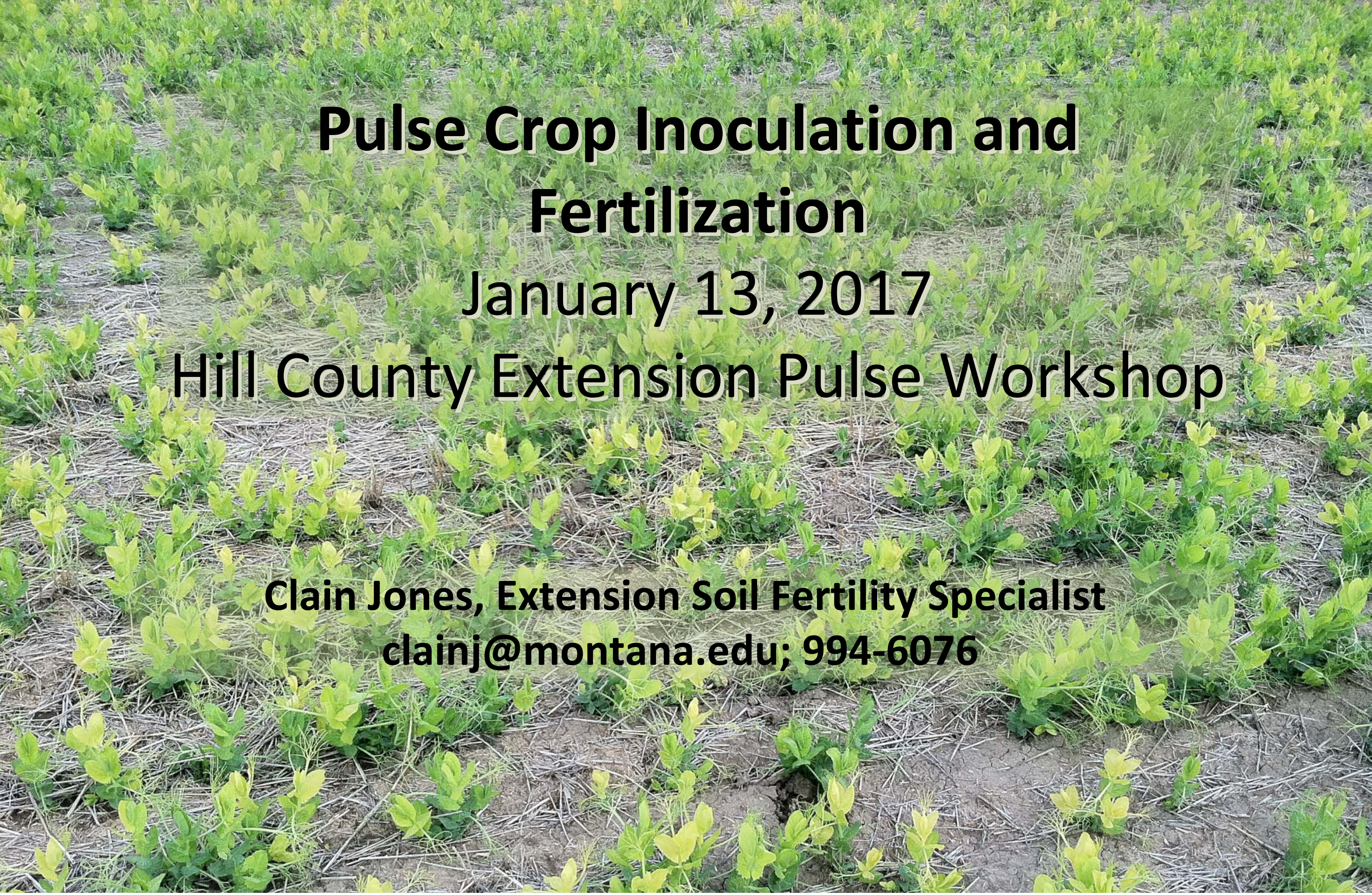

Pulse Crop Inoculation and Fertilization

January 13, 2017

Hill County Extension Pulse Workshop

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Objectives

- How are pulse growth and fertility needs different from small grains?
- N-fixation by growth stage
- N fertilization and inoculation effects
- P, K, S needs
- Fertilizer rates, placement, timing
- Calculating N credits

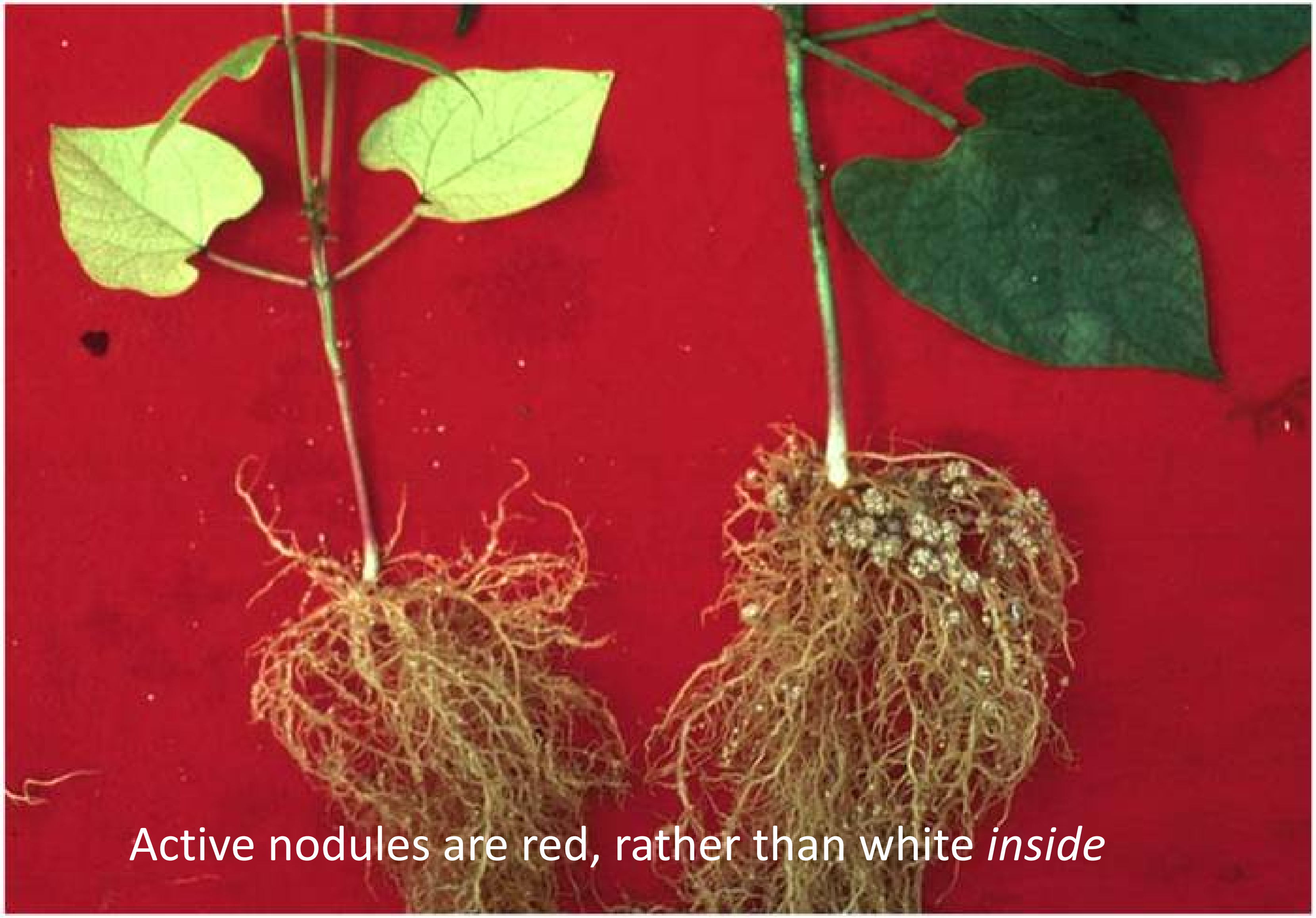
Nitrogen fixation process

- Nodulation begins 2-3 weeks after plant emergence
- Nodules are active 3-4 weeks after plant emergence
- Peak activity by 4-5 weeks
- Active nodules are pink to red inside
- Amount fixed depends on species

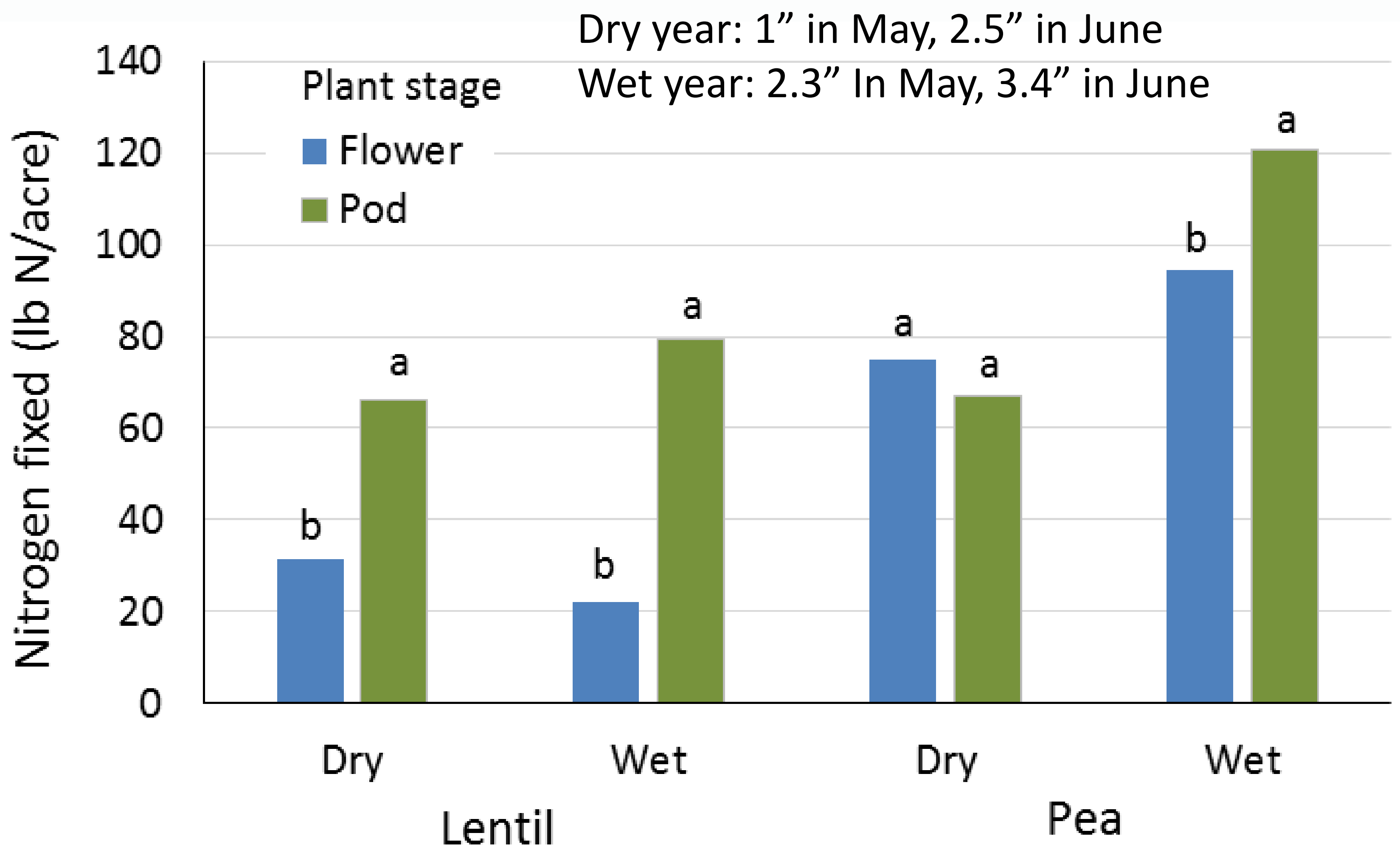
(faba bean > pea > chickpea > lentil)

Nodulated pea root
Courtesy A. McCauley

Without healthy nodules legumes don't fix N



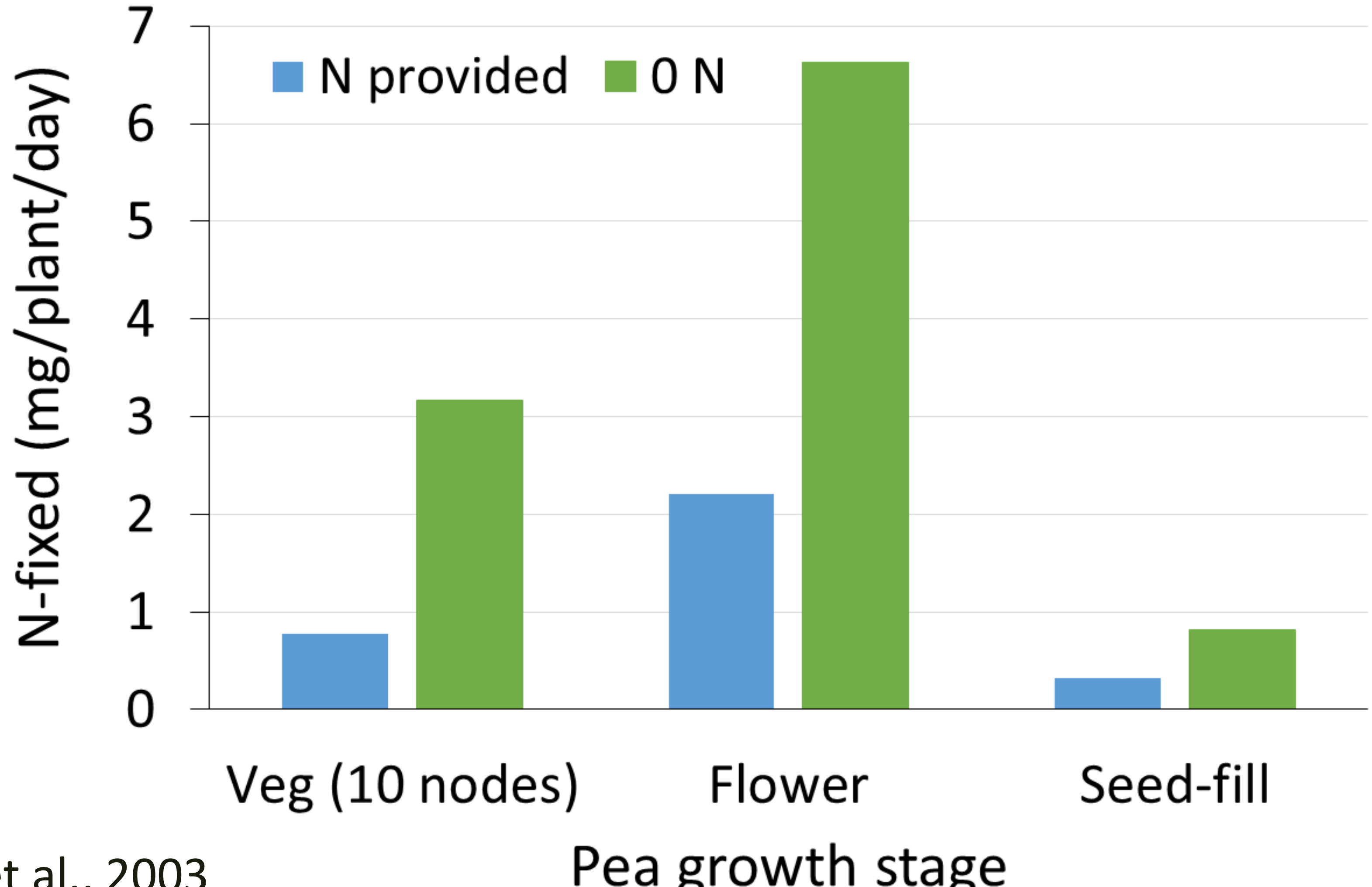
N fixation by lentil and pea in wet and dry years



McCauley, 2011
Gallatin Valley, spring planted
Determined by N difference method

Nodules are very sensitive to water stress

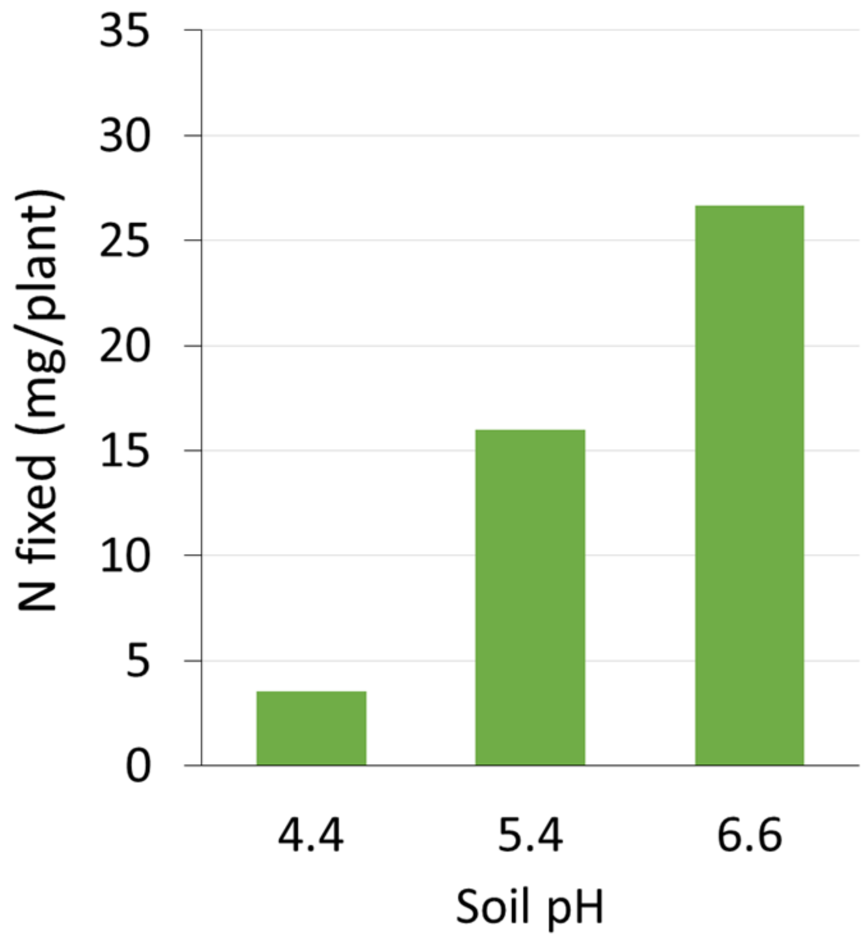
N-fixation declines as plant matures; is reduced if fertilized with N



Voison et al., 2003
greenhouse study

Uncontrollable factors negatively affecting nodulation & N fixation

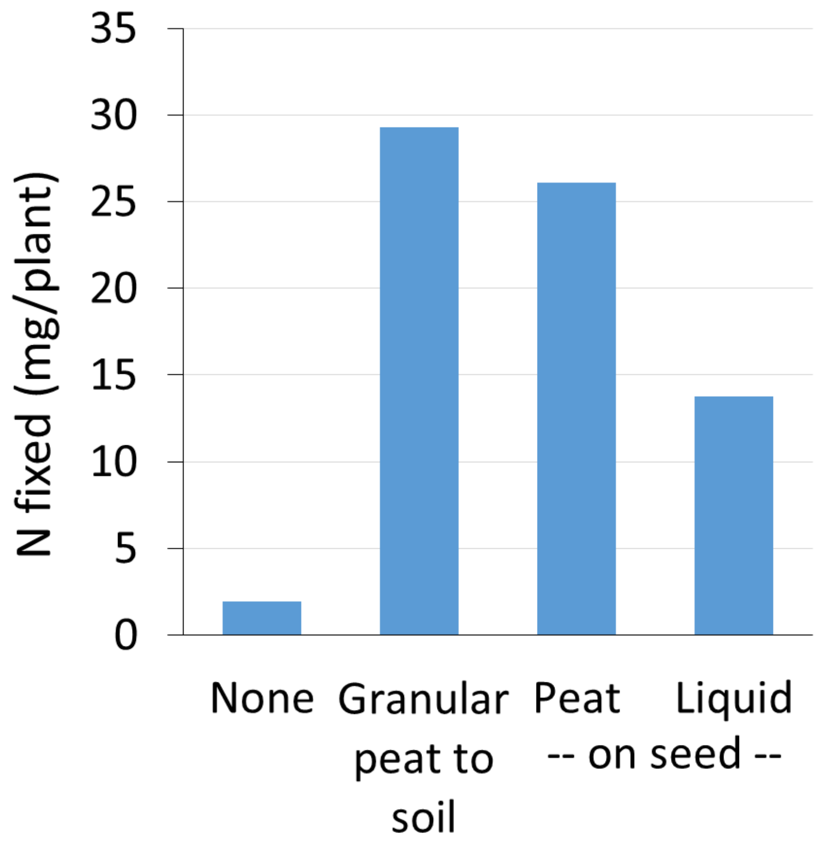
- Extreme soil temps
- Waterlogged or dry soil
- Soil pH < 5.5, >8.5 inoculant strains differ in tolerance
- Saline soils



Rice et al., 2003, greenhouse

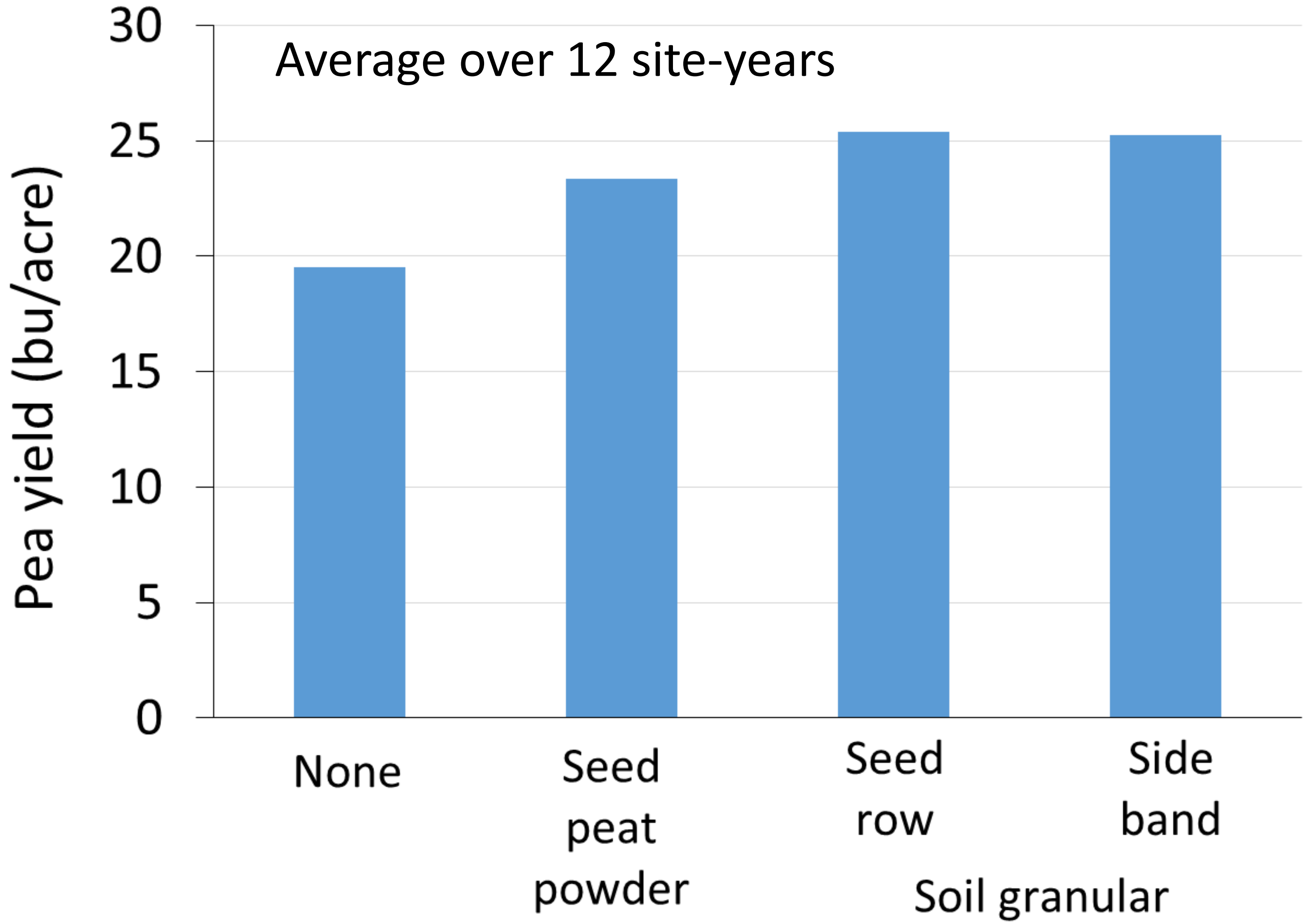
Practices to improve nodulation & N fixation

- Use species specific inoculant
- Keep inoculant cool, dark; granular more reliable than liquid
- Apply proper inoculant rate
- Avoid fertilizer salts (mixing with fertilizer kills most inoculant bacteria in hours)
- Adequate P, K, S
- Soil N: too much inhibits
- No-Till = retained soil moisture



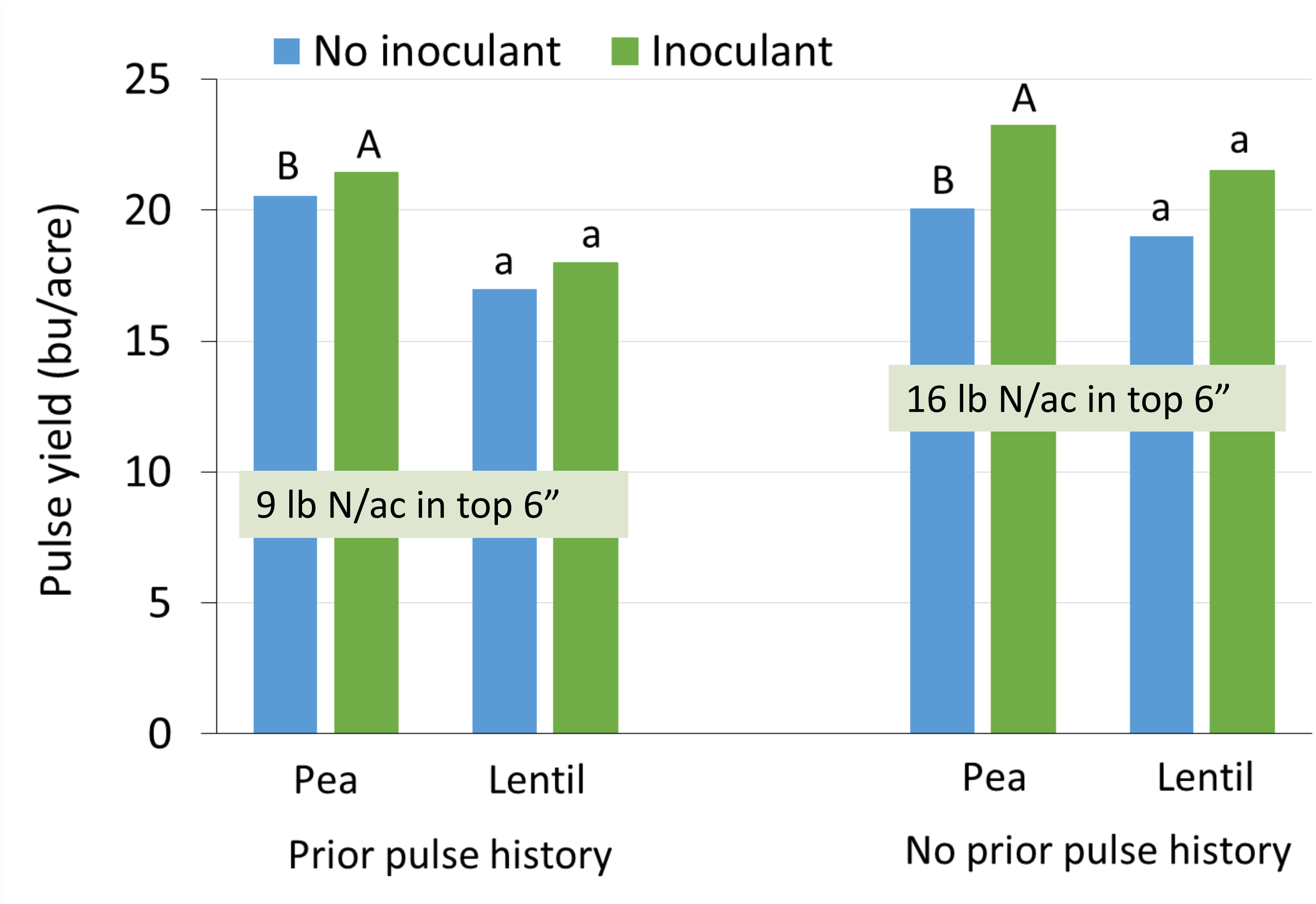
Rice et al., 2003, greenhouse

Inoculant source and placement



Gan et al., 2005, SK

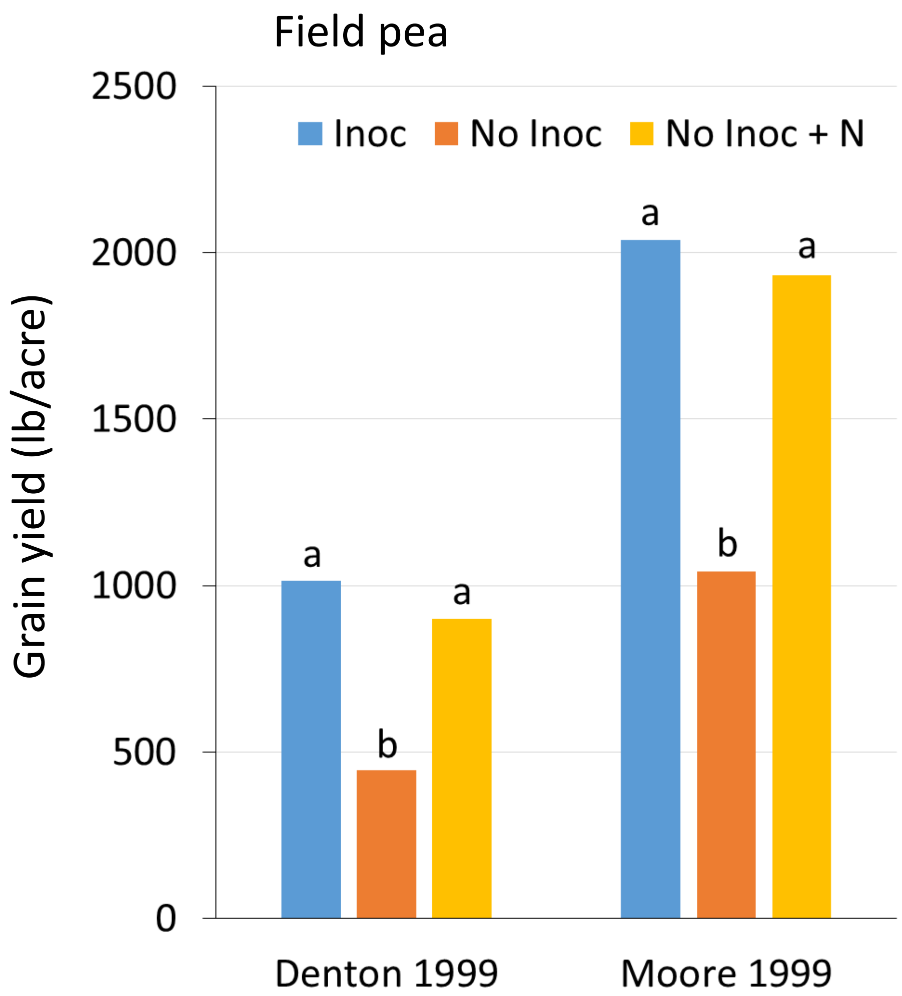
Effect of inoculation on pea and lentil yield, fields with and w/out pulse crop history

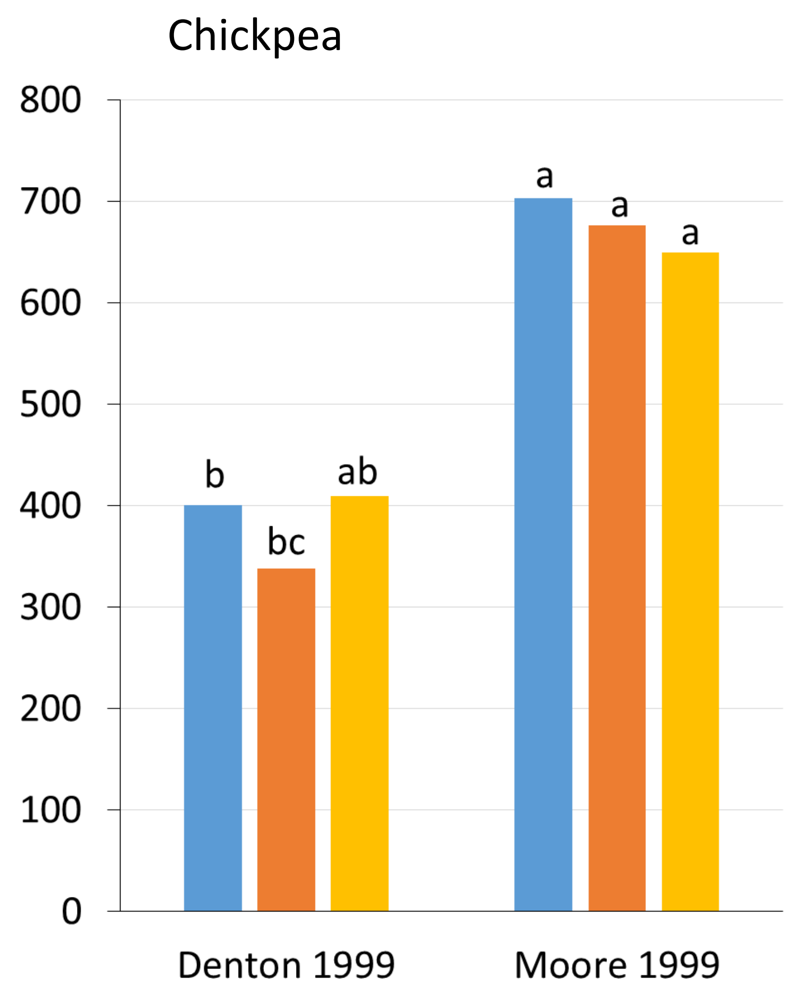


Inoculation more important in ‘new’ fields

Huang et al., 2017 in press, Moccasin

Inoculation and N on field and chick pea, on sites with no recent pulse history





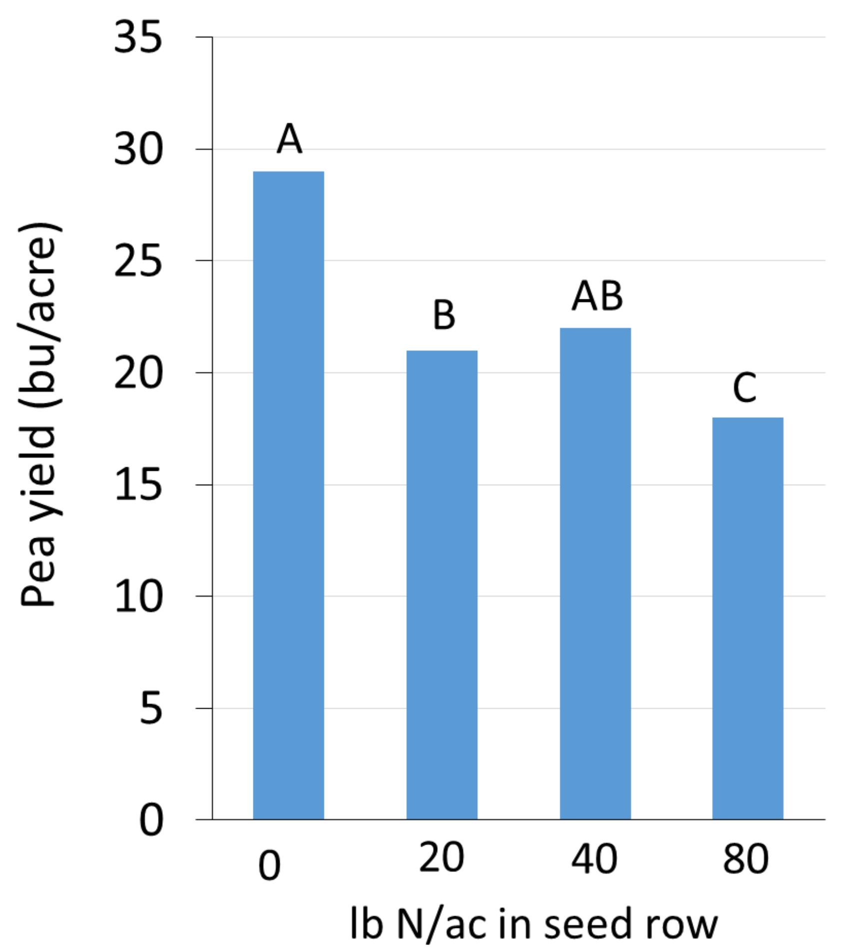
McConnell et al., 2002, stat letters (a, b) are w/in location-year

If legumes fix N, why add fertilizer N?

- Nodulation is carbon expensive, requires healthy plants
- Little N contributed by nodules until 3rd node, must come from top 12” of soil
- Rhizobial fed plants take 2-3 weeks longer to get going
- If insufficient N, plants get ‘stuck’ – can’t grow to feed nodules, nodules aren’t actively providing N for growth
- Insurance against nodule loss to pea leaf weevil
- N-fixation stops if soil nodule dries up, but the plant can keep producing, if there is soil N

How much seed row N is too much?

- Too much N
  - inhibits nodulation
  - excess vegetation
  - reduced yield
- > 25-35 lb total available N/ac (soil + fertilizer) nodulation/fixation is reduced
- >50 lb N/acre delays or eliminates fixation (SK Pulse Growers)



Huang et al., 2017 in press, Moccasin

Starter N

- SK suggests add starter N if soil N < 10 lb/acre (12” depth)

  How know? *Soil test in the spring*

- Starter N if crop shows poor nodulation (van Kessel and Hartley, 2000)

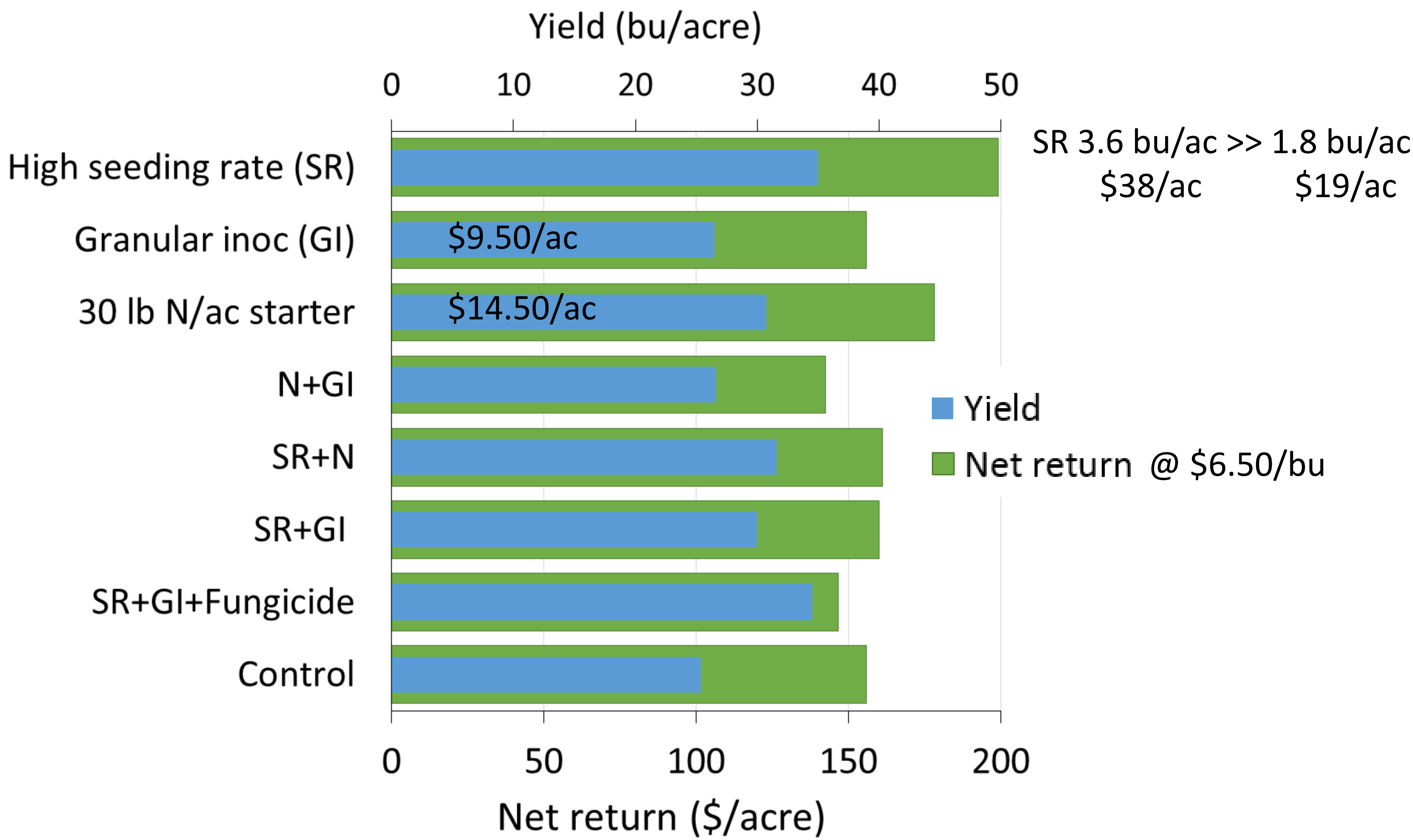
  How know? *Dig and look for rosy red nodules (white indicates not active), yellow lower leaves (N deficiency)*

- Place to side of seed, not with the seed
- With lentil and chickpea starter N benefits earlier growth & maturity and improved harvestability (lowest pod higher off the ground, Gan et al., 2003).

Rescue N

- SK suggests 40-50 lb N/ac topdress
- Up to 6 weeks after seeding (McConnell et al., 2002).
  - Pea: 9-12 node stage
  - Chickpea: 10-13 node stage
- If later, get too much vegetative growth, poor pod set and delayed maturity
- Yield gain may not offset cost (McConnell et al., 2002)
- Need water/rain to move N into soil

Input effects on pea on 'low yielding' (<45 bu/ac) sites



Grenkow et al., 2014, Saskatchewan

Why might granular inoculant (GI) not always pay?

Yields usually go up, but not always enough to offset the cost of inoculant. Considerations?

- Soils high in N (McKenzie et al., 2006)
- Fields with long or recent history of inoculation
- Dry soils – rhizobia die and water is limiting yield (McKenzie et al., 2006)
- Premium for protein? GI tends to consistently increase protein (data not shown). Protein may become a factor in price paid for pulse grains.

Questions on S?

On to S, P and K

Is this plant N deficient?

- Sulfur (S) deficiency is yellow upper (new) leaves
- S is necessary to take up N and make protein
- Soil tests are not reliable for S
- Base S on prior crop performance, S removal rate (0.15 lb S/bu seed) or tissue concentration (varies by crop)

Sulfur

Preventive

- Bank elemental S. 71 lb S/acre before canola in canola, barley, pea system provided enough for the pea rotation 3 years later (Wen et al., 2003, SK)
- Sulfate S: 15-20 lb/acre at planting (<18 lb/ace in seed row)
- Liquid S: to the side of seed row at <18 lb/acre (Ahmed et al., 2017, SK)
- Save the seed row for P

Rescue

- 3-5 lb S/acre as granular or liquid

Plant tissue S concentrations

Leaf S concentration at which 90% of maximum yields were obtained.	
Crop	Plant tissue S concentration (%)
Chickpea	0.18
Lentil	0.29
Faba bean	0.038
Sampling 2nd to 4th mature leaf at 7th leaf stage, 4 weeks after seeding. Huang et al. 1992.	

BOTH P and K needed for N fixation!

Phosphorus and Potassium removal by harvest		
Nutrient	Peas, lentils, chickpeas	Wheat grain (barley hay)
	lb/bu (lb/ton hay)	
P_2O_5	0.67 (11)	0.62 (13[1.])
K_2O	0.87 (32)	0.38 (38[1.])
[1.] Shewmaker 2012, Univ Idaho.		

P levels often low in Montana (due to calcareous soils)

K levels often moderate to high in Montana
No research located on K and legumes in region

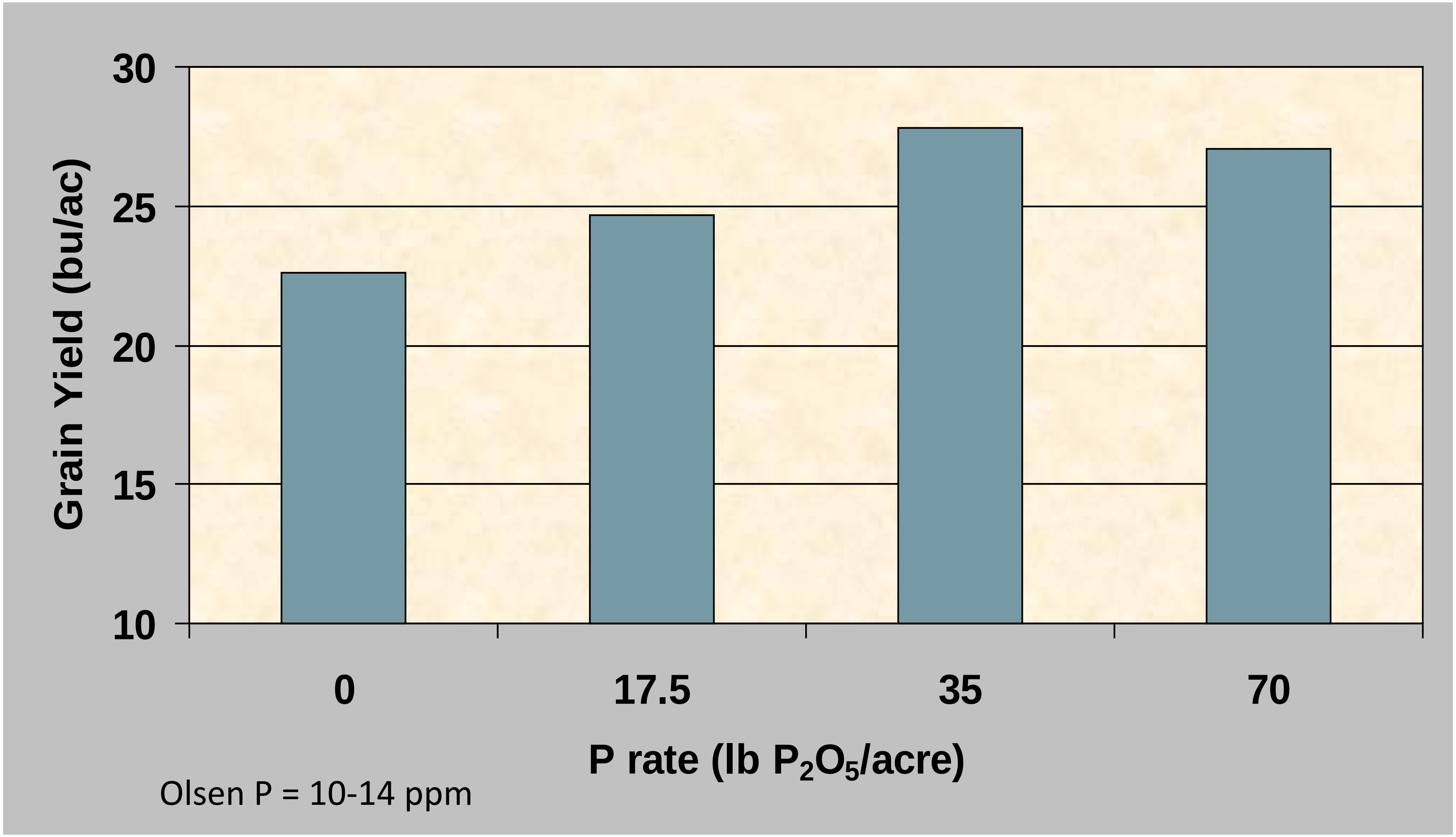

Not Fertilized
Fertilized w/ P, K, and S
ORG1 # 308 CD
Winter Pea, Bozeman, 5/17/07

Montana phosphorus fertilizer guidelines for annual legumes vs winter wheat

Olsen P (ppm) 0 to 6"	Annual legume application rate (lb P_2O_5/acre)	W wheat application rate (lb P_2O_5/acre)
4	30	50
8	25	45
12	20	40
16	15	35
Above 16	0 up to crop removal*	

* Assume 2/3 lb P_2O_5 per bushel of grain

Effect of P on spring pea yield (2004-2005)



Data from J. Waddell, Sidney, MT

Why are P needs of annual legumes somewhat less than for small grains and oilseeds?

- Lower yields
- Annual legumes root shallower:

  Better able to take advantage of higher P levels in upper 6 inches
- Legumes lower soil pH, mobilizing P, however this benefit does not appear to carry over to the next crop (Rick et al. 2011)

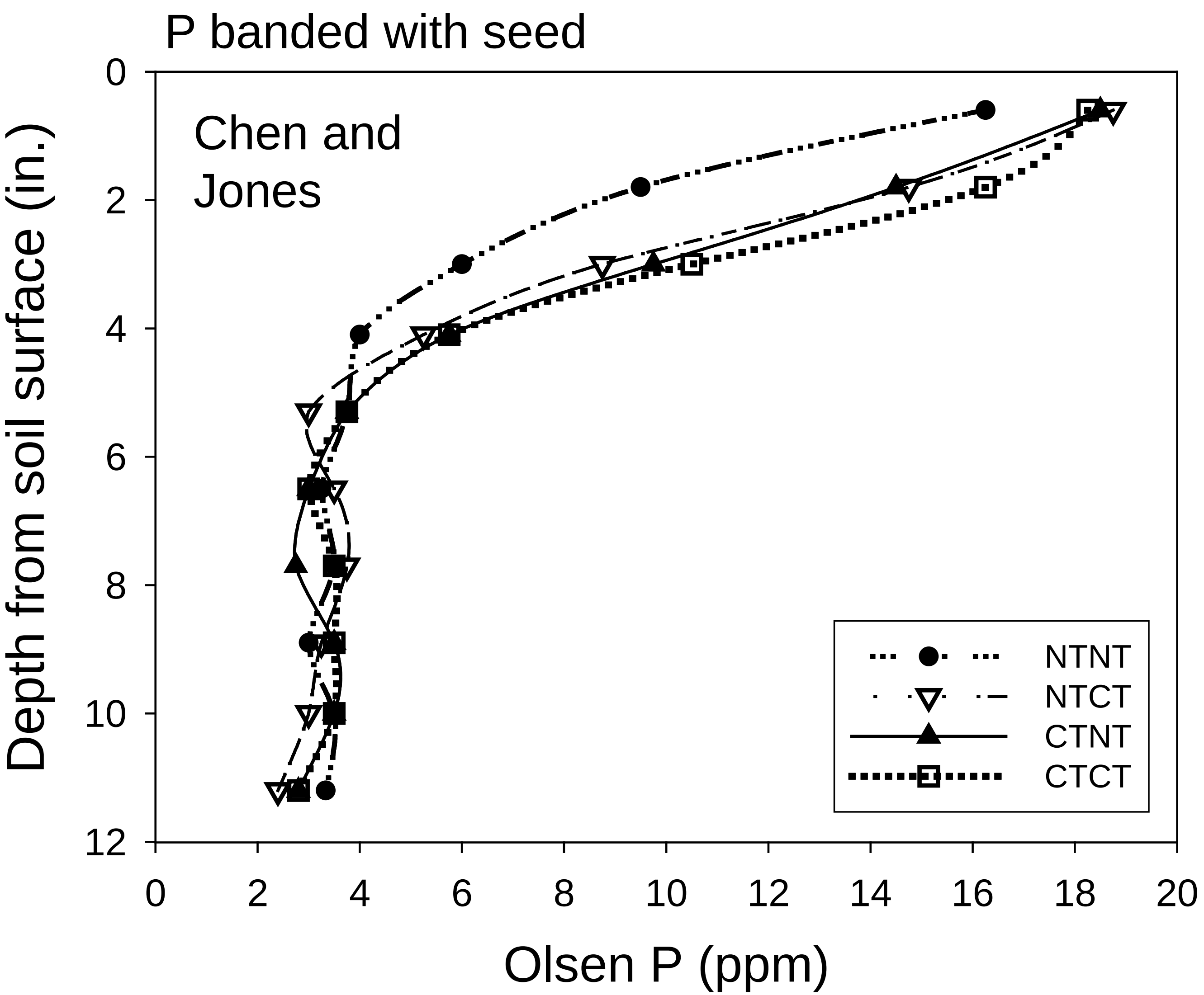
Maximum rooting depths (Mandan, ND)

Crop	Average maximum rooting depth (ft.)
Dry Pea	3.0
Canola	3.5
Spring Wheat	4.0
Sunflower	4.5

Merrill et al. 2002

Why does rooting depth matter?

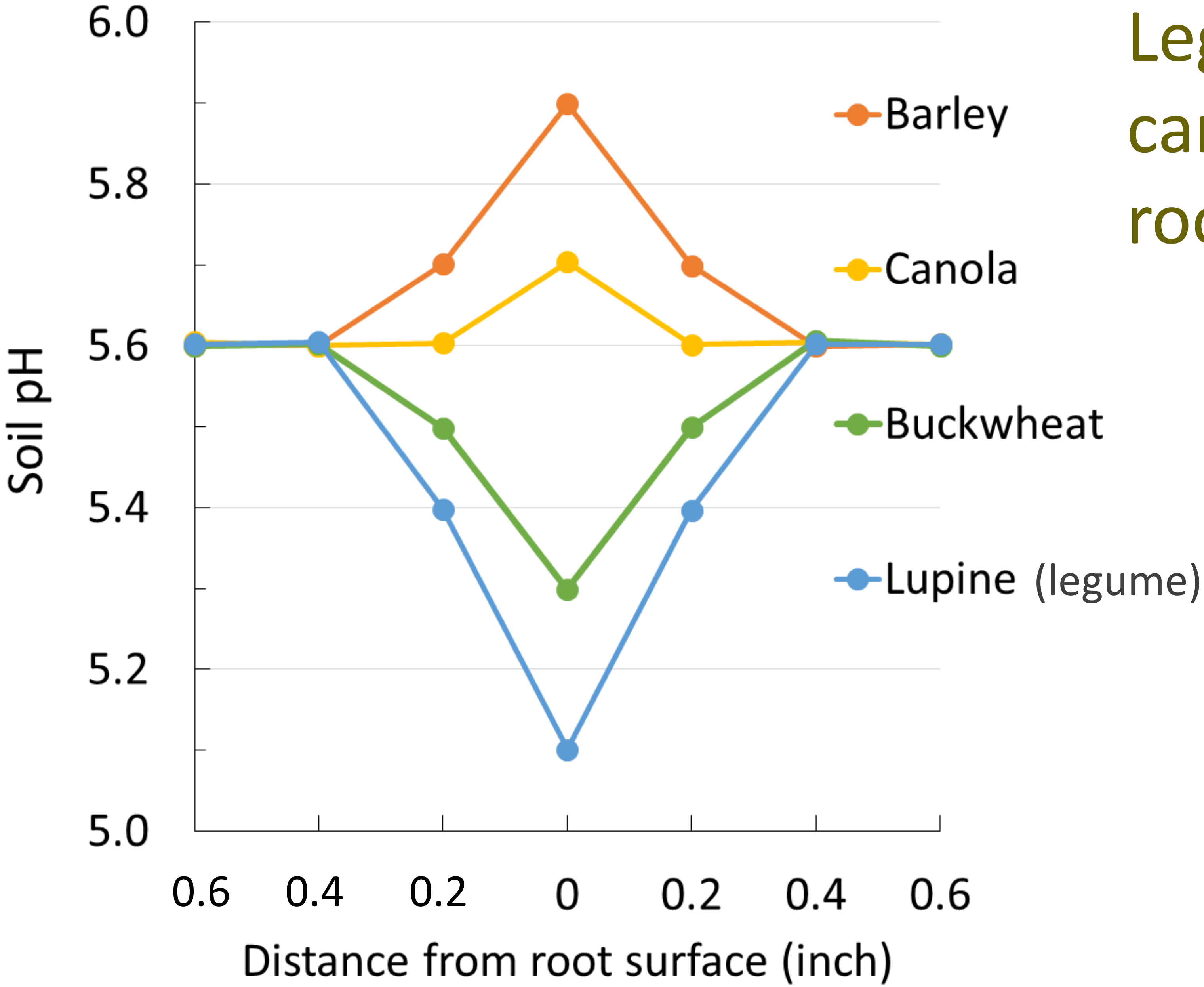
P accumulates near surface



Why important?

Shallow rooted crops can better utilize P from near surface

Legumes can acidify root zone

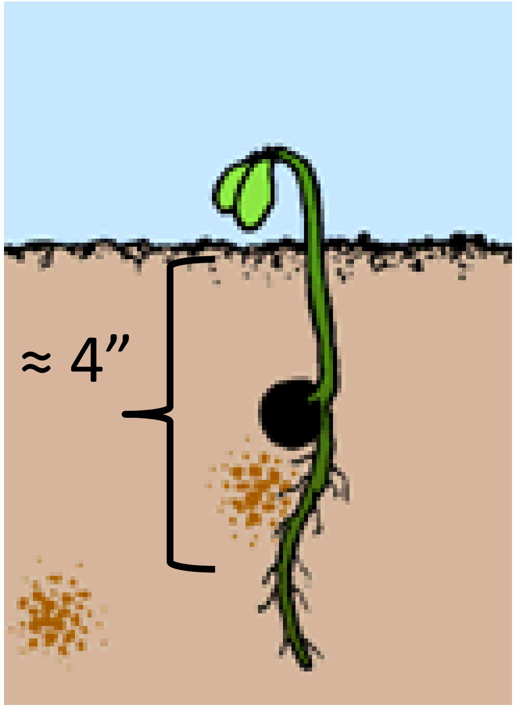


P response – depends on species and variety

- P response better when soil P < 9-13 ppm, add 30-40 lb P_2O_5/acre (Ffact No. 38; McKenzie et al., 2001; Karamanos et al., 2003)
- At soil P > 13 ppm, up to 15 lb P_2O_5/acre as maintenance amount ≈ max safe seed placed rate. Higher rates likely don't pay (Wen et al., 2008)
- P response loamy >> than clay loam soils (Karamanos et al., 2003)
- Starter P may increase harvestability rather than pod production in lentil (Gan unpub. 2003).

Phosphorus source for seed row placement

- MAP < 5-20 lb P_2O_5/acre seed placed
- DAP use CAUTION = toxic to seedlings
- Liquids – equally potent as MAP, but close proximity of band to seed = higher risk to seed (Grenkow et al., 2013).



- Coated specialty P – 2x safe seed placed rate, unsure on ability to provide needed P (Qian and Schoenau, 2010; Grenkow et al., 2013, SK)

Phosphorus placement

Seed row safe rates depend on soil and moisture

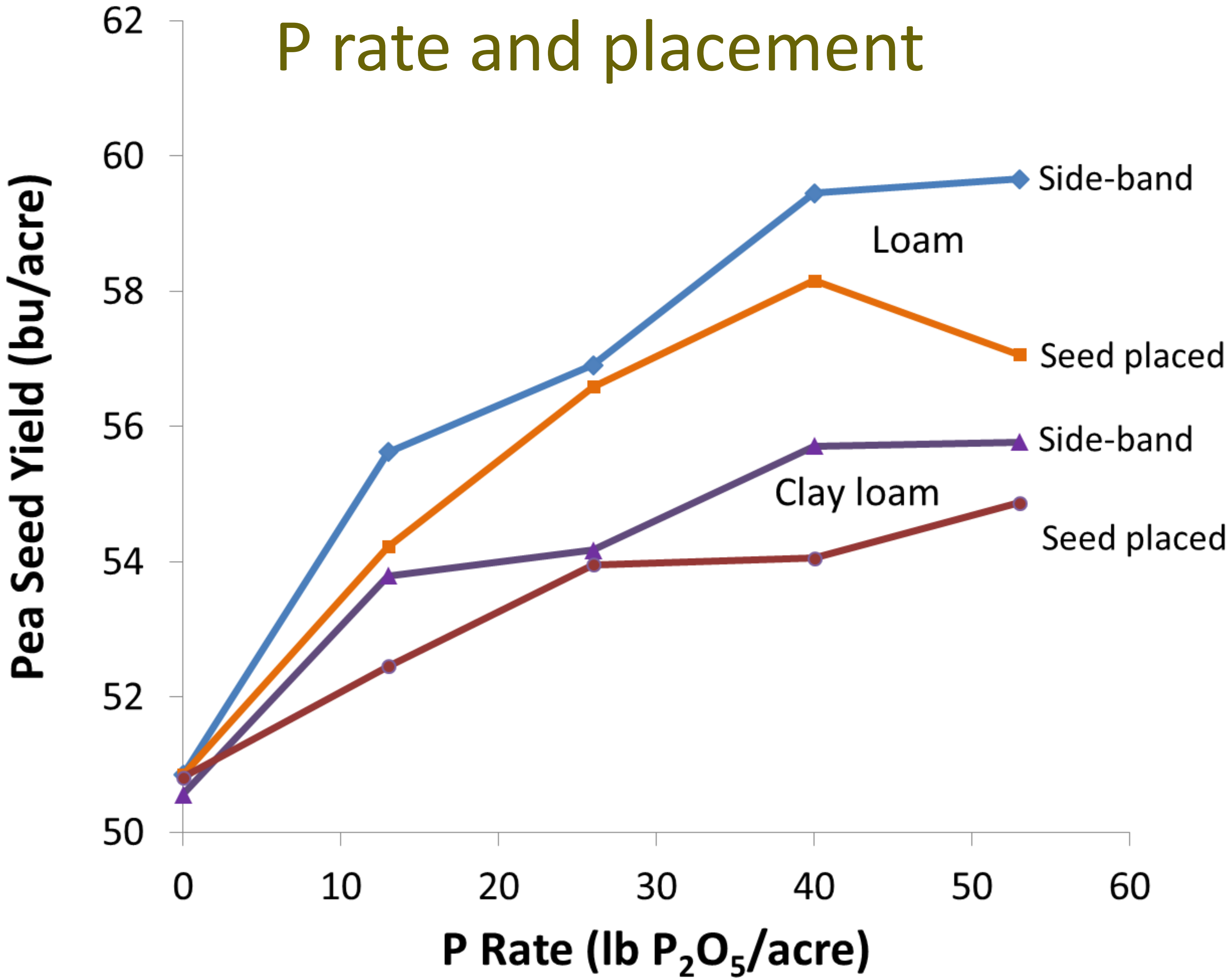
- heavy clay soil >> coarse
- high SOM >> low SOM
- high moisture >> dry soils

Equipment

Use wide openers, or put P in knife and seed in fertilizer slot

If more P required – sub-surface side band next to seed, broadcast incorporate before seeding, build with prior crop

P rate and placement



Karamanos et al. 2003, Alberta

Take home messages on P

- Annual legumes need similar amounts of P PER bu as wheat.
- P is necessary for N fixation.
- Legumes are better able to access soil and fertilizer P than small grains.
- Be cautious with seed placed, but don’t let that limit amount provided.

Potassium (K)

- K generally doesn't limit yield
- Guidelines for MT pulse crops

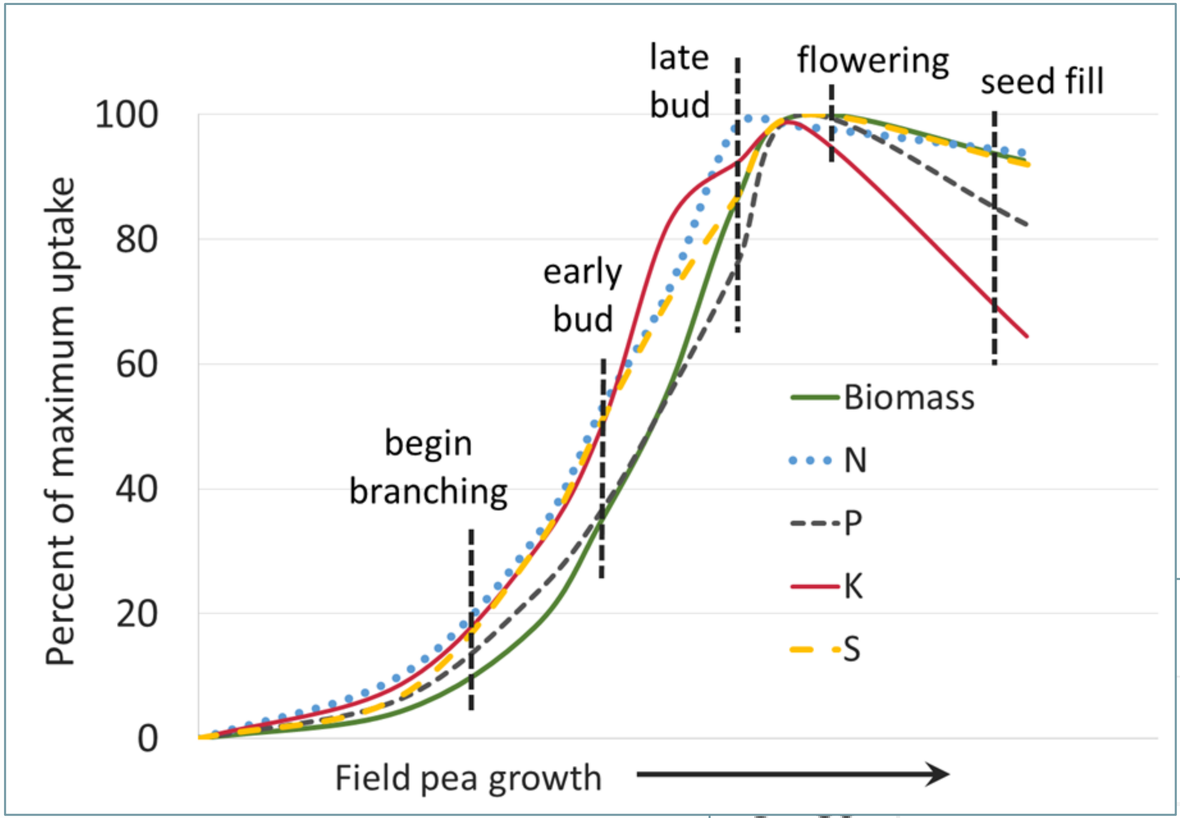
Soil K (ppm) 0 to 6 inches	Application rate (lb K_2O/acre)
0	45
50	40
100	35
150	30
200	25
250	20
Above 250	0 up to crop removal (0.9 lb/bu)

Questions?

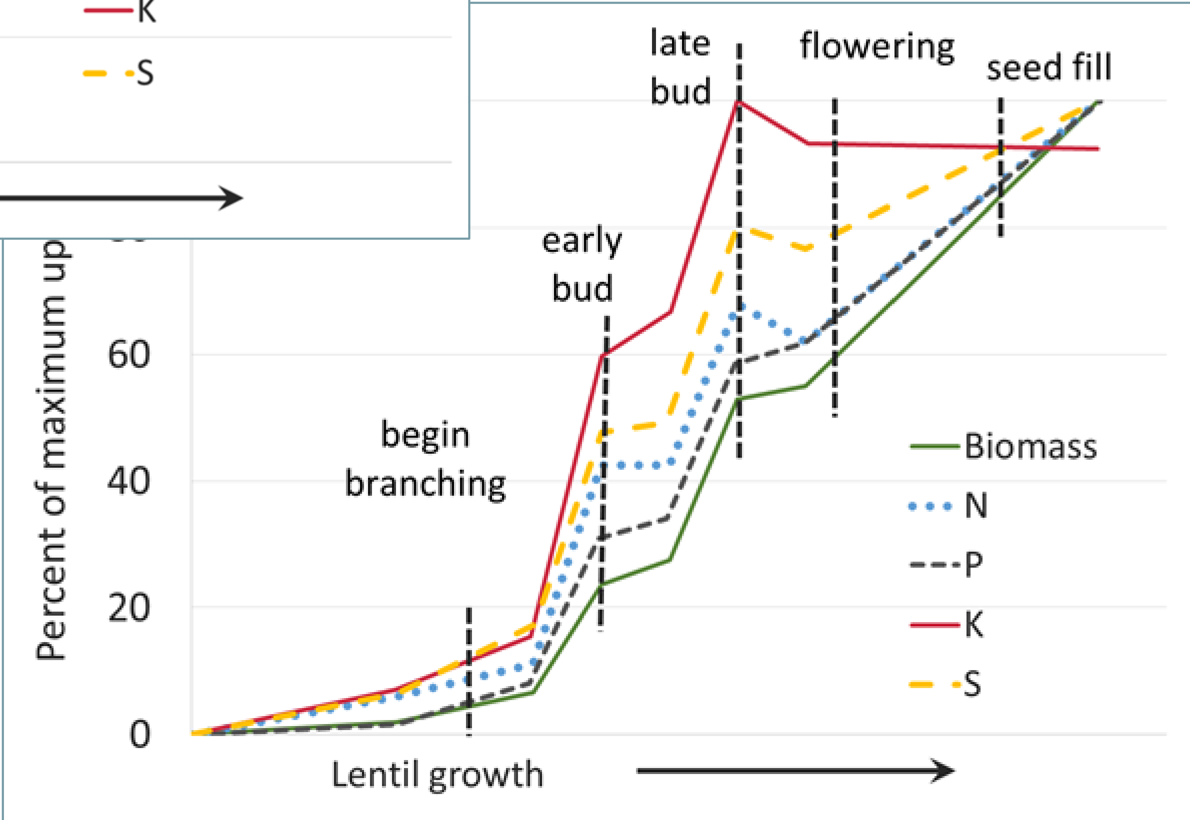
On to timing

Nutrient uptake

- Nutrient uptake precedes biomass
- Rapid demands once branching
- Indeterminates just keep growing



Pea



Source: Malhi et al., 2007, Saskatchewan

Lentil

Take home messages on Timing

- N: at seeding, or as rescue
- P: build up with prior crop, in very small amount at seeding, side band at seeding
- K: build up with prior crop, side band below the seed, not seed-placed
- S: elemental with prior crop, sulfate at seeding or as liquid for rescue

Conclusions on fertilization of pulses

- Encourage N-fixation
- P response likely higher on low P soils, low amounts of seed-placed may pay off
- K needs are high for legumes, but little research on pea or lentil
- Elemental S can last for several years
- With high pulse prices, fertilization can pay for itself, if water isn't limiting

Questions?

On to N credits from pulses

N credit from pulse/legumes

- N Credit = Fertilizer N (lb/ac) to back off from a standard recommendation (e.g., lb N/bu of yield goal) when previous crop is a legume (ideally based on late fall to early spring nitrate)
- N benefit = Soil nitrate after pulse
  – soil nitrate after non-pulse
  + N released from pulse residue
- N benefit > N credit. This is important.

What affects amount of N contributed to soil?

- Total yield, i.e., species and year productivity
- High N removed by harvest leaves less in soil, e.g. chickpea harvest removes more N than lentil. Can’t use pulse grain yield to estimate N credit
- Low biomass plants (semi-leafless varieties) contribute less N
- Species differences. In dryland environment, N contributed by field pea>lentil> chickpea
- N contribution is cumulative - increases with increased # of rotations

(Walley et al., 2007)

Recommended N credits in Montana

Crop	N Credit (lb N/acre)
Pulse grain crop grown 1-2x	~10
Pulse grain crop grown 3+ times	~20
Pulse cover crop grown 1-2x	20-30
Pulse cover crop grown 3+ times	30-50

Example N rate calculation
(Big Sandy study, Miller and Jones, unpub. data)

	Fallow	Grain pulse grown 1x	Legume cover crop grown 1x
WW yield goal (bu/ac)	45	35	40
Spring soil N (lb/ac)	80	55	65
Total soil N recommended (bu/ac x 2.6 lb/bu)	45 x 2.6 = 117	35 x 2.6 = 91	40 x 2.6 = 104
N credit (lb/ac)	0	10	25
Fertilizer N (lb/ac)	117-80-0 = **37**	91-55-10 = **26**	104-65-25 = **14**

Summary on increasing N benefit to next crop

- Manage pulses to encourage N-fixation
- Keep records of late fall to early spring soil tests and subsequent wheat grain protein to develop farm-field specific knowledge of N credits
- Pulse crop benefits don’t happen overnight

For additional information

Soil Fertility Website:

http://landresources.montana.edu/soilfertility

Contains links to my presentations including this one, the bulletin *Montana Cool Season Pulse Production Guide*, and more.

SK Pulse Growers' Nodulation and N-Fixation Field Assessment Guide

http://proof.saskpulse.com/files/general/150521_Nodulation_and_Nitrogen_Fixation_Field_Assessment_Guide.pdf

We Need Your Continued Support to Identify How Management Affects Yellow Pea Protein

- Can you provide MSU with YELLOW pea samples from your fields?
  - Send sample directly to MSU
    Attn: Mike Bestwick
    MSU-LRES
    334 Leon Johnson Hall
    Bozeman, MT 59717
  - Montana State Seed Lab Samples
- MSU analyzes your pea sample for protein for FREE and YOU complete a 10 question survey about pea management
  - Contact Mike directly or download surveys at www.peaproteinproject.com
- MSU identifies if management affects yellow pea protein.

MORE SAMPLES = BETTER RESULTS

With good soil fertility you can grow big pods

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