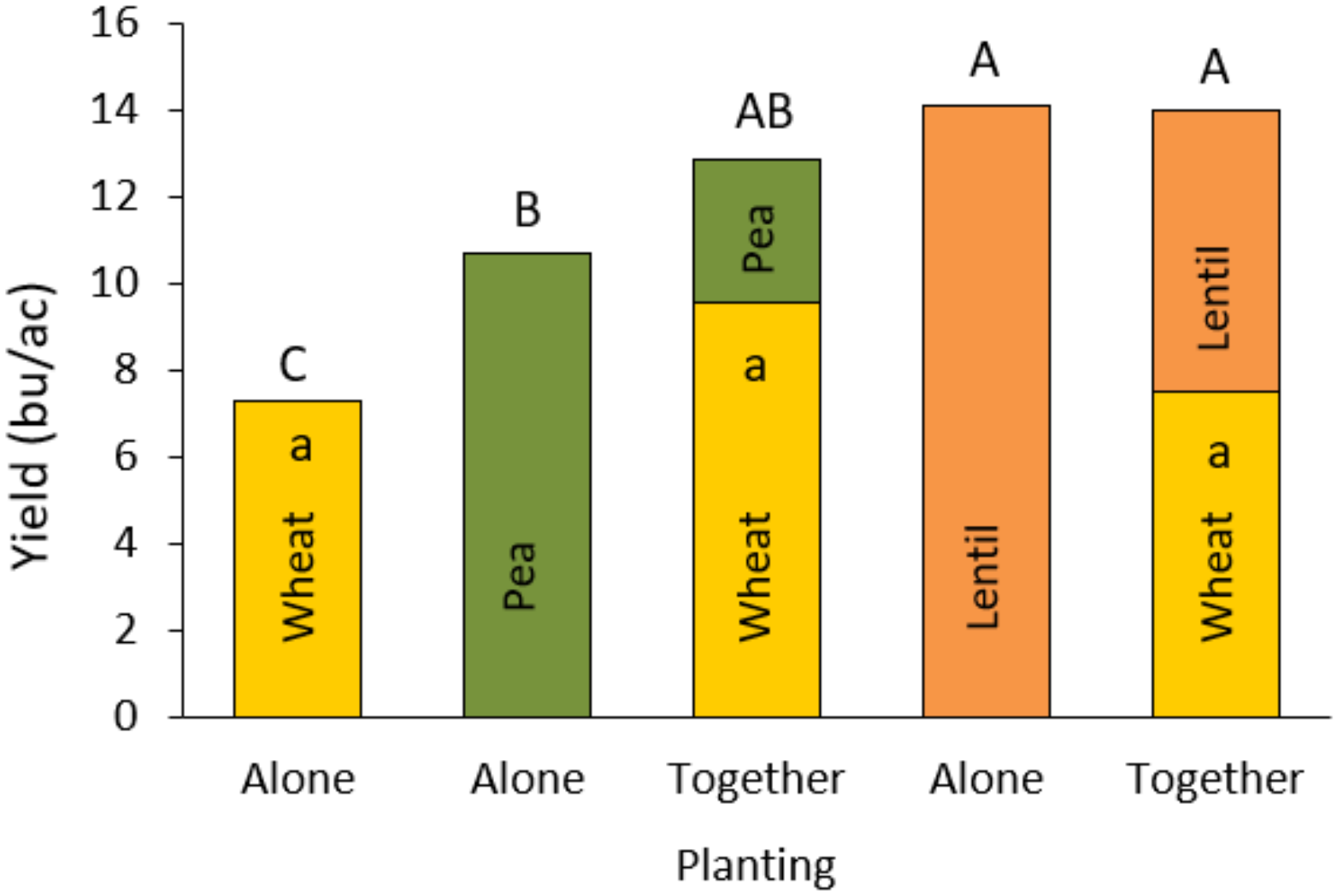
Allen et al., 2011, Culbertson, MT, conventional

Pulse/legume rotations benefit protein before yields



Allen et al., 2011, Culbertson, MT, conventional

Interseeding may produce higher yields



Wheat did not receive N fertilizer

Chen et al. 2010, Moccasin, MT, conventional

Questions?

On to manure

Manure

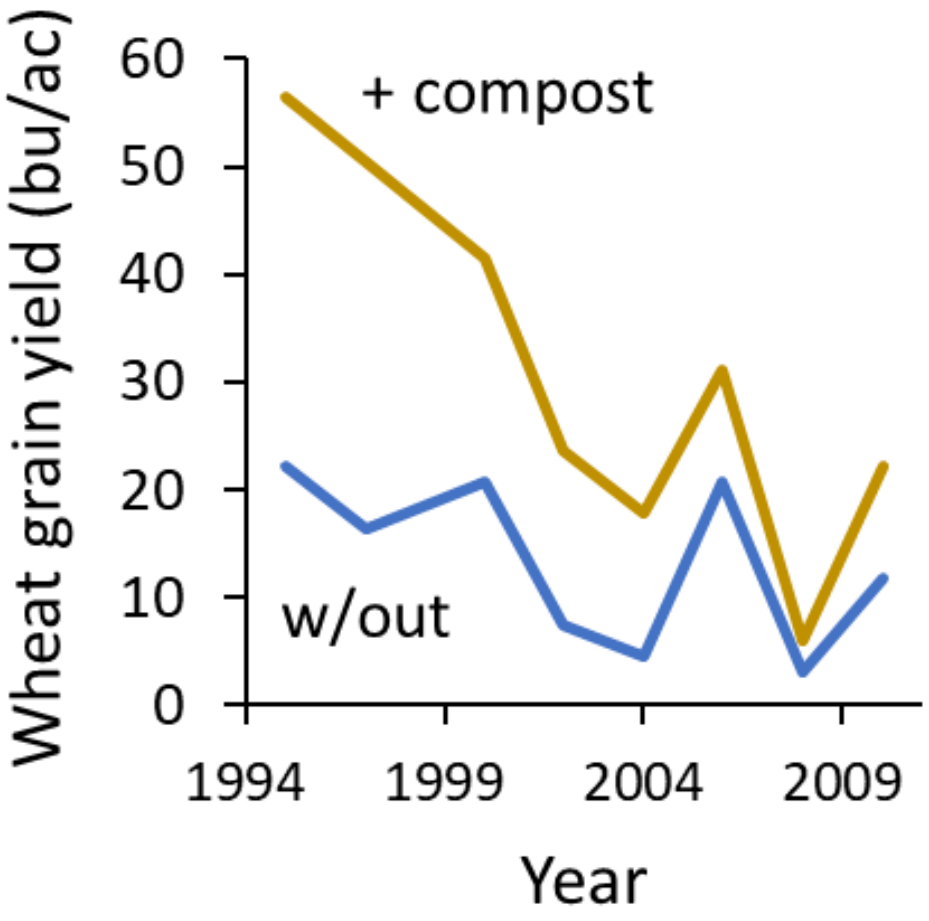
- **Highly variable content** even w/in species
  - Most sources low in N, 10% of that available in 1st year
  - 70- 100% of P available (Hoskins 2015)
  - Contains micronutrients
  - Adds Ca and Mg = pH buffer

Approx NPK content *per ton* of manure as is			
Source	N	P_2O_5	K_2O
Beef	14	5	8
Dairy solids	10	4	8
Dairy slurry/1000 gal	28	13	25
Swine	40	35	20
Poultry w/ litter	56	27	39

- P surface run-off, N leaching/volatilization (up to 70%)
- Need to incorporate
- P and K increase at higher rate than needed by plants if manure applied to meet N need – watch for excess, at Olsen P ≈ 30 ppm, reduce manure rate

Manure benefits

22.2 ton/ac cattle manure compost added 1x ≈ 650 lb N/ac

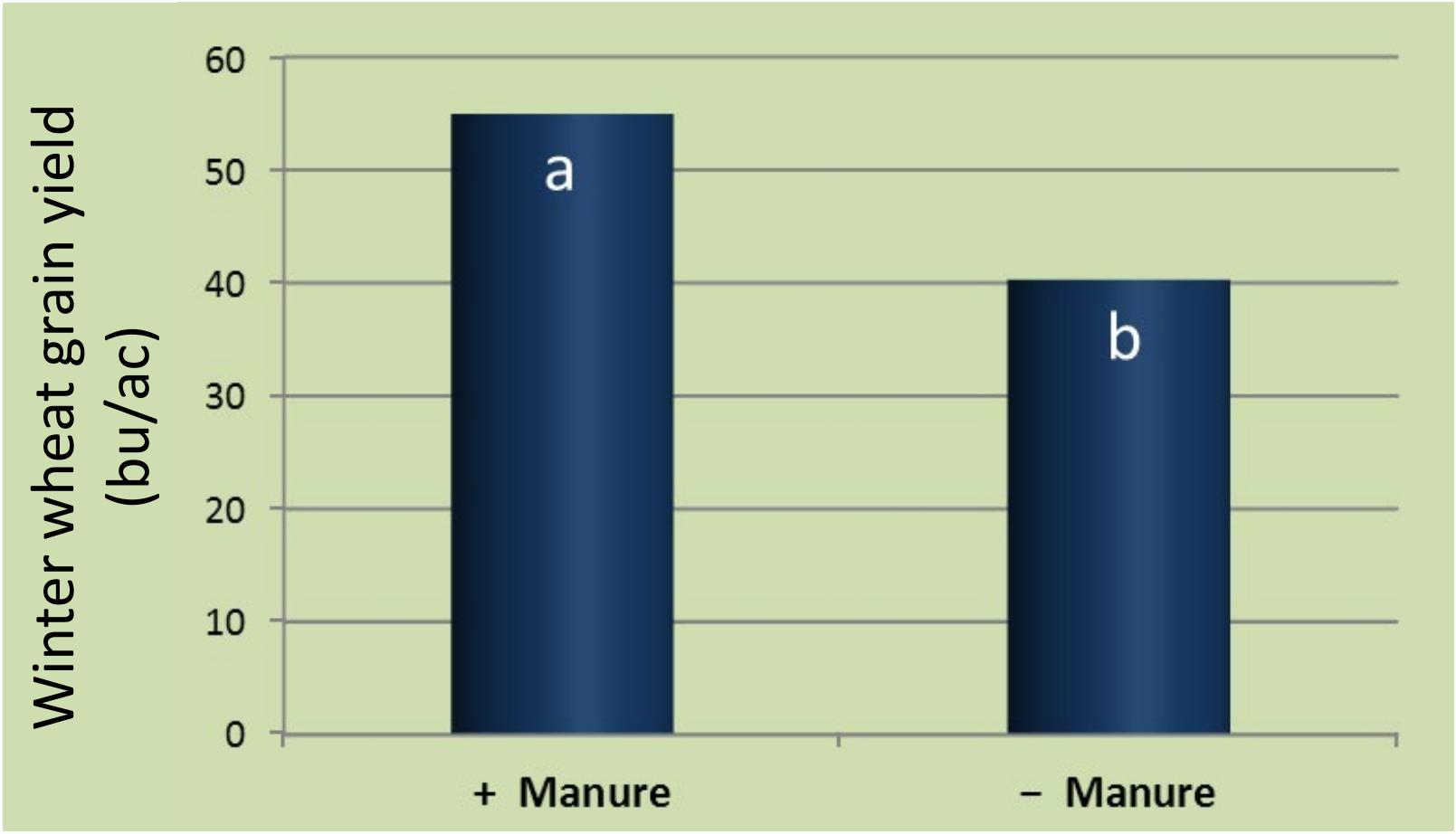


Based on 2 sites:

- Yield benefit for many years
- Winter wheat protein ≤ 12.5%
- Yield benefit higher at site with lower precip and soil nutrients
- Benefits minimal at lower compost rates
- Economical?

Reeve et al. 2012, Adeleke et al. 2021, dryland farms, Utah

9-ton/ac organic beef manure Fall 2009, tilled
= 75 lb TOTAL P_2O_5/ac and ~400 lb TOTAL N/ac
2010 winter wheat grain yield



No effect on grain protein, weeds, 2011 lentil yield

Post Farm, Bozeman, Jones and Miller, unpub data

Manure – to reduce water contamination

- Incorporate
- Not on snow or frozen ground
- Slow/trap runoff (contour tillage, ponds, diversions, cover crops)
- Maintain vegetated buffer strips
- Maintain crop residue on soil to reduce erosion
- Not on > 15% slope or < 10” deep soil

Image from Ontario Ministry of Ag.

USDA with Purdue Univ. Manure Management Plan with state specific guidance.
https://www.purduemmp.myfarms.com/

Questions?

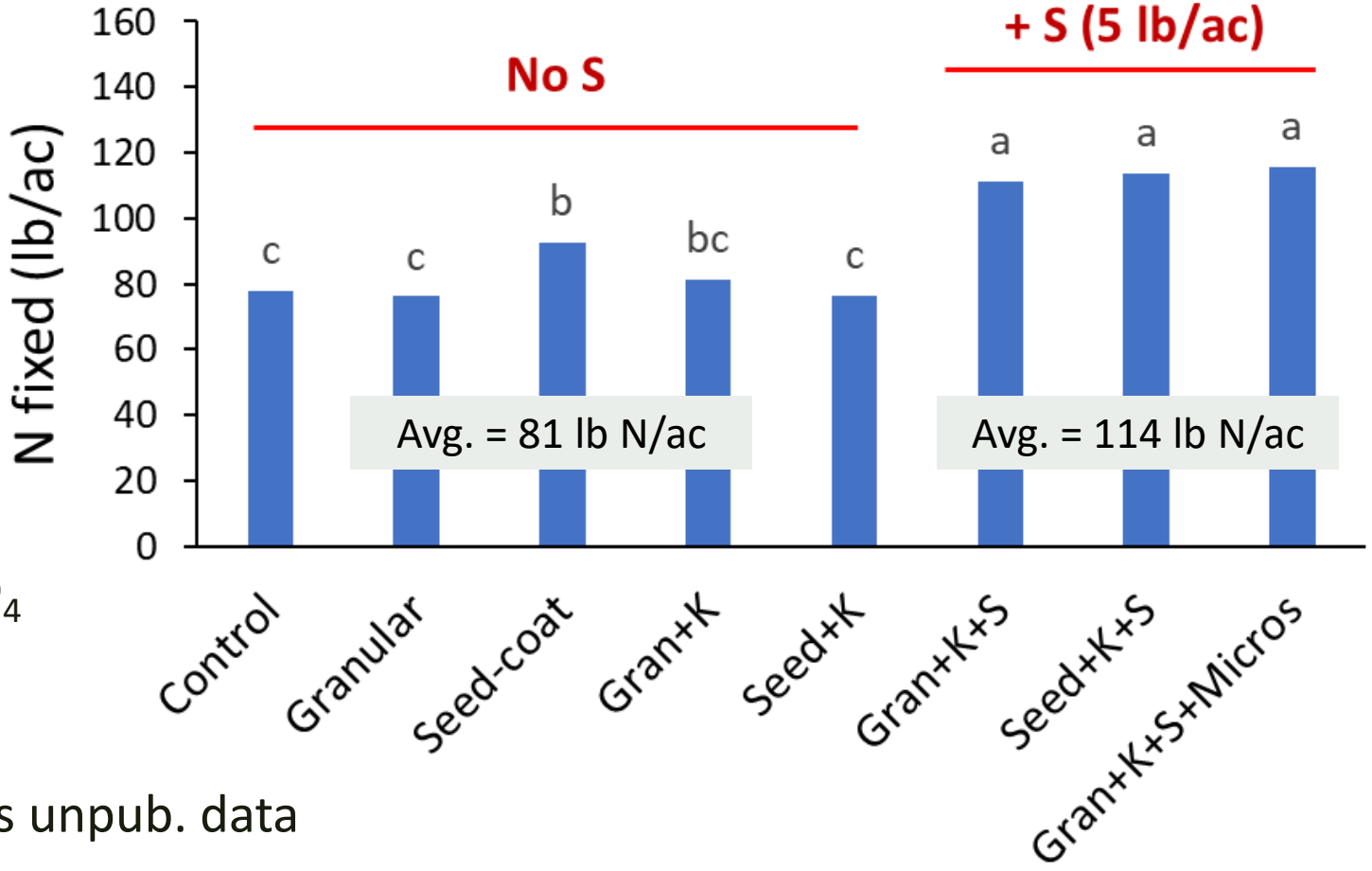
If not responding to N amendment, could be S deficiency

Image by C. Jones

S fertility

- Limiting in cold dry soils, coarse soils, hilltop and slopes
- Gypsum ($CaSO_4$; 17% S) readily available S. $ Organic ≈ $ conventional. Adds Ca, but doesn't increase pH
- Elemental: 80-90% S, takes weathering to break down, finer particles and high microbial activity increase break down, lowers soil pH
- Sulfate of potash (K_2SO_4 ; 0-0-50-17) readily available S
- Manure highly variable (< 0.5% S). 0 to 80% available depending on source (Paulsen 2005)

S important for N fixation and uptake in dry years



Gallatin Valley
Post Farm 2020

5 lb S/ac as K_2SO_4

15 lb K_2O/ac

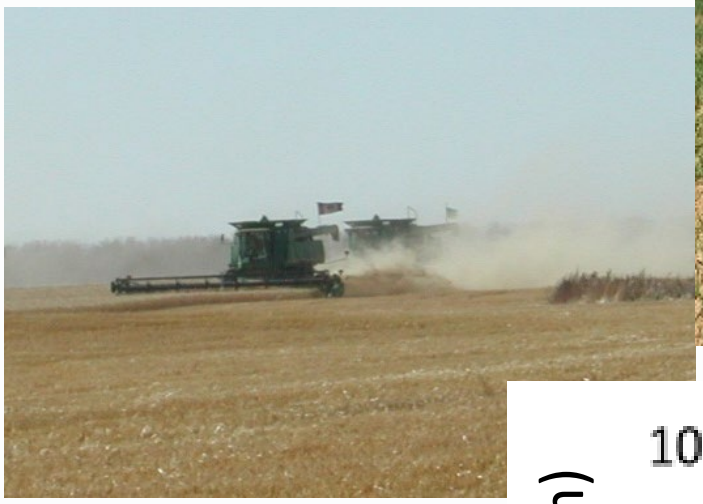
Baber and Jones unpub. data

Questions?

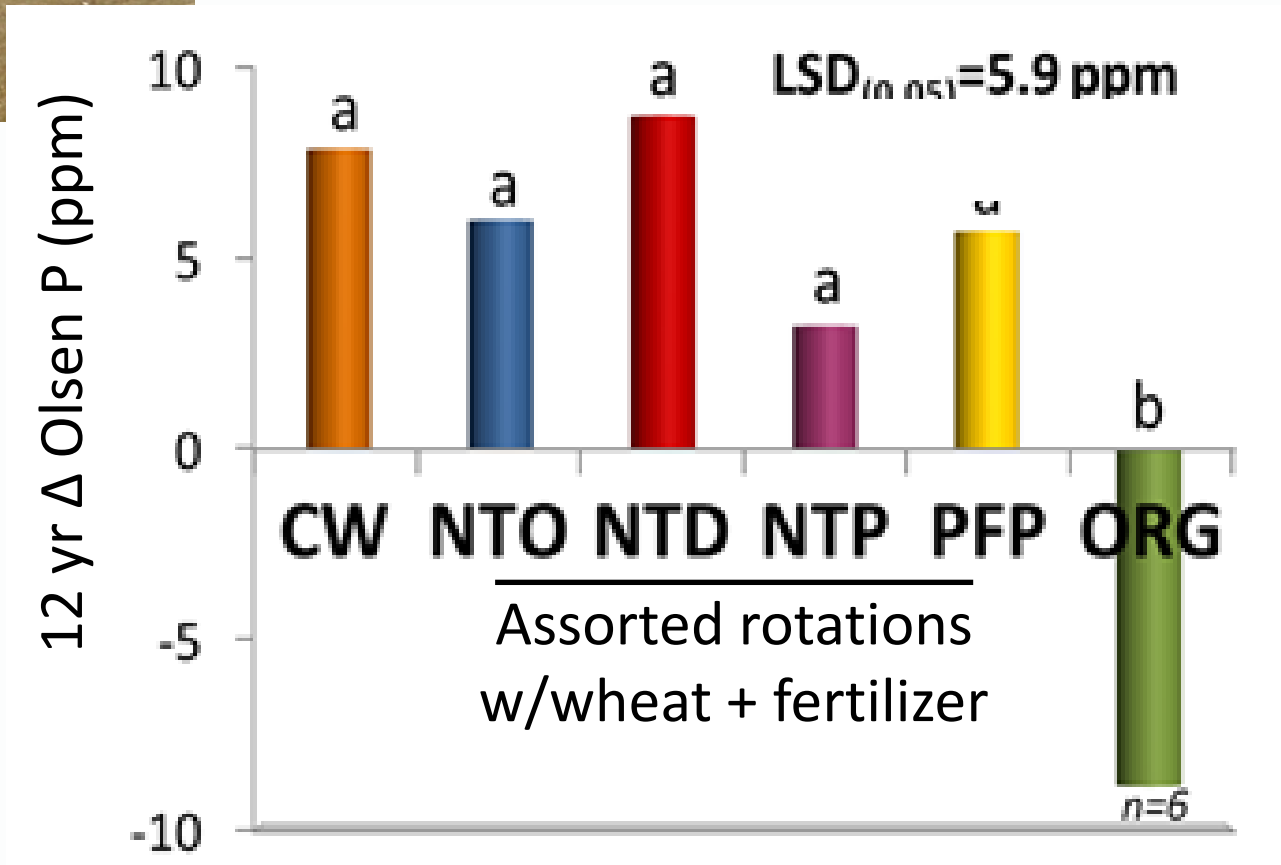
On to phosphorus

Image from IPNI

Image by S. Subbiah, IPNI



P losses from fields



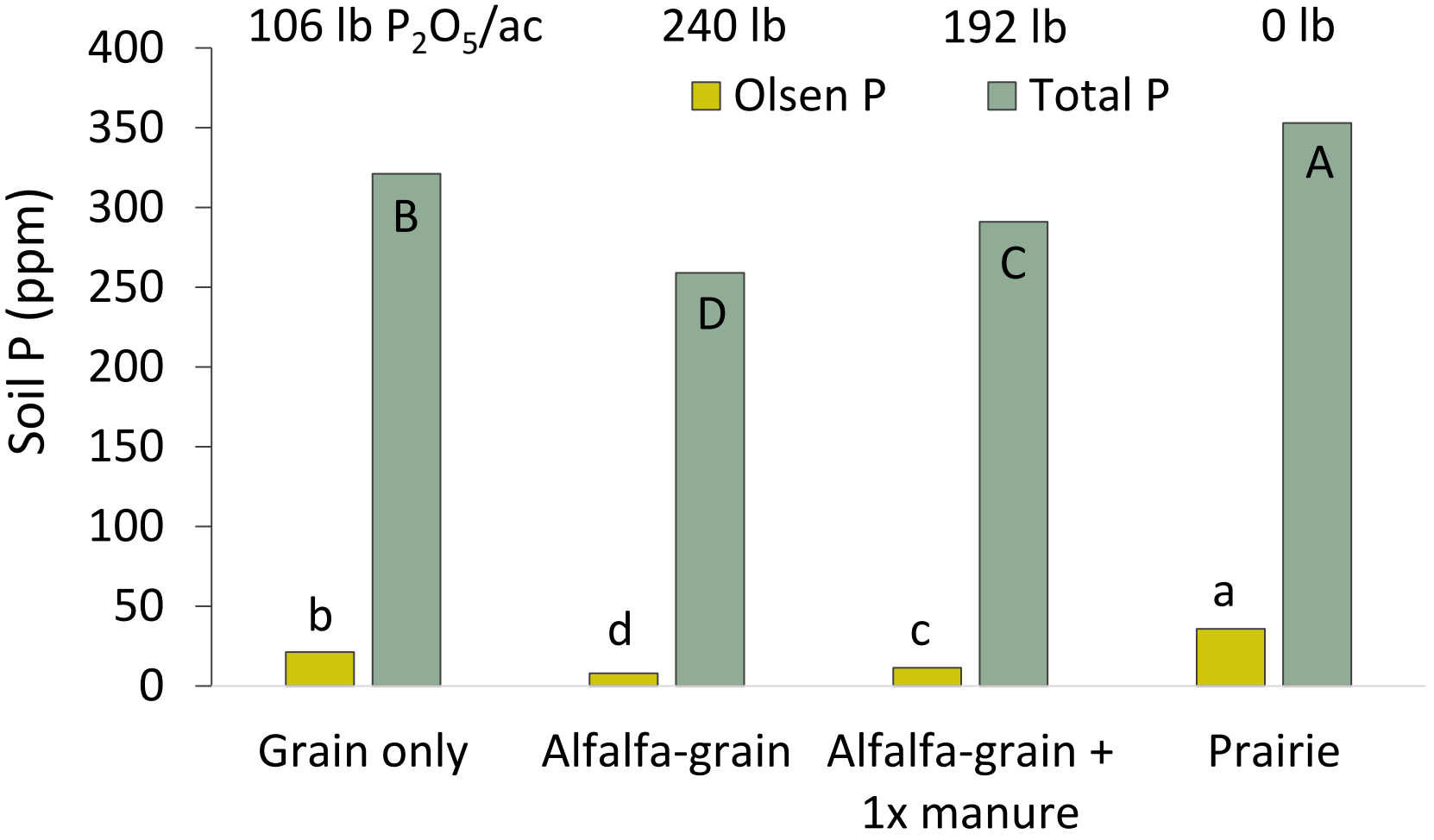
MSU Post Farm, Organic received no inputs

Organic rotation = legume GM/Wwheat/Lentil/Barley or Safflower

Harvest removes P from soil reserves

About 50-100 yrs P left in MT soils. Yields will suffer well before.

Removed by 12 years' harvest



Welsh et al. 2009, Manitoba, 6.7 to 8.1% SOM, pH around 7

Base P input on removal

Use P removal rather than soil P to budget P

Diff crops have diff ability to extract P

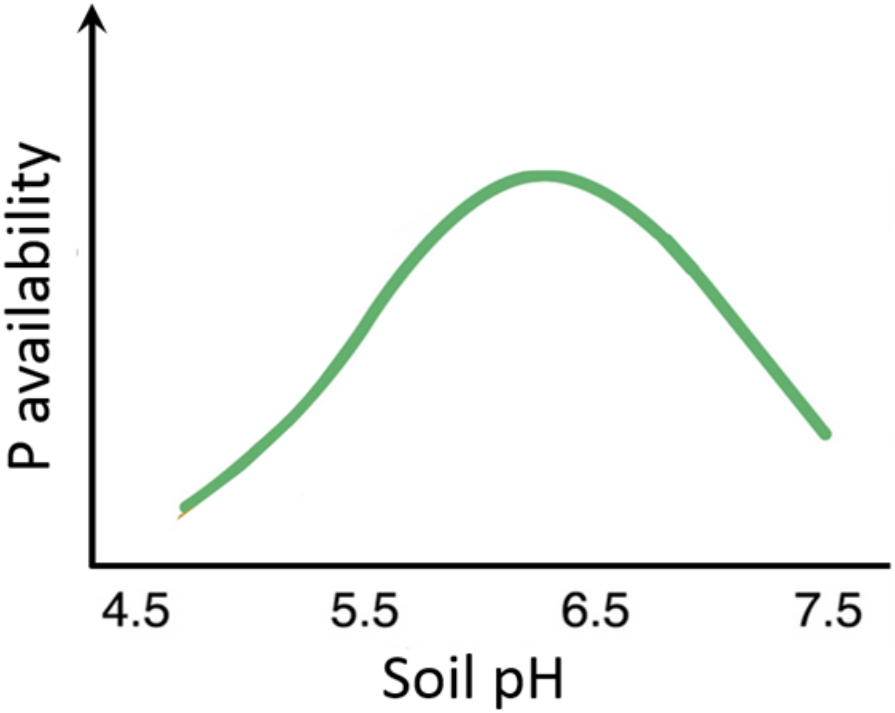
Crop	Uptake lb P_2O_5/bu	Removed by harvest lb P_2O_5/bu
Swheat	0.7	0.5
Barley	0.3	0.3
Oat	0.3	0.2
Flax	0.7	0.6
Canola	0.9	0.7
Faba bean	2.0	1.2
Lentil	0.8	0.6
Pea	0.5	0.4

Data from Grant and Flaten 2019

Factors for P availability

- Increased availability

  5.5 < Soil pH < 7.0
- Low Ca soils
- SOM
- Composting the P source (e.g., RP or bone meal) or applying with compost
- Fine particle size
- Contact with soil → incorporate



Rock phosphate and bone meal

Rock phosphate (0-27-0)

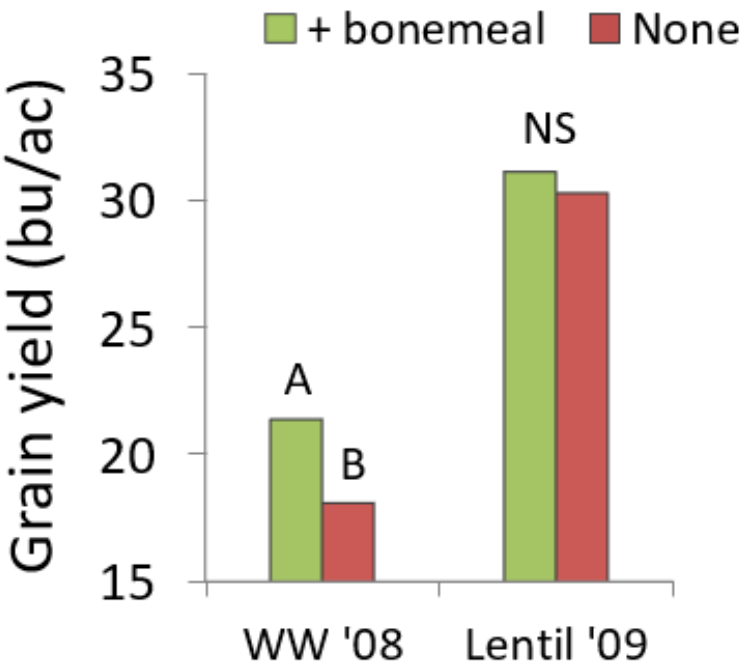
- high-reactive (sedimentary rock) source worked in > pH 7, Ca-soils; low-reactive (igneous) did not (Arcand et al. 2010, ON)
- finer grind of low-reactive sources doesn't help
- limited resource w/mining & transportation cost

Bone meal (3-18-0)

- intermediate solubility
- fine grind helps

➢ broadcast and **incorporate** several weeks to months in advance or place near seed

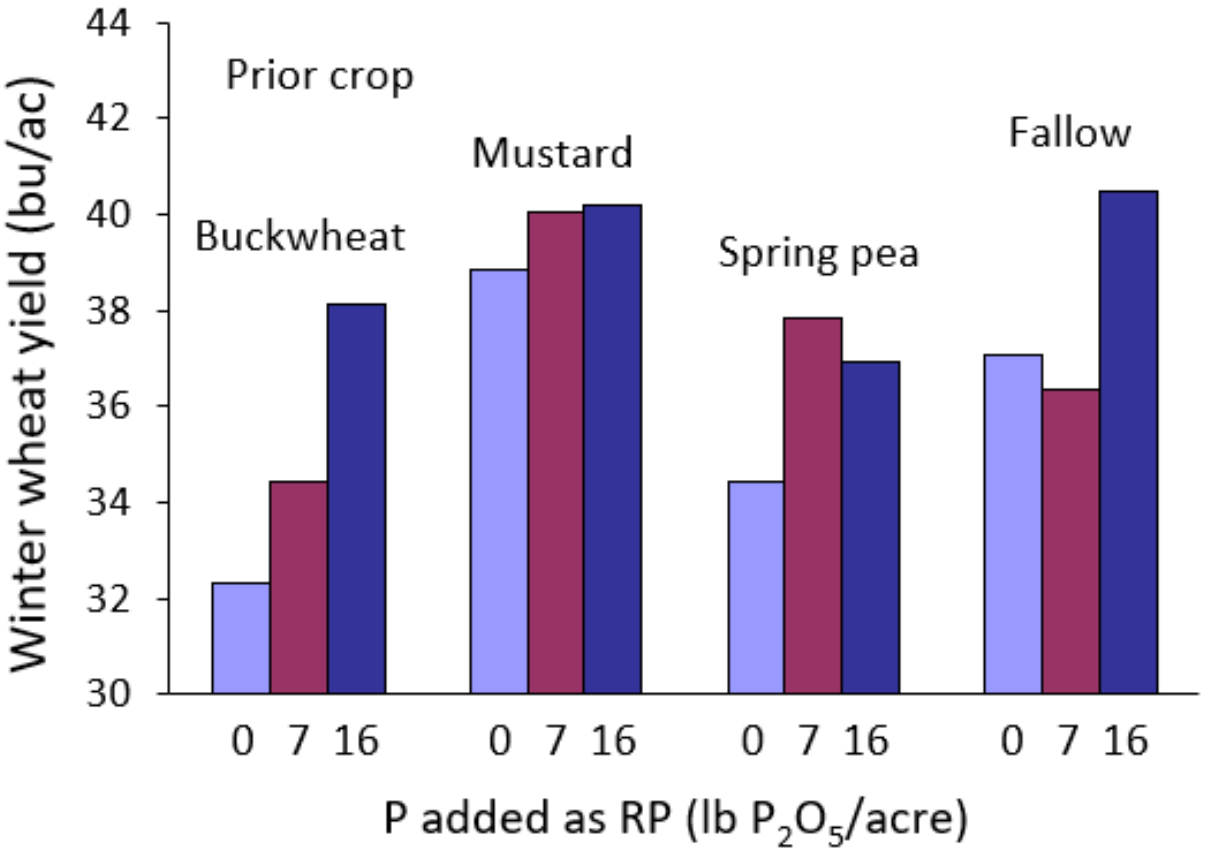
25.5 lb P_2O_5/ac added fall 2007



Jones unpub. data

Nelson and Mikkelsen Better Crops 2008 vol 92, No.1

Crop rotations and P availability from rock P



- Some crops better at 'extracting' P (e.g., legumes, buckwheat, some brassicas)
- Doesn't always benefit next rotation.
- Yields increased with P rate, not by cover species.
- Rotations and covers do not supply new P

Rick et al. 2011, organic system, Big Sandy, MT, Olsen P = 16 ppm

Other options – mixed results

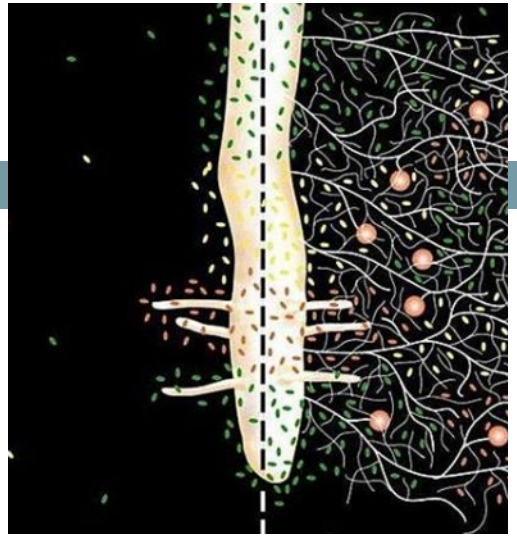


Image by Earth's Internet & Natural Networking

Arbuscular mycorrhizal fungi (AMF) reach places roots can't

- Cereals, legumes, sunflowers host AMF; brassicas do not
- Greater potential benefit in low P soils
- Encourage AMF with reduced tillage, perennial forage

Bacteria (e.g., *Penicillium spp*.) alone or with RP

- Greater potential benefit in low P soils

Before you spend $ on an amendment such as *P. bilaiae* or humic acid, do test strips.

Iowa State Univ Compendium of Research Reports on Use of Non-Traditional Materials for Crop Production as resource

Summary

- Nitrogen can be supplied with livestock manure and legume cover crops.
- Legumes must be used every 2 to 3 years to build soil N.
- Phosphorus can be supplied with manure or certified organic products, yet P availability is often low in those products.
- Cover crops do not appear to affect P availability for subsequent crop.
- Mixed results with amendments such as *P. bilaiae.*
- Sulfur can be supplied with manure or certified products (economics??).
- Proper timing and placement increases fertilizer use efficiency.

THANK YOU

QUESTIONS?

CCAs scan this QR code and put name and CCA number in chat box if don't have app and as backup.

For additional information on cover crops and soil fertility, see http://landresources.montana.edu/soilfertility and *Soil Nutrient Management on Organic Grain Farms in Montana (EB0200)*