Pulse Crop Inoculation and Fertilization
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Hill County Extension Pulse Workshop

Clain Jones, Extension Soil Fertility Specialist
clainj@montana.edu; 994-6076
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)
Without healthy nodules legumes don’t fix N

Active nodules are red, rather than white inside.
**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

<table>
<thead>
<tr>
<th>Plant stage</th>
<th>Nitrogen fixed (lb N/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flower</strong></td>
<td>Dry: a, Wet: b</td>
</tr>
<tr>
<td></td>
<td>Dry: a, Wet: b</td>
</tr>
<tr>
<td><strong>Pod</strong></td>
<td>Dry: a, Wet: b</td>
</tr>
<tr>
<td></td>
<td>Dry: a, Wet: b</td>
</tr>
</tbody>
</table>

McCuauley, 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

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

Average over 12 site-years

Pea yield (bu/acre)

- None: 19
- Seed peat powder: 23.5
- Seed row: 25.5
- Side band: 24

Gan et al., 2005, SK
Effect of inoculation on pea and lentil yield, fields with and w/out pulse crop history

Huang et al., 2017 in press, Moccasin

Inoculation more important in ‘new’ fields

9 lb N/ac in top 6”

16 lb N/ac in top 6”

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

SR 3.6 bu/ac >> 1.8 bu/ac
$38/ac    $19/ac

$9.50/ac
$14.50/ac

N+Gl
SR+N
SR+Gl
SR+Gl+Fungicide
Control

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

<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>
<tr>
<td>Faba bean</td>
<td>0.038</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!**

<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 (131.)</td>
</tr>
<tr>
<td>$K_2O$</td>
<td>0.87 (32)</td>
<td>0.38 (381.)</td>
</tr>
</tbody>
</table>


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
Montana phosphorus fertilizer guidelines for annual legumes vs winter wheat

<table>
<thead>
<tr>
<th>Olsen P (ppm) 0 to 6&quot;</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
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)
## Maximum rooting depths (Mandan, ND)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Average maximum rooting depth (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Pea</td>
<td>3.0</td>
</tr>
<tr>
<td>Canola</td>
<td>3.5</td>
</tr>
<tr>
<td>Spring Wheat</td>
<td>4.0</td>
</tr>
<tr>
<td>Sunflower</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Merrill et al. 2002
Why does rooting depth matter?

P accumulates near surface

Chen and Jones

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$_2$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. 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$_2$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).

- 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

<table>
<thead>
<tr>
<th>Soil K (ppm) 0 to 6 inches</th>
<th>Application rate (lb K₂O/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
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

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

<table>
<thead>
<tr>
<th></th>
<th>Fallow</th>
<th>Grain pulse grown 1x</th>
<th>Legume cover crop grown 1x</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW yield goal (bu/ac)</td>
<td>45</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>Spring soil N (lb/ac)</td>
<td>80</td>
<td>55</td>
<td>65</td>
</tr>
<tr>
<td>Total soil N recommended</td>
<td>45 x 2.6 = 117</td>
<td>35 x 2.6 = 91</td>
<td>40 x 2.6 = 104</td>
</tr>
<tr>
<td>N credit (lb/ac)</td>
<td>0</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>Fertilizer N (lb/ac)</td>
<td>117-80-0 = 37</td>
<td>91-55-10 = 26</td>
<td>104-65-25 = 14</td>
</tr>
</tbody>
</table>
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
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](http://www.peaproteinproject.com)

- **MSU** identifies if management affects yellow pea protein.

**MORE SAMPLES = BETTER RESULTS**
With good soil fertility you can grow big pods