Nutrient Management of Pulses and N Credits
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CCA and dealer training, Huntley

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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)
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**

Dry year: 1” in May, 2.5” in June
Wet year: 2.3” In May, 3.4” in June

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**Bar graph**

- **Y-axis:** Nitrogen fixed (lb N/acre)
- **X-axis:** Plant stage (Dry, Wet, Dry, Wet)
- **Legend:**
  - Flower
  - Pod

**Dry year**
- Lentil: 60 lb N/acre
- Pea: 80 lb N/acre

**Wet year**
- Lentil: 20 lb N/acre
- Pea: 120 lb N/acre

**Legend:**
- a
- b

**Notes:**
- 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. Average over 12 site-years.

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

- Pea:
  - No inoculant: B
  - Inoculant: A
- Lentil:
  - No inoculant: a
  - Inoculant: a

- Pea:
  - No inoculant: B
  - Inoculant: A
  - 16 lb N/ac in top 6”
- Lentil:
  - No inoculant: a
  - Inoculant: a
  - 9 lb N/ac in top 6”
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 3\textsuperscript{rd} 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
Input effects on pea on ‘low yielding’ (<45 bu/ac) sites

Grenkow et al., 2014, Saskatchewan

High seeding rate (SR) $38/ac $19/ac
Granular inoc (GI) $6.80/ac greater than liquid at low SR $14.50/ac
30 lb N/ac starter
N+GI
SR+N
SR+GI
SR+GI+Fungicide
Control

Yield (bu/acre)

Net return ($/acre)

SR 3.6 bu/ac >> 1.8 bu/ac

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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Plant tissue S concentration (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickpea</td>
<td>0.18</td>
</tr>
<tr>
<td>Lentil</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Leaf S concentration at which 90% of maximum yields were obtained.

Sampling 2\textsuperscript{nd} to 4\textsuperscript{th} mature leaf at 7\textsuperscript{th} leaf stage, 4 weeks after seeding. Huang et al. 1992.
BOTH P and K needed for N fixation and yield!

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Peas, lentils, chickpeas</th>
<th>Wheat grain (barley hay)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lb/bu (lb/ton hay)</td>
<td></td>
</tr>
<tr>
<td>$P_2O_5$</td>
<td>0.67 (11)</td>
<td>0.62 (13(^1))</td>
</tr>
<tr>
<td>$K_2O$</td>
<td>0.87 (32)</td>
<td>0.38 (38(^1))</td>
</tr>
</tbody>
</table>

$^1$: 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

Winter Pea, Bozeman, 5/17/07

Image by T. Rick
Montana phosphorus fertilizer guidelines for annual legumes vs winter wheat

<table>
<thead>
<tr>
<th>Olsen P (ppm) 0 to 6”</th>
<th>Annual legume application rate (lb P$_2$O$_5$/acre)</th>
<th>W wheat application rate (lb P$_2$O$_5$/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>45</td>
</tr>
<tr>
<td>12</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>16</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>Above 16</td>
<td>0 up to crop removal*</td>
<td></td>
</tr>
</tbody>
</table>

* Assume 2/3 lb P$_2$O$_5$ 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)

Data from J. Waddell, Sidney, MT

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$_2$O$_5$/acre (Fact No. 38; McKenzie et al., 2001; Karamanos et al., 2003)

- At soil P > 13 ppm, up to 15 lb P$_2$O$_5$/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$_2$O$_5$/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

<table>
<thead>
<tr>
<th>Soil K (ppm)</th>
<th>Application rate (lb K$_2$O/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>45</td>
</tr>
<tr>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>100</td>
<td>35</td>
</tr>
<tr>
<td>150</td>
<td>30</td>
</tr>
<tr>
<td>200</td>
<td>25</td>
</tr>
<tr>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>Above 250</td>
<td>0 up to crop removal (0.9 lb/bu)</td>
</tr>
</tbody>
</table>
Questions?

On to timing
Nutrient uptake

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

Source: Malhi et al., 2007, Saskatchewan
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

<table>
<thead>
<tr>
<th>Crop</th>
<th>N Credit (lb N/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse grain crop grown 1-2x</td>
<td>~10</td>
</tr>
<tr>
<td>Pulse grain crop grown 3+ times</td>
<td>~20</td>
</tr>
<tr>
<td>Pulse cover crop grown 1-2x</td>
<td>20-30</td>
</tr>
<tr>
<td>Pulse cover crop grown 3+ times</td>
<td>30-50</td>
</tr>
</tbody>
</table>
Are there situations when should not recommend a credit?

2015 net revenue at Big Sandy (@ low discounts)

Taking a N credit (lowering avail N) did not increase (or decrease) net revenue

sandy clay loam
low organic matter (1.4%)

X = recommended MSU N rate for WW (2.6 lb N/bu yield)

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

IPNI Seed Damage Calculator
http://seed-damage-calculator-herokuapp.com/
With good soil fertility you can grow big pods

Remember Extension guides