Inoculants and Nutrient Management of Pulses
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Ag Agent Update, Havre

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Objectives

Provide you info on pulse fertility so you can better answer producers’ questions

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

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

• Use species-specific inoculant
• Keep inoculant cool, dark; granular more reliable than liquid
• 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 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)

![Graph showing pea yield (bu/acre) vs. lb N/ac in seed row]

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
- 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 N cost
- Need water/rain to move N into soil
Input effects on pea on ‘low yielding’ (<45 bu/ac) sites

High seeding rate (SR)  
Granular inoc (GI)  
30 lb N/ac starter  
N+GI  
SR+N  
SR+GI  
SR+GI+Fungicide  
Control

Yield (bu/acre)

0 10 20 30 40 50

$6.80/ac greater than liquid at low SR
$14.50/ac

Liquid inoc, low SR, no N or fungicide

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

Net return ($/acre)

0 50 100 150 200

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.
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.

<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>

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>$\text{P}_2\text{O}_5$</td>
<td>0.67 (11)</td>
<td>0.62 (13&lt;sup&gt;1&lt;/sup&gt;)</td>
</tr>
<tr>
<td>$\text{K}_2\text{O}$</td>
<td>0.87 (32)</td>
<td>0.38 (38&lt;sup&gt;1&lt;/sup&gt;)</td>
</tr>
</tbody>
</table>

<sup>1</sup> 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
Effect of P on spring pea yield (2004-2005)

Data from J. Waddell, Sidney, MT

Olsen P = 10-14 ppm
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 (Fact 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 $\approx$ 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 P₂O₅/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) 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
Pea

Source: Malhi et al., 2007, Saskatchewan

Lentil

Nutrient uptake
- Nutrient uptake precedes biomass
- Rapid demands once branching
- Indeterminates just keep growing
Take home messages on Timing

- **N**: at seeding, or as rescue
- **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
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