FarmTech 2007 **Proceedings**

Global Perspectives... Local Knowledge

GROWING YOUR OWN NITROGEN

Sheri Strydhorst, PhD Candidate, University of Alberta

INTRODUCTION

Pulse crops are an essential component of any sustainable cropping system. If we can “grow our own nitrogen” and reduce our dependence on inorganic nitrogen (N) fertilizer, we are one step closer to creating a cropping system that is environmentally sound, economically viable, and socially acceptable.

78% of the air we breath is atmospheric N, but most plants are unable to take N from the atmosphere and make it into a plant usable form. Pulses and legumes have a unique ability to benefit cropping systems by fixing N, thereby eliminating the need for N fertilizer in the pulse crop year and reducing the need for N fertilizer in the subsequent crop.

RHIZOBIA AND PULSE CROP SYMBIOSIS

Pulse crops form a symbiotic relationship with Rhizobia bacteria and it is the bacteria that fixes N.

The bacteria gives the pulse crop N in a usable form which is why pulse crops can flourish on low N soils where cereal and canola crops would suffer without inorganic N fertilizer. In exchange for the usable N, the pulse crop gives the bacteria: i) a safe place to live (in root nodules) and ii) energy - N fixation is a very energy intensive process whether it is made in a factory or in a pulse crop.

ENERGY REQUIREMENTS OF N FIXATION

The Haber-Bosch process is used for mass production of inorganic N fertilizer (NH3). In this process, N2 from the air is combined with hydrogen at 300-400oC with a pressure of 35-100MPa. To put this in perspective, when inorganic N fertilizer is made, approximately 1.5kg of fossil fuels are required to make and deliver 1kg of N fertilizer to the farm (Hopkins and Huner, 2004). As fossil fuels become more costly and less available, it is easy to see how production of inorganic N fertilizer could be at risk.

Surprisingly, the N fixing process is more costly for the pulse plant. To fix 1g of N, it costs the plant 12g of carbohydrate (Hopkins and Huner, 2004). For example, a plant can produce 12g of sugar or 1g of N. Therefore, the pulse plant diverts energy from growing leaves, stems, and seed to fuel the N fixation process. To supply the energy for N fixation, the pulse plant must be actively photosynthesizing and producing surplus energy.

OPTIMIZING NITROGEN FIXATION

By working together, the Pulse/Rhizobia team can fix up to 80% of the total N in the plant (Danso et al., 1987). Obviously, we want to use management techniques to optimize N fixation.

i. Properly Inoculate. The bacteria that fix N for soybean will not fix N for field pea and vice versa. Therefore, producers must supply the correct bacteria for each crop. The other reason to inoculate your pulse crops is that there are native soil bacteria that can form nodules on your pulse crop; they receive sugars from the pulse crop but do NOT fix N in exchange for that sugar. The idea is to increase the concentration of beneficial bacteria around the seed which can “out compete” the native soil bacteria. This results in the beneficial bacteria nodulating the pulse crop and receiving sugars which will be used to fuel N fixation.

ii. Plant pulses on soils with low levels of soil available N. As discussed above, N fixation is an energy intensive process, therefore pulse plants will obtain N in the easiest way possible – from available soil N. Pulses fix N as a last resort. When pulse crops are supplied with N fertilizer or are grown on manured land, the pulse crop will uptake the available N BEFORE diverting energy to fixing N. This is the most cost effective way to optimize N fixation: cut all N fertilizer inputs, save manured land for cereals and oilseeds, and enjoy the reward of higher N fixation rates.

iii. Create a hospitable environment for the bacteria. The rhizobia bacteria are responsible for N fixation and without a healthy rhizobia population, N fixation will not occur. Light, heat, and desiccation are lethal to rhizobia; therefore it is critical to properly handle inoculant to ensure that live, healthy bacteria are planted with the pulse seed. In addition, rhizobia are also sensitive to acidic soils. For example, alfalfa can be grown on acidic soils but its poor production is linked to the fact that the rhizobia species that fix N for alfalfa are sensitive to acid soils (pH <6.0) so they do not survive to fix N. In order to optimize N fixation, the health and well being of the Rhizobia must be remembered.

iv. Grow a healthy and vigorous pulse crop that can fuel the N fixation process. To optimize N fixation, we need to use best management practices to grow vigorous and healthy pulse crops that can supply energy to fuel the N fixing process. When a pulse crop is properly fertilized with P, K and S, given good moisture and warmth, and managed to control diseases and insects, this will result in high rates of N fixation. Anything that stresses the pulse crop will reduce rates of N fixation. When making management decisions for pulse crops, producers are determining how much N they are able to grow for the current pulse crop but also how much N will be fixed for subsequent crops.

FATE OF FIXED NITROGEN

Current Research: Pulses in Crop Rotations

N fixation rates vary depending on the pulse crop. For example, field pea fixes 152 kg N/ha/year, narrow leafed lupin fixes 168 kg N/ha/yr, and faba bean fixes 235 kg N/ha/year (Cuttle et al., 2003). The N fixed by the pulse crop has many different fates and unfortunately growing a faba bean crop does not leave 235 kg N/ha in the soil for the subsequent crop.

Research is being conducted in Barrhead, Devon, and Lacombe to trace the fate of fixed N into a subsequent wheat crop. More specifically, the research is examining how different pulse species, pulse planting densities, and weed pressure affect N and non-N rotational benefits. Most producers are familiar with the "better" crops that are grown on field pea stubble and the "better" crop is typically attributed to residual N, which was fixed by the pea crop. Due to the higher N fixation abilities of faba bean and lupin, it was assumed that the wheat crop grown on faba bean and lupin stubble would be superior to the wheat crop grown on pea stubble.

Results from the research experiment found wheat yields on pea stubble were 12% better than wheat yields on faba bean or lupin stubble. However, wheat yields on pulse stubble were always better than wheat yields on barley stubble. Pea stubble produced 27% better wheat yields than barley stubble and wheat yields on faba bean and lupin stubble were 16% better than wheat yields on barley stubble. To explain these trends, we traced the fates of the fixed N.

Nitrogen in Pulse Seed

Although faba bean and lupin fix more N than field pea, they also produce seed that has a higher protein content (protein content = N content x 6.25). Field pea seed is 22% protein, faba bean seed is 27% protein, and lupin seed is 34% protein. The N that is stored in the seed, in the form of protein, is exported off the field in the harvested grain. For example, a faba bean seed yield of 5.0t/ha (5000kg/ha) with a protein content of 27%, represents an export of 216 kg N/ha off the field. The majority of the fixed N is exported off the field; however, there are still N rotational benefits associated with pulse crops.

Nitrogen in Pulse Straw and Stubble

The majority of the fixed N, remaining in the field, is contained within the pulse straw and stubble. Release of this N into the soil requires microbial decomposition of the straw and stubble. Decomposition rates depend on the straw fibre types and the size of the soil microbial community.

Pea straw has higher levels of cellulose and hemicellulose which are easily decomposable fibers and therefore N tied up in these fibers is readily available to the growing wheat crop. Faba bean straw contains more lignin, which is a fibre that decomposes very slowly, and the N associated with these fibers is slowly released over a longer time period.

Preliminary soil analysis has found that pea soil may contain more soil microbes relative to other pulse soils. The more abundant microbe population is able to rapidly decompose the straw and breakdown organic matter making large amounts of N available to the subsequent crop.

Non-Nitrogen Benefits of Pulse Crops

Since the majority of fixed N is exported off the field in the harvested grain, the rotational benefits of pulse crops must be attributed to things other than fixed N. Research conducted by Stevenson and van Kessel (1996) found that 8% of the rotational benefit of field pea can be explained by additional soil N and the remaining 92% of the field pea rotational benefit is explained by non-N factors such as: reduced root and leaf diseases, reduced weed pressure, increased P,K,S availability, improved soil structure, and growth substances released from the pulse residue. Pulse crops do increase soil N levels for subsequent crops but that is only a small part of the picture. Pulse crops are very effective at growing THEIR OWN N, but the majority of rotational benefits attributed to pulse crops can be explained by non-N benefits.

CONCLUSION

Regardless of how you look at it, pulses are an essential component in sustainable cropping systems. High yielding pulse crops are grown without N fertilizer, the pulse seed is high in protein, and the pulse crop leaves N and non-N benefits for next year's crop.

REFERENCES

Cuttle, S., Shepherd, M., and Goodlass, G.. 2003. A review of leguminous fertility-building crops, with particular reference to nitrogen fixation and utilization. Defra Project OF0316.

Danso, S.K.A, Zapata, F., and Hardarson, G. 1986. Nitrogen fixation in faba beans as affected by plant population density in soil or intercropped systems with barley. Soil Biol. Biochem. 19(4):411-415.

Hopkins, W.G. and Huner, N.P.A. 2004. Introduction to Plant Physiology. John Wiley & Sons, Inc.

Stevenson, F.C. and van Kessel, C. 1996. The nitrogen and non-nitrogen rotational benefits of pea to succeeding crops. Canadian Journal of Plant Science 76(4):735-745.