Nutrient Management of Pulses and N Credits

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CCA and dealer training, Huntley

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MSU Soil Fertility Extension and SARC

Objectives

Provide you info on pulse fertility so you can better answer your clients' questions

- N-fixation by growth stage
- N fertilization and inoculation effects
- P, K, S needs
- Fertilizer rates, placement, timing
- N credits from pulse crops

Nitrogen fixation process

- Nodulation begins 2-3 weeks after plant emergence
- Nodules are active 3-4 weeks after plant emergence (≈ 3rd node)
- Active nodules are pink to red inside
- Amount fixed depends on species

(faba bean > pea > chickpea > lentil)

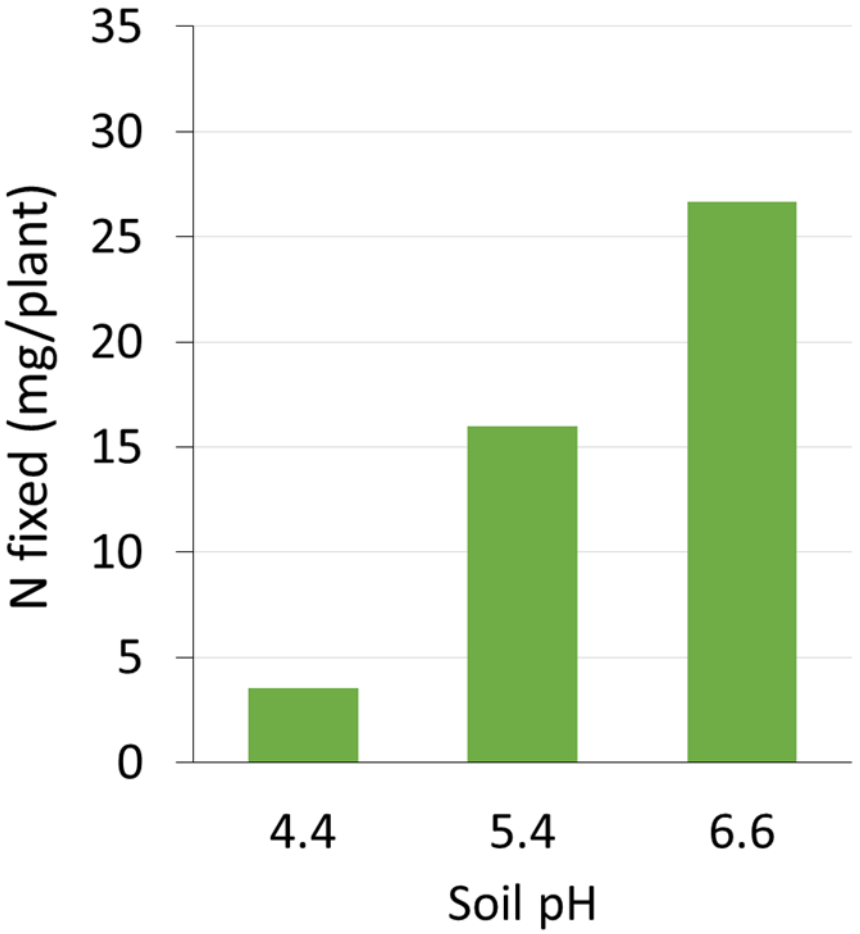
Nodulated pea root
Courtesy A. McCauley

Without healthy nodules legumes don’t fix N

Active nodules are red, rather than white *inside*

Uncontrollable factors negatively affecting nodulation & N fixation

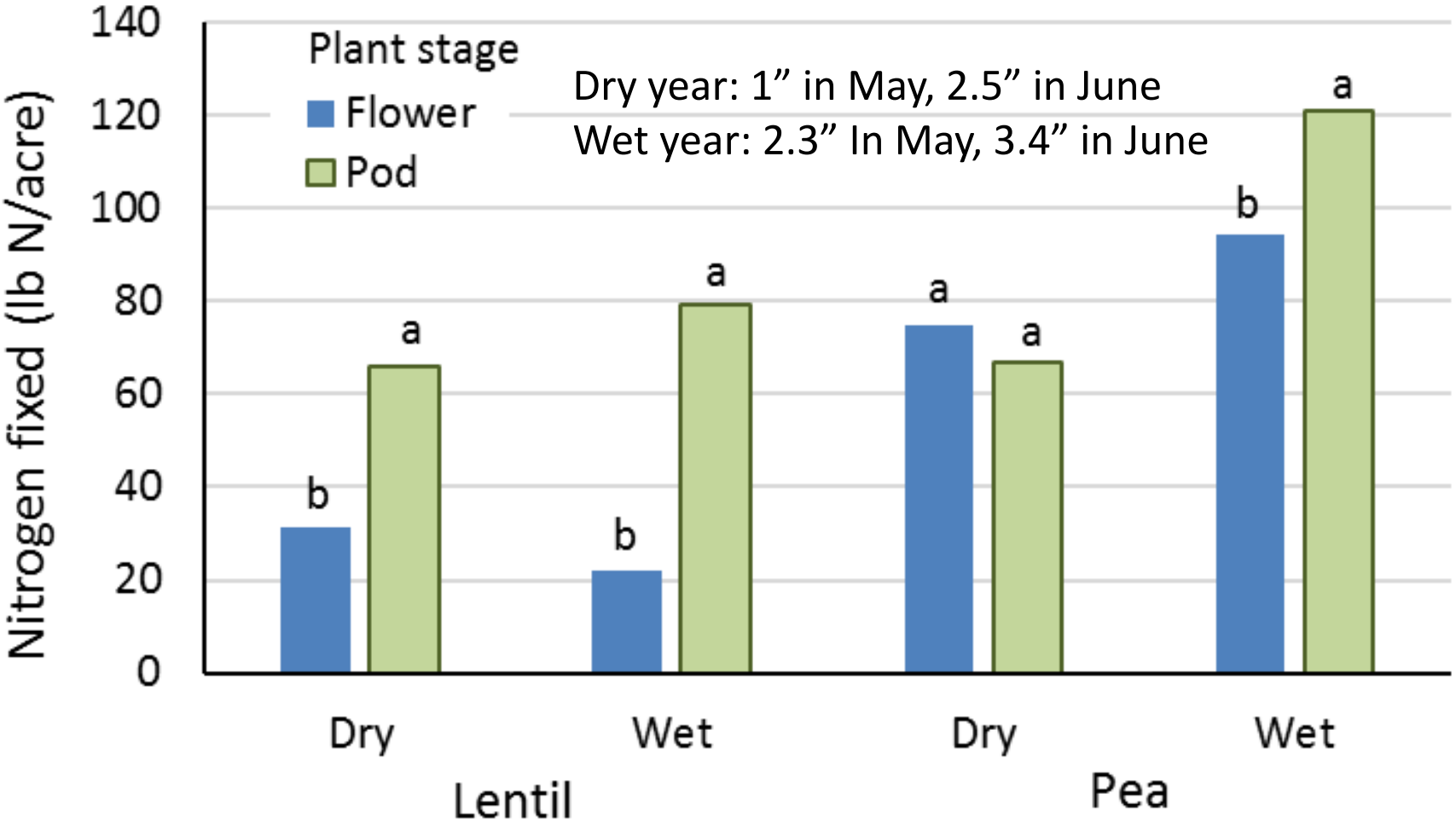
- Extreme soil temps
- Waterlogged or dry soil
- Soil pH < 5.5, > 8 inoculant strains differ in tolerance
- Saline soils



Rice et al., 2003, greenhouse

Nodules are very sensitive to water stress

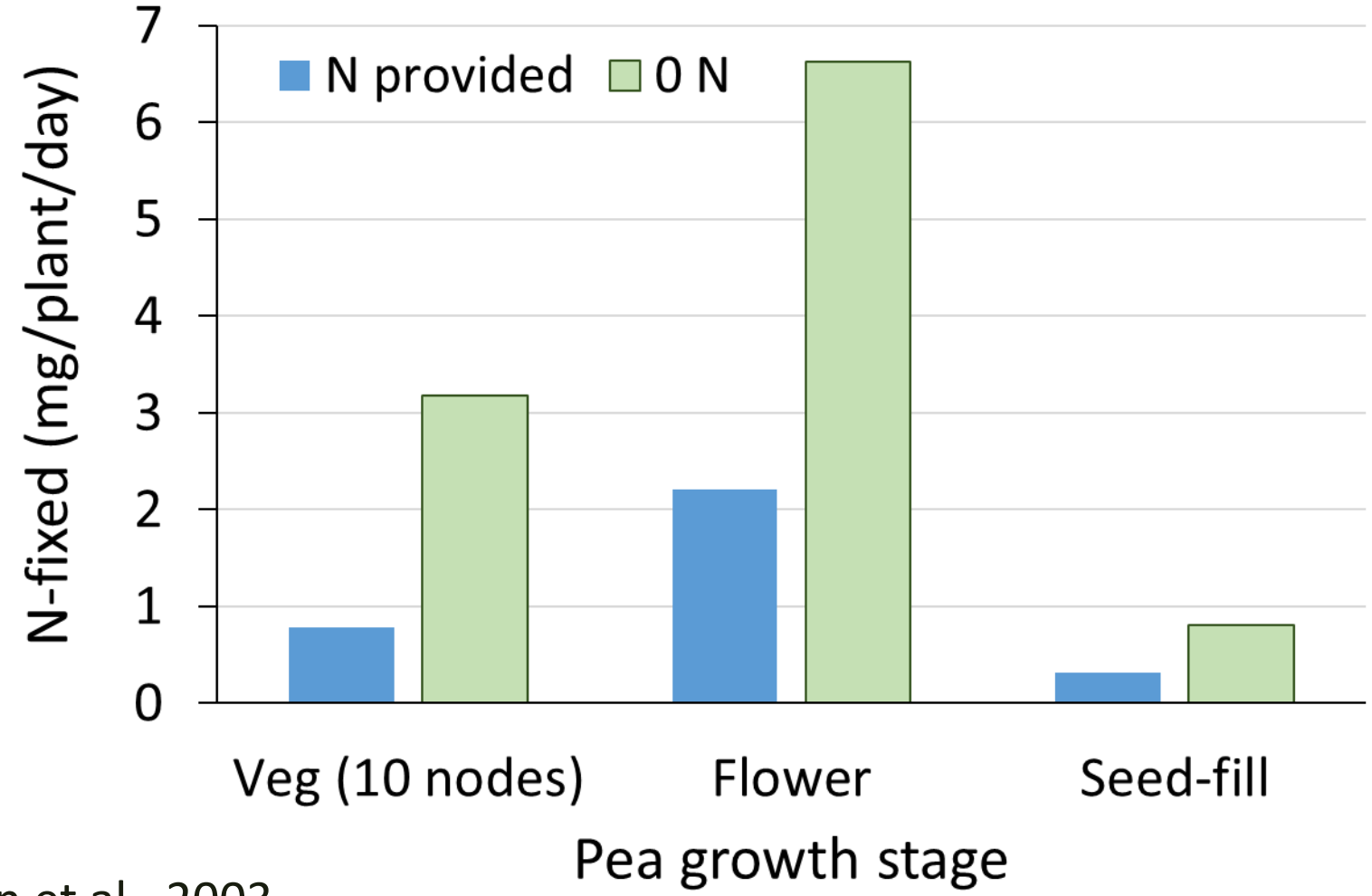
N fixation by lentil and pea in wet and dry years



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

N fixation can stop by flower stage at least in pea

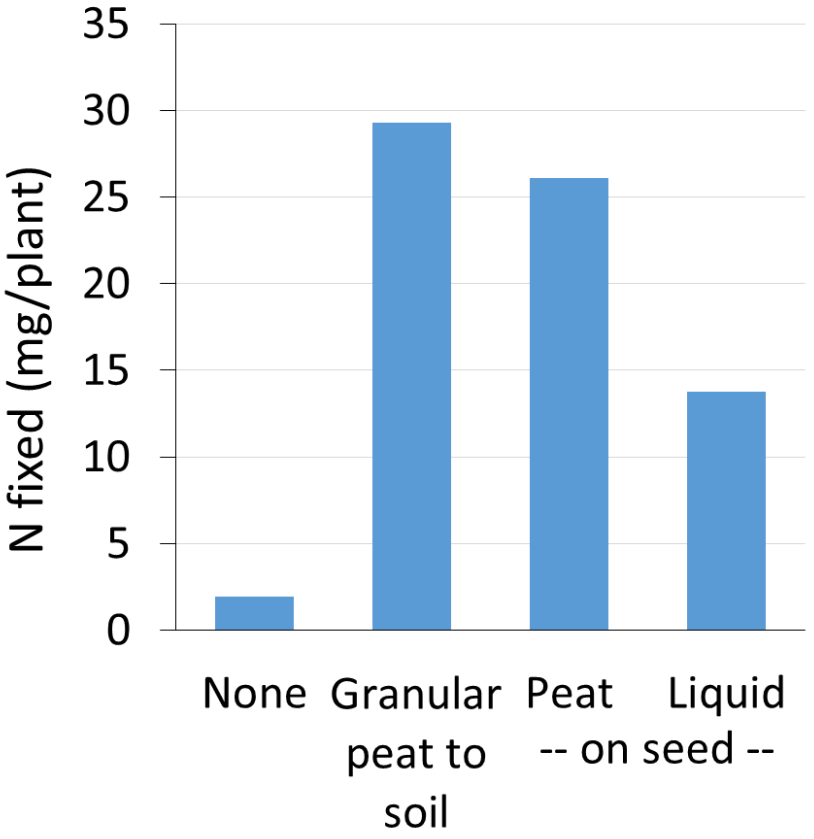
N-fixation declines as plant matures; is reduced if fertilized with N



Voison et al., 2003
greenhouse study

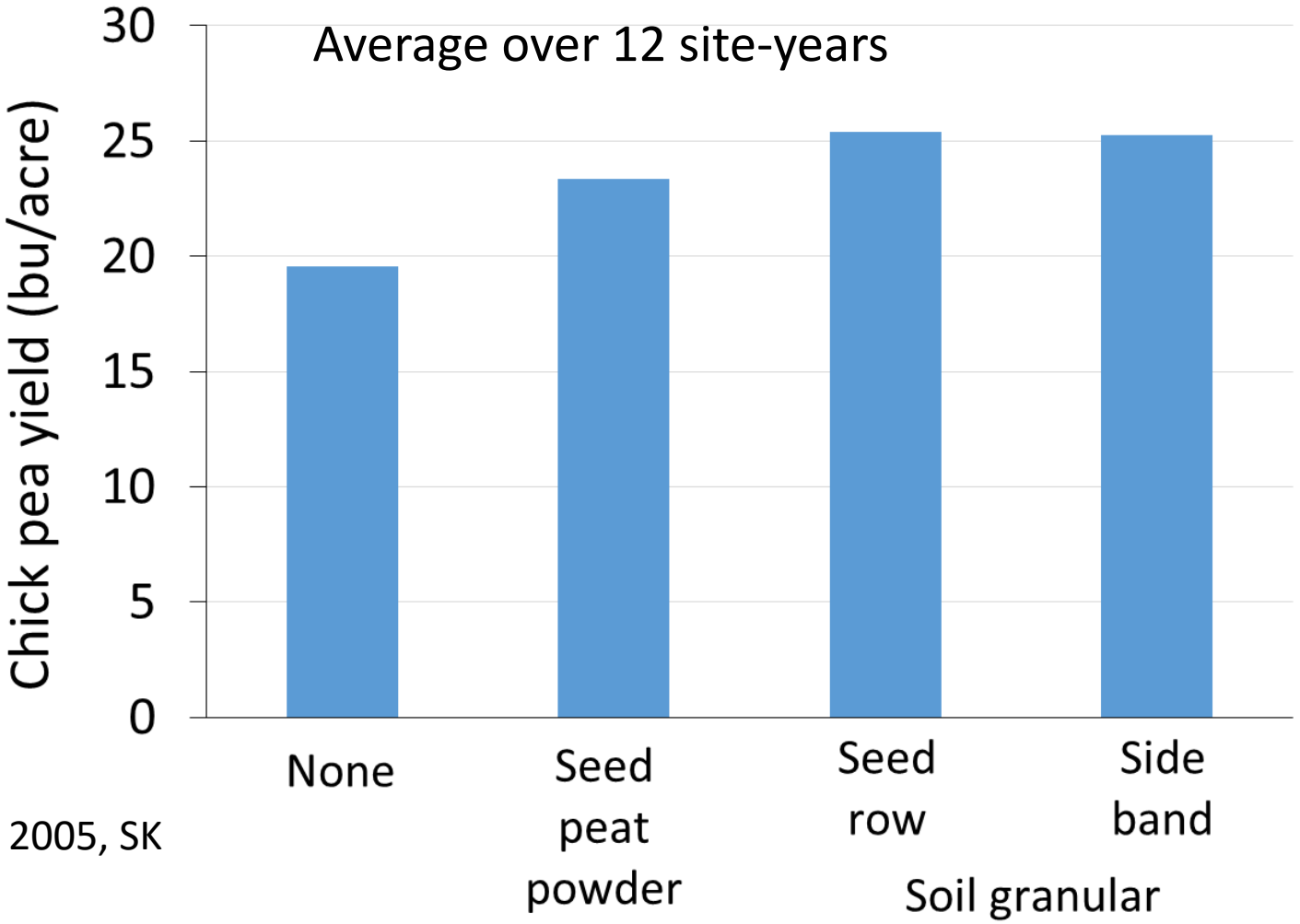
Practices to improve nodulation & N fixation

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



Rice et al., 2003, greenhouse

Soil granular seed placed and side-band increased yields 8/12 yrs compared to seed peat powder or no inoculant on “new” fields

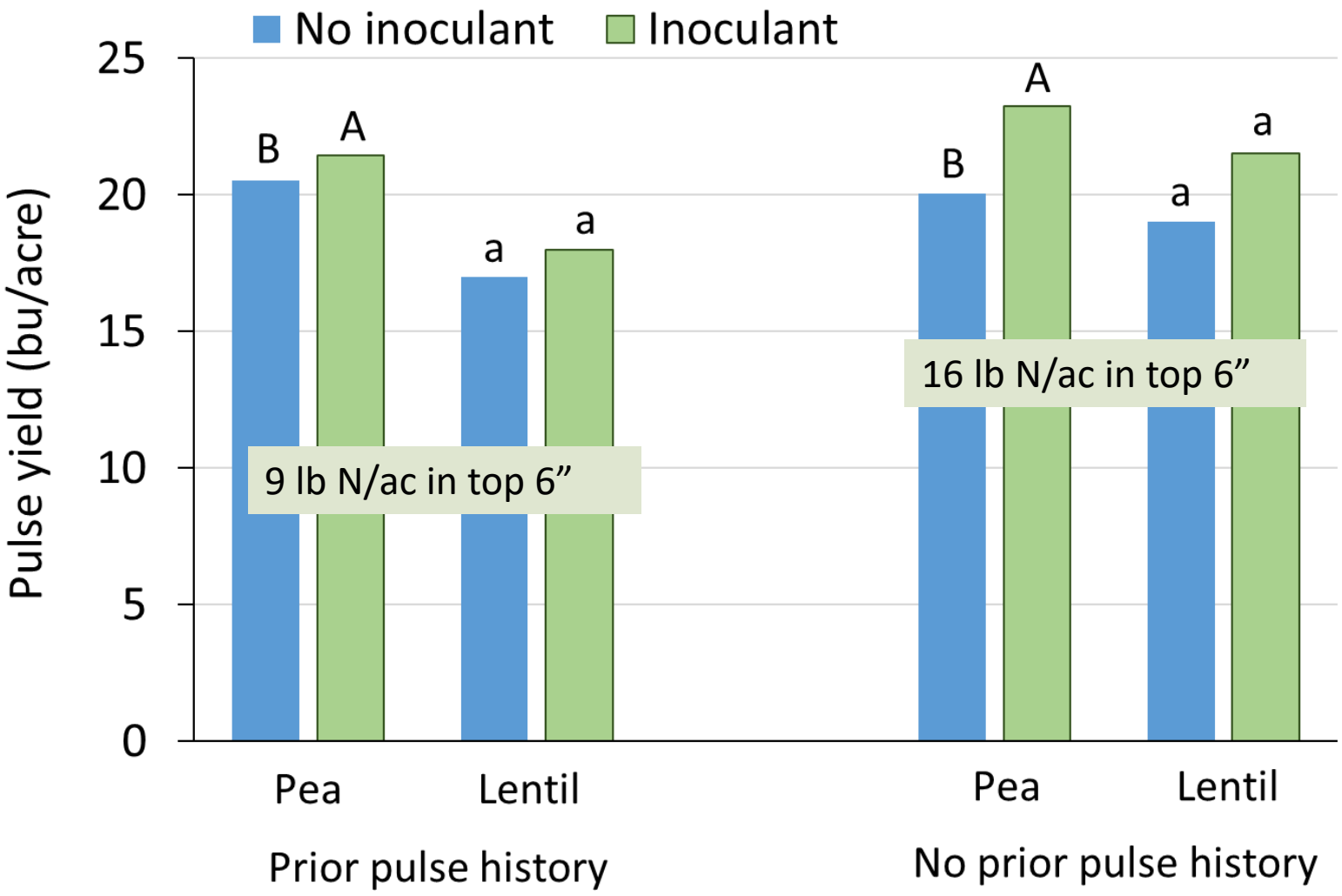


Gan et al., 2005, SK

“New” fields: Granular = more effective

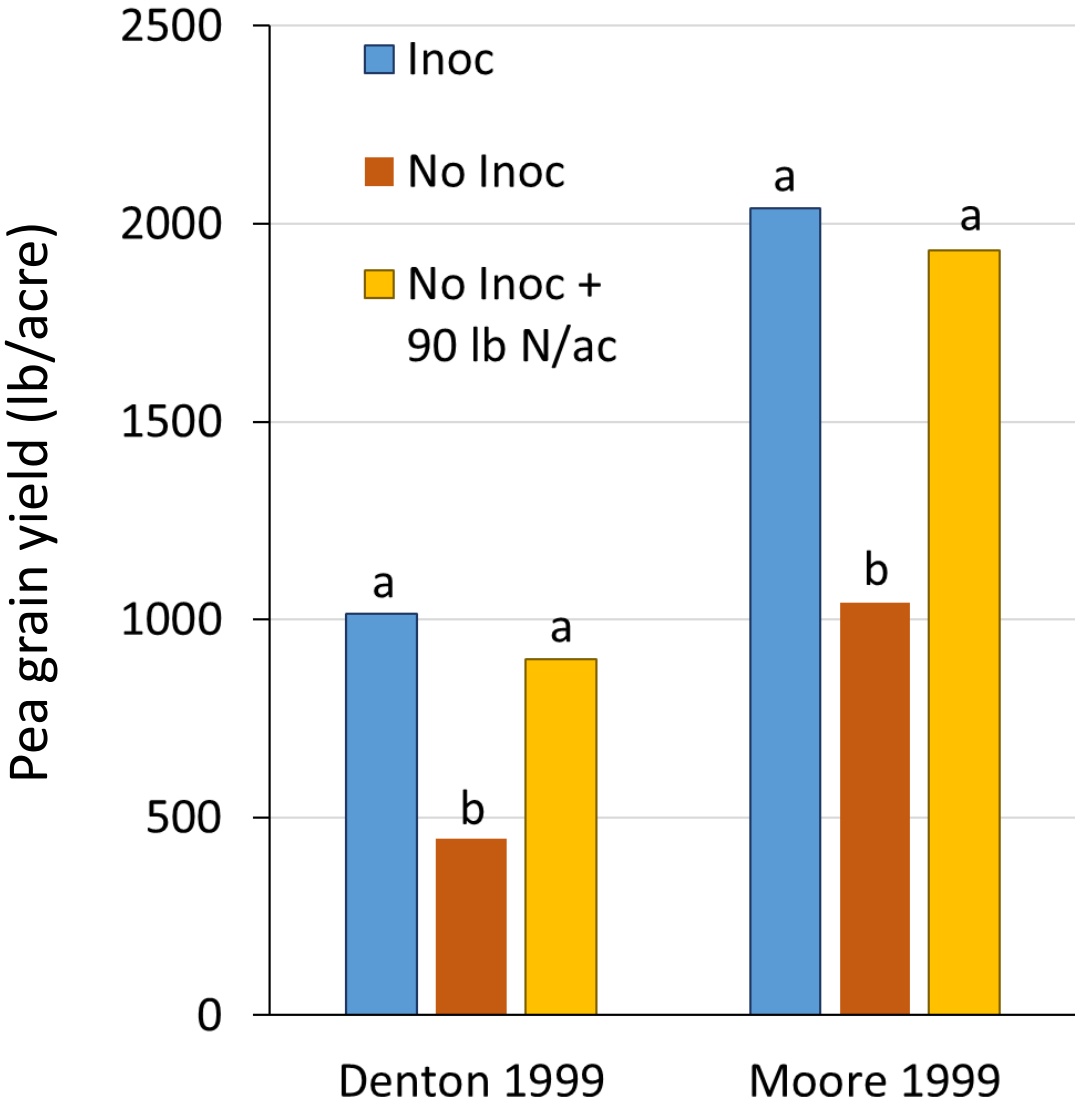
Field with pulse history: Liquid or peat = less expensive

Inoculation more important in ‘new’ fields



Huang et al., 2017 in press, Moccasin

Peas benefit from N either from fertilizer or through inoculation, especially on sites with no recent pulse history.



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

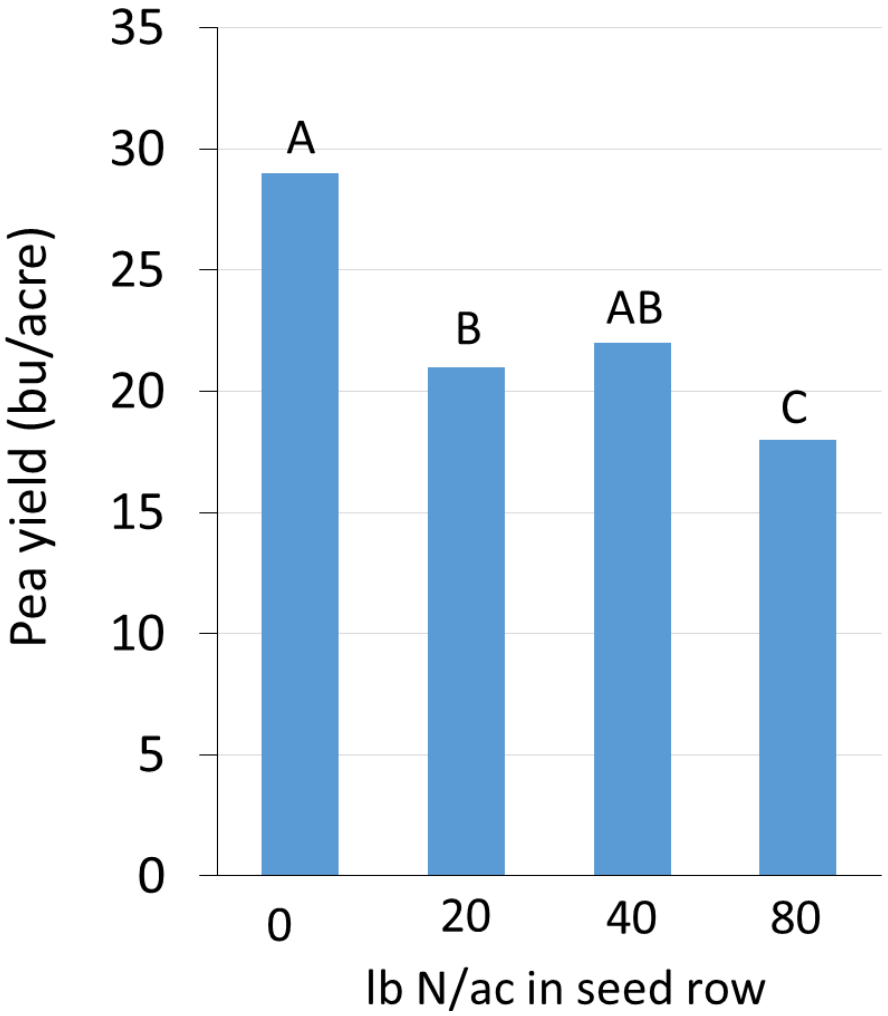
Fields had no recent pulse history

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?

- Too much N
  - inhibits nodulation
  - get excess vegetation
  - reduced yield
- Aim for 10-15 lb total available N/ac (soil + fertilizer) in top 12” in spring
- Place to side of seed row
- With lentil and chickpea, starter N reduces time to maturity, improves harvestability (Gan et al. 2003)



Huang et al., 2017 in press, Moccasin

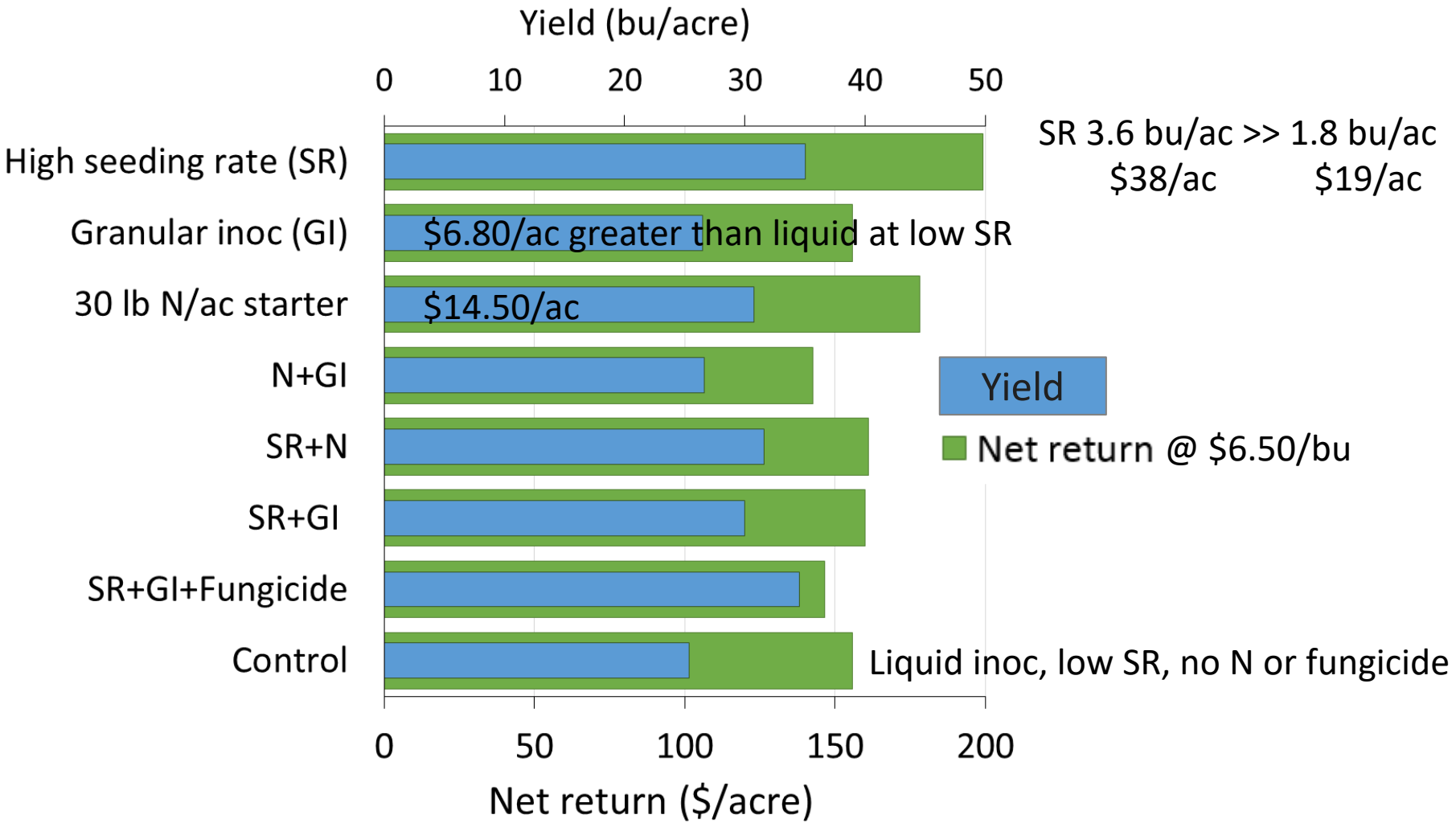
Rescue N

- If have yellow lower leaves (N deficiency) dig and look for rosy red nodules
- SK suggests 40-50 lb N/ac topdress
- Yield gain may not offset N cost
- Need water/rain to move N into soil

Image: C. Jones

Image: Flicker Pennstatelive

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 increase protein in "new" or low soil N or drought conditions (McKenzie et al., 2006; Clayton et al., 2004; Bestwick et al., 2018). Protein may become a factor in price paid for pulse grains.

Questions on N?

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) 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/acre 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
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 and yield!

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

Image by T. Rick

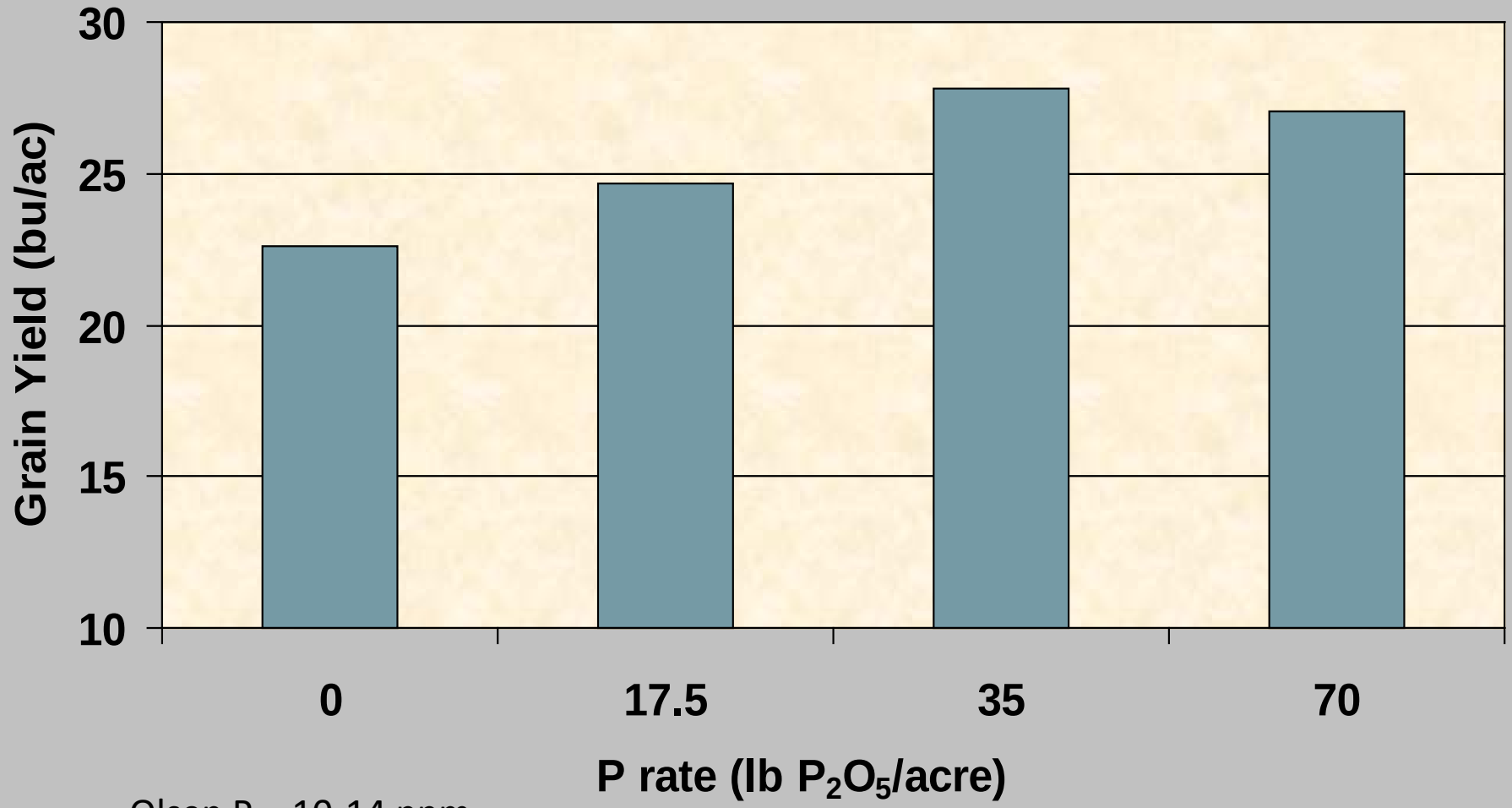
Montana phosphorus fertilizer guidelines for annual legumes vs winter wheat

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

Crit P level for N-fixation ≈ Olsen P 10 ppm
(producer in Judith Basin, 2016)

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



Olsen P = 10-14 ppm

Data from J. Waddell, Sidney, MT

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

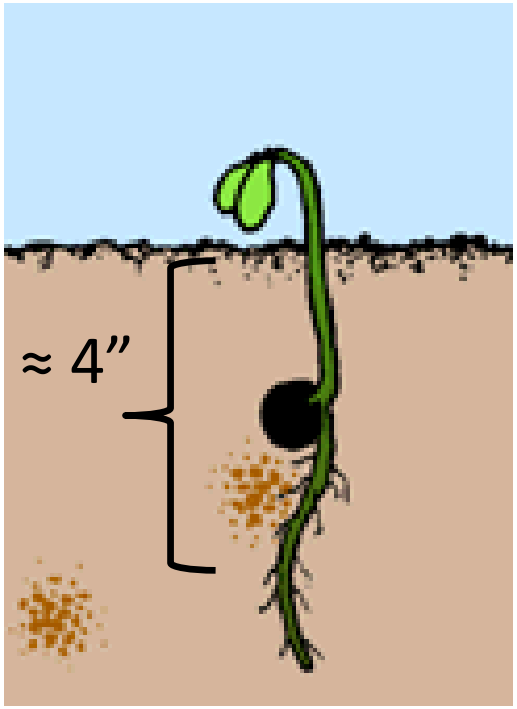
- Lower yields
- Annual legumes root shallower:
  Better able to take advantage of higher P levels in upper 6 inches
- Legumes lower soil pH, mobilizing P, however this benefit does not appear to carry over to the next crop (Rick et al., 2011)

P response – depends on species and variety

- P response better when soil P < 9 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.
- P is more likely to pay off with pulse forage than grain when soil P is near adequate (Wen et al., 2008)
- P response loam >> 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).



Phosphorus placement

Seed row safe rates depend on soil and moisture

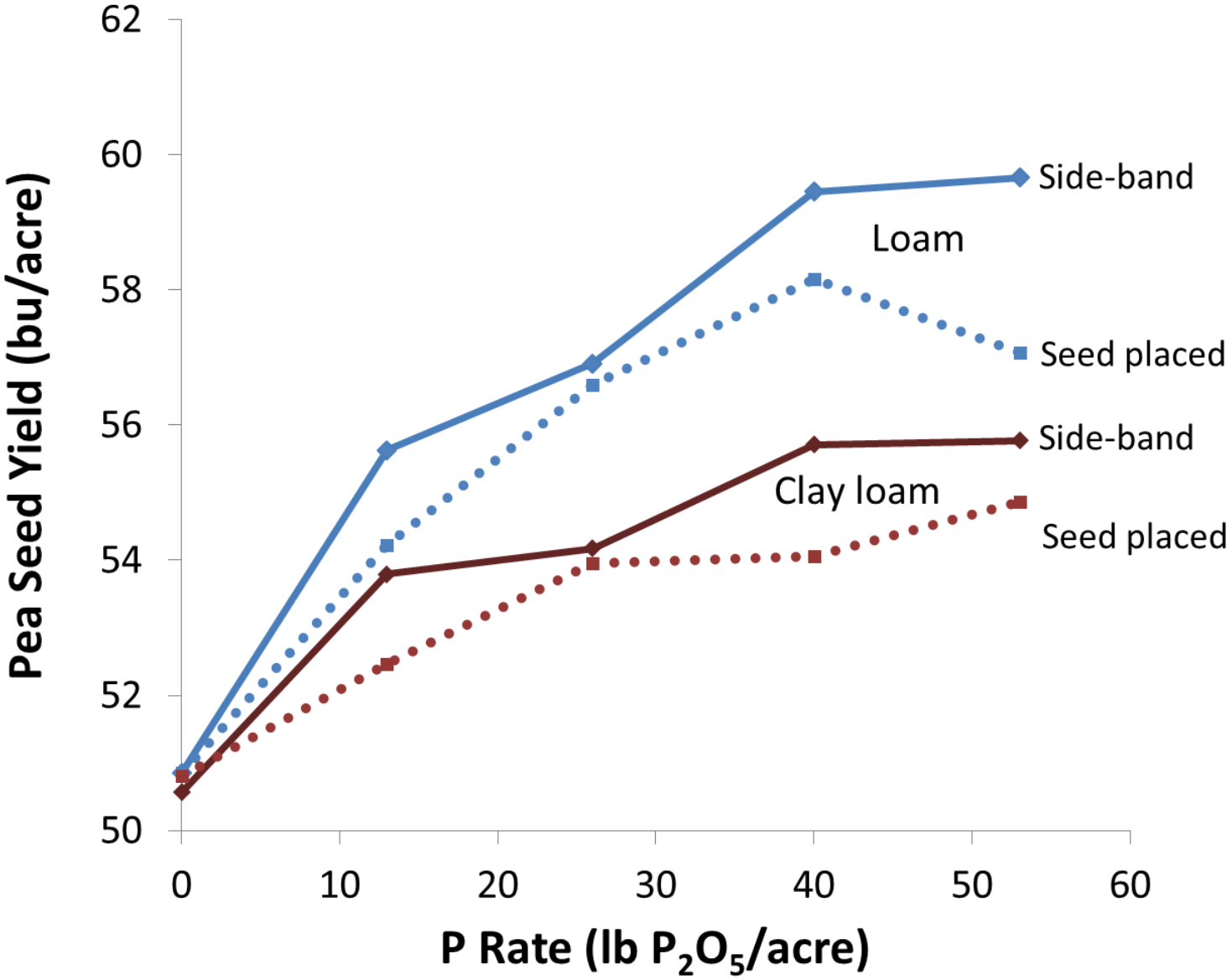
- heavy clay soil >> coarse
- high SOM >> low SOM
- high moisture >> dry soils

Equipment

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

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

Safe rates of seed placed P depend on soil conditions



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

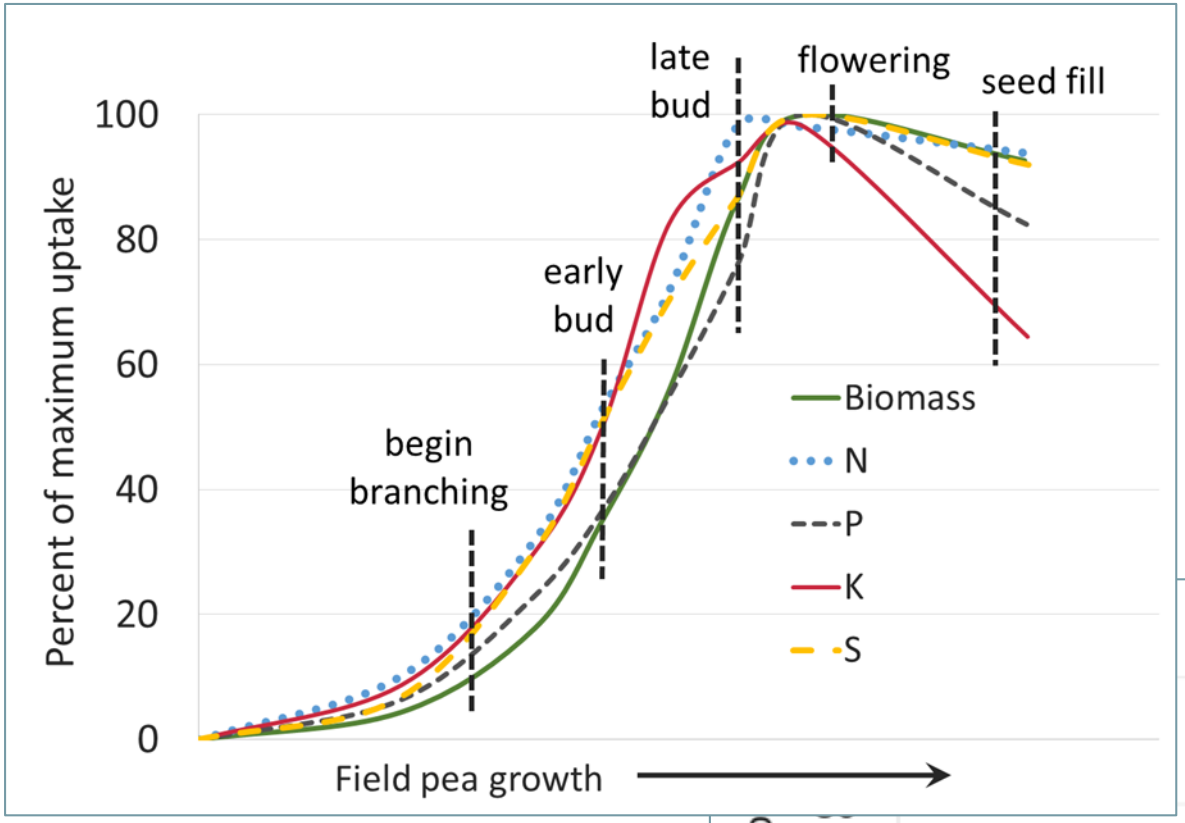
Soil K (ppm) 0 to 6 inches	Application rate (lb K_2O/acre)
0	45
50	40
100	35
150	30
200	25
250	20
Above 250	0 up to crop removal (0.9 lb/bu)

Questions?

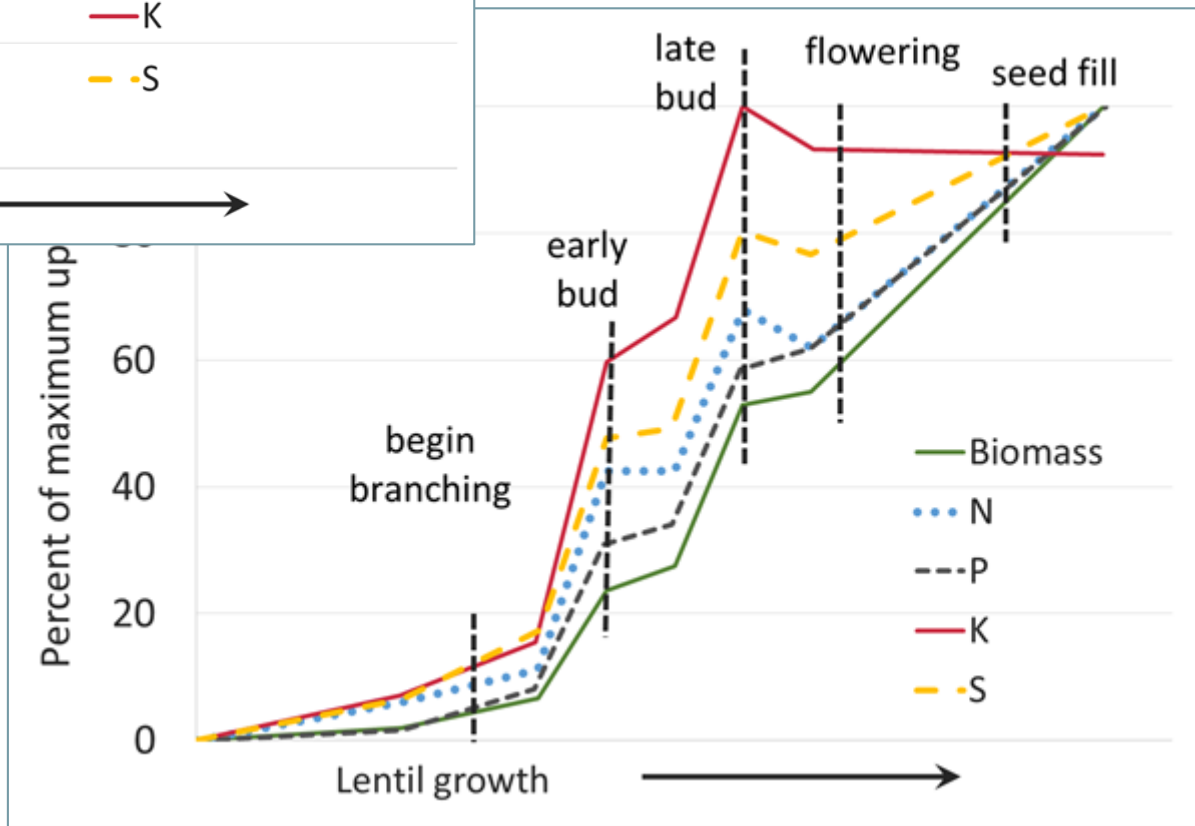
On to timing

Nutrient uptake

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



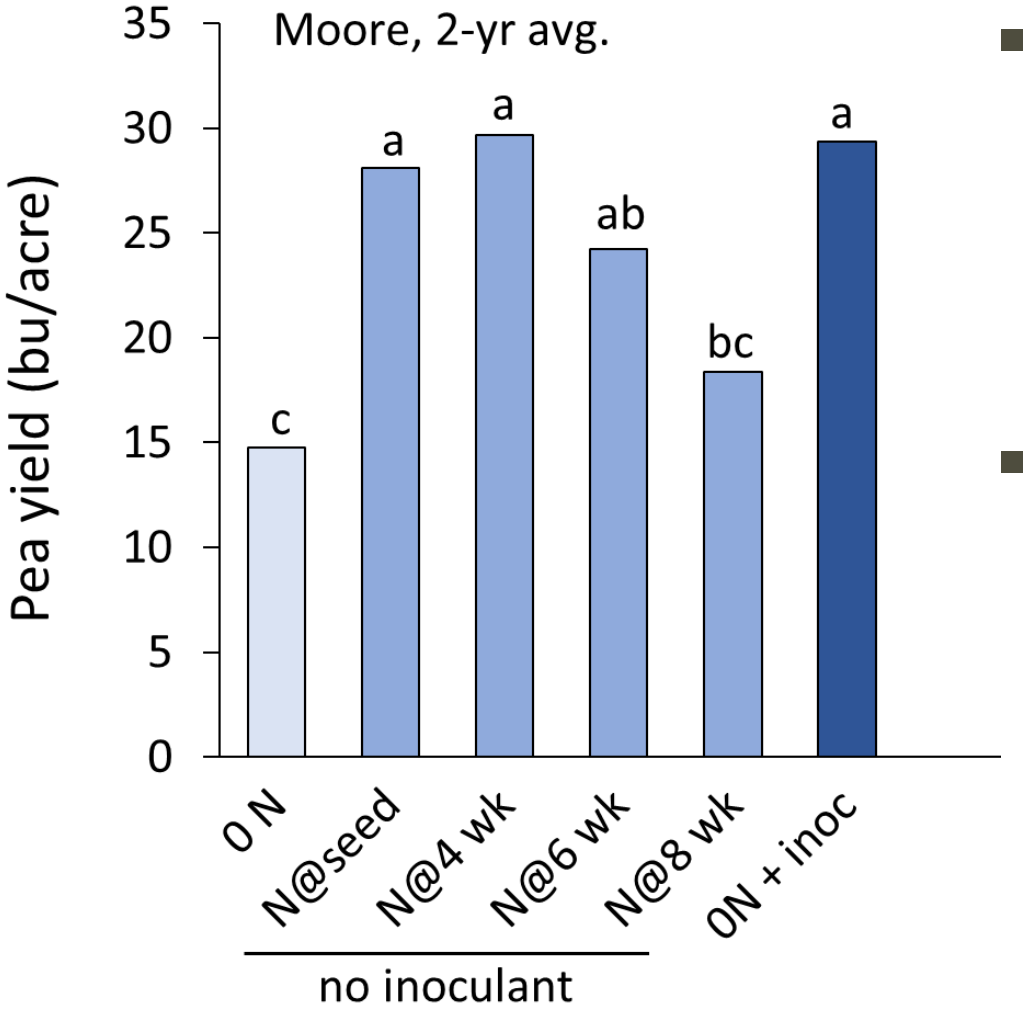
Pea



Source: Malhi et al., 2007, Saskatchewan

Lentil

Rescue N timing



- Up to 6 weeks after seeding
  - Pea: 9-12 node stage
  - Chickpea: 10-13 node
- If later
  - too much vegetative growth
  - poor pod set
  - delayed maturity

(McConnell et al., 2002, Moore, MT, 90 lb N/ac)

Take home messages on Timing

- N: at seeding, or as rescue, but no later than 6 weeks after seeding
- P: build up with prior crop, in very small amount with seed, or 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

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)

What affects rate that residue N becomes available?

- Slower in no-till than till, e.g., pea residue 43% (NT) vs. 55% (till)
- Faster with higher N and phosphorus (P) concentrations
- Pulse cover crop decomposes faster than pulse residue (Lupwayi et al. 2004, north-central Alberta)

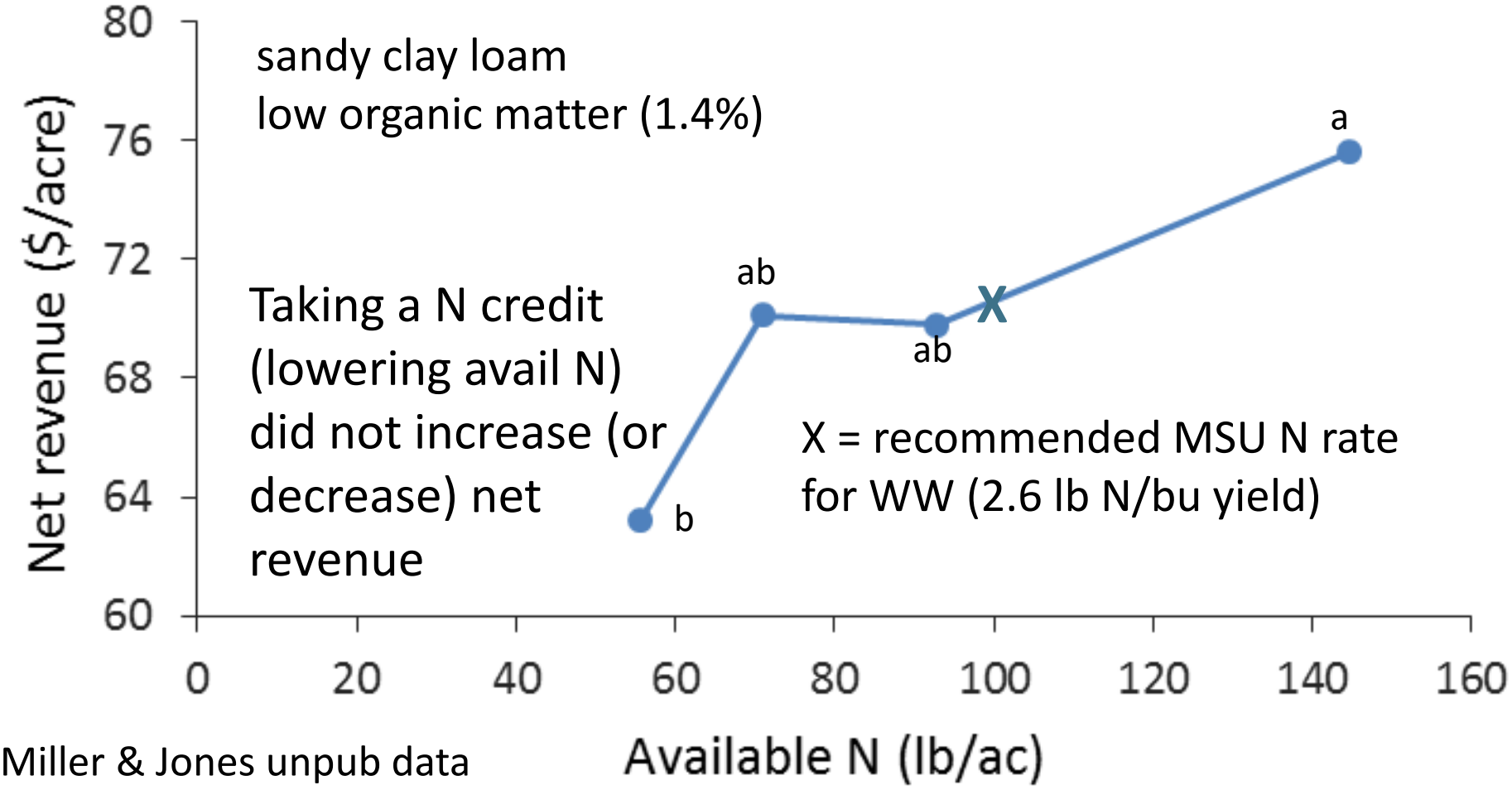
BUT: rapid nutrient release is not necessarily desirable because potential loss from system before uptake by next crop

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

Are there situations when should not recommend a credit?

2015 net revenue at Big Sandy (@ low discounts)



Miller & Jones unpub data

How decide whether to take an N credit, and if so, how much given every soil and farm different?

- Pulse grown 1-2x:
  Use general recommendation of ~10 lb N/ac for pulse grain and 20 -30 lb N/ac for cover crop

- Track wheat grain protein after pulse:
  If consistently > 13.2% (spring wheat) or > 12.5% (winter wheat), then should keep taking N credit. Otherwise, likely should not b/c yield is compromised from insufficient N.

See Fertilizer Facts 21 and 34 for more info

N credit summary

- 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

IPNI Seed Damage Calculator
http://seed-damage-calculator.herokuapp.com/

With good soil fertility you can grow big pods

?

Remember Extension guides