Nutrient Management of Pulses
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Crop and Pest Management School
Bozeman

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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
Nitrogen fixation process

- Nodulation begins 2-3 weeks after plant emergence
- Nodules are active 3-4 weeks after plant emergence (≈ 3\textsuperscript{rd} node)
- Active nodules are pink to red inside
- Amount fixed depends on species (pea > chickpea > lentil)
Without healthy nodules legumes don’t fix N
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 drought 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

Nitrogen fixed (lb N/acre)

Plant stage
- Flower
- Pod

Nitrogen fixed in lentil and pea under dry and wet conditions with different plant stages.

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

Voon et al., 2003 greenhouse study
Practices to improve nodulation & N fixation

- Keep inoculant cool, dark
- Granular more reliable than liquid esp. as pH <5.4, only source providing nodules at pH 4.4 (Rice et al., 2000)
- Use species-specific inoculant
- Apply proper inoculant rate
- Avoid fertilizer salts (mixing with fertilizer can kill bacteria)
- Ensure adequate P, K, S
- Watch soil N (high in northeast in 2017!): too much inhibits N-fixation
- No-till to retain 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

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Chick pea yield (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>20</td>
</tr>
<tr>
<td>Seed peat powder</td>
<td>25</td>
</tr>
<tr>
<td>Seed row</td>
<td>28</td>
</tr>
<tr>
<td>Side band</td>
<td>28</td>
</tr>
</tbody>
</table>

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, Moccasin

- 16 lb N/ac in top 6”
- 9 lb N/ac in top 6”

Bar graph showing pulse yield (bu/acre) with and without inoculant for Pea and Lentil, with and without prior pulse history.
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
Inoculation is more important in recrop than fallow due to soil nitrate differences

Gan et al. 2009, SK
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
Seed row N

- Too much N
  - inhibits nodulation
  - produces excess vegetation
  - reduces 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 with data points A, B, AB, C at 0, 20, 40, 80 lb N/ac in seed row.](Huang et al., 2017, Moccasin)
Starter N helps reduce chickpea days to maturity, especially under moist, long, growing seasons.

In 90 – 107 days-to-maturity years, N reduced days to maturity by 4-5 days.
Input effects on pea on ‘low yielding’ (<45 bu/ac) sites

Grenkow et al., 2014, Saskatchewan

High seeding rate (SR)
- SR 3.6 bu/ac >> 1.8 bu/ac
- $38/ac $19/ac

Granular inoc (GI)
- $6.80/ac greater than liquid at low SR

30 lb N/ac starter
- $14.50/ac

N+GI

SR+N

SR+GI

SR+GI+Fungicide

Control

Liquid inoc, low SR, no N or fungicide

Yield

Net return @ $6.50/bu

Grenkow et al., 2014, Saskatchewan
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). One MT buyer is already paying $0.25 to 0.75/bu for protein > 22%. 
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)
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>Chickpea¹</td>
<td>0.18</td>
</tr>
<tr>
<td>Field pea²</td>
<td>0.20</td>
</tr>
<tr>
<td>Lentil¹</td>
<td>0.29</td>
</tr>
</tbody>
</table>

¹Sampling 2nd to 4th mature leaf at 7th leaf stage, 4 weeks after seeding. Huang et al. 1992.
²Sampling top half of shoot. Gov. W. Australia, Ag & Food
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
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
Winter Pea, Bozeman, 5/17/07

Not Fertilized

Fertilized w/ P, K, and S
Effect of P on spring pea yield (2004-2005)

![Graph showing the effect of P rate on grain yield. The x-axis represents P rate (lb P$_2$O$_5$/acre) with values 0, 17.5, 35, and 70. The y-axis represents grain yield (bu/ac) with values 10, 15, 20, 25, and 30. The graph indicates that there is a significant increase in grain yield as the P rate increases, with the highest yield at 70 lb P$_2$O$_5$/acre. Olsen P = 10-14 ppm.]

Data from J. Waddell, Sidney, MT
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)
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 (Ffact 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 required for N-fixation
- K levels often moderate to high in Montana, generally not limiting
- 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
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
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

Question for you: How would you apply N 6 wk after seeding?

(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

• Pulses are sensitive to too much N, P, K and S in the seed row

• 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-calculator.herokuapp.com/
With good soil fertility you can grow big pods

Remember Extension guides