# Inoculation and Soil Fertility Management to Optimize Pulse Crop Yield and Protein

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## IMPACT STATEMENT

*Proper inoculation and soil fertility management to encourage nitrogen fixation may be a worthwhile investment for optimal economic pulse crop production.*

## SUMMARY

Pulse crops require nitrogen from either the soil or nitrogen (N) fixation by rhizobia in root nodules. There are agronomic decisions that promote healthy nodulation and N fixation. We summarize regional research on factors that affect N fixation and pulse seed yield and protein. This report is a synopsis of our paper published in Crops & Soils Magazine, Volume 51, Issue 4 (https://dl.sciencesocieties.org/publications/cns/tocs/51).

## INTRODUCTION

Pulse crops acquire N either from the soil or through N fixation by rhizobia bacteria in nodules on their roots. Given a choice, a plant will generally extract available N from the soil, rather than go through the carbon-expensive relationship with rhizobia. Most soils contain some N-fixing rhizobia; however, an inoculant with rhizobia specific to the pulse crop provides the most effective N fixation.

## NODULATION & N FIXATION

Native rhizobia populations are lower and nodule activity is severely limited in dry or waterlogged soil, at extreme soil temperatures, and in acidic and saline soils (Denton et al., 2013), although inoculant strains and their host plants differ in pH and salinity tolerance (Bordeleau and Prevost, 1994). Rhizobia persistence in the soil is reduced under adverse soil conditions, especially when host plants are not present. Nodule activity decreases as plants mature past flowering.

There are several practices which can improve nodulation and N fixation. Liquid and seed-applied peat inoculants need to be kept cool and dark before application. Contact with fertilizer and some fungicides may also be detrimental to inoculants (Kutcher et al., 2002). The pulse/rhizobia system needs adequate phosphorus (P), potassium (K), sulfur (S) and micronutrients for optimal N fixation. Too much soil nitrate inhibits nodulation and N fixation, while no-till enhances N fixation by retaining soil moisture.

## INOCULATION

Peat-powder or liquid inoculant applied to the seed is less expensive, but more challenging to properly care for before and during application than soil-applied peat granular inoculant. When compared to seed-applied powder, granular inoculant produced higher protein in Montana especially under drought conditions (Bestwick et al., 2018), higher yields in fields with no pulse history (Gan et al., 2005, SK), higher protein and yield with little or no N-fertilizer (Clayton et al., 2004a), more active nodules at soil pH 4.4, and greater N fixation and plant biomass at soil pH 5.4 (Rice et al., 2000).

Granular soil-applied inoculant promotes rhizobia populations that are evenly distributed on tap and lateral roots, whereas seed-applied results in nodules clustered near the root crown (Figure 1; Rice et al., 2000). Tap and lateral root nodules provide a benefit where surface soils may dry out, or in low pH soils with low populations of indigenous rhizobia. Some

**Figure 1**. Nodule formation along the length of the tap and lateral roots with granular inoculant (left) and in clusters near the soil surface with seed-applied inoculant (right; photos by P. Miller).

farmers use two forms of inoculant to decrease odds of inoculant failure.

Inoculant is most effective in fields without recent pulse history. An Alberta study found the likelihood of a significant increase in seed yield from granular inoculant was independent of spring soil nitrate-N, yet the magnitude of the response was higher at low soil nitrate-N (18 lb N/acre; McKenzie et al., 2001a). The same study found inoculant is more likely to increase protein under low spring soil nitrate levels (less than 18 lb N/acre) and very unlikely to increase protein under high spring nitrate (greater than 36 lb N/acre).

**FERTILIZER N**

Nodulation is carbon expensive, meaning it requires healthy plants. Since little N is contributed by nodules until the third node, N for initial growth must come from top foot of soil. Nitrogen hunger can lead to plants getting 'stuck'; they can't grow to feed nodules, and nodules aren't actively providing N for growth. Rhizobia-fed plants in low N soil take two to three weeks longer to get going than pulse plants with adequate soil or fertilizer N (P. Miller, pers. comm.). Finally, fertilizer N is insurance against nodule loss to pea leaf weevil, whose larvae feast on nodules.

There is a balance between enough soil nitrate for plant growth and too much N, which can inhibit nodulation, produce excess early vegetation, and reduce yield. Based on Montana and Alberta studies (McConnell et al., 2002; McKenzie et al., 2001a) it is reasonable to aim for 10-15 lb total available N/acre (soil + fertilizer) in the top foot in spring, keeping in mind that seed row N may hurt germination. The close proximity of seed row fertilizer N has more negative impact on nodulation than high residual soil nitrate level (Clayton et al., 2004b). Starter N appears to be more important with seed-applied peat-powder inoculant than peat granular inoculant (Clayton et al., 2004a). However, there is no guarantee that starter N will increase either yield or protein.

**RESCUE N**

If nodulation failure is suspected, rescue N can 'salvage' yields if applied by six weeks after seeding (pea, 9-12 node, 7-10 leaf; chickpea, 10-13 node, 8-11 leaf; McConnell et al., 2002, MT). If applied later there is higher risk of too much vegetative growth, poor pod set, and delayed maturity. Rescue N requires rain/irrigation to move N into the soil where it can be taken up by plants. Although starter or rescue N may appear to boost early crop growth, yield gain may not offset N cost.

**OTHER NUTRIENTS**

Optimizing availability of all nutrients should increase N fixation and yield.

Sulfur is important for N uptake and protein production. Sulfate S can be applied at planting as a side band liquid or granular, saving the seed row for P. Alternatively, bank elemental S a rotation or two prior to the pea rotation (except in acidic soils since elemental S decreases pH).

Phosphorus and potassium are important for N fixation and should be supplied based on soil tests and regional guidelines. In general, P response is more likely when Olsen P is less than 9 ppm (Chen et al., 2006; McKenzie et al., 2001b; Karamanos et al., 2003). When Olsen P is greater than 13 ppm, low maintenance rates can be added. If soil tests suggest higher P rates, side band the additional amount at seeding, or build up P with the prior crop. Potassium is generally not limiting in soils of the northern Great Plains, although it should be monitored in rotations with high removal of stems and leaves and in coarse soils. Some K should be added if the soil test K is less than 250 ppm.

**ECONOMICS**

In low N soils, yield and protein may increase with starter N or inoculant, but until protein is more commonly rewarded with higher prices, the reward may not offset the cost. Yet, the risk of crop failure due to low N or failed nodulation are reasons it may not be worth skimping on inoculant or low rates of starter N. For example, given soil acidification in the soil surface is a growing problem in traditionally neutral to alkaline soils (http://landresources.montana.edu/soilfertility/acidif.html), a surface soil pH test and providing granular inoculant if the soil has pH < 6 may pay off.

Factors to consider when selecting inoculant and starter fertilizer are: spring soil nitrate levels, field history with pulses and inoculation, whether water is the likely yield limiting factor, soil conditions that limit nodulation and the indigenous rhizobia population, and whether a premium will be paid for protein.

**RESOURCES**

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

Montana Cool Season Pulse Production Guide http://landresources.montana.edu/soilfertility/documents/PDF/pub/MTCool-SeasPulseProd%20EB0210.pdf

Montana State University Soil Fertility Extension website for presentations on pulse inoculation and soil nutrient management http://landresources.montana.edu/soilfertility/presentations.html

Pea Protein Formation and Management Options. 2018. M. Bestwick, P. Miller, C. Jones, and K. Olson-Rutz. http://landresources.montana.edu/soilfertility/documents/PDF/reports/Bestwick2018PeaProtFormation.pdf

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

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