NITROGEN CREDITS FROM LEGUME COVER CROPS

By Keith Reid

INTRODUCTION

Keeping the soil protected with cover crops provides many benefits for farmers, but most of these benefits don't show up easily on a financial balance sheet because they are long-term benefits that are hard to quantify. The exception is the nitrogen benefit from legume cover crops, which can reduce the fertilizer bill significantly. The key question is how much of a nitrogen credit to apply so the following crop does not miss out on potential yield.

There are two phases to supplying nitrogen to a cash crop from a legume:

1. The leguminous crop (i.e. peas, clovers, vetches, etc.) accumulating nitrogen from the atmosphere through symbiotic N fixation, and
2. Release of the accumulated nitrogen from the cover crop tissue at a time and place where it is available to the following crop.

Both phases are affected by the weather and soil conditions but also by the way the crops are managed.

NITROGEN ACCUMULATION IN LEGUME COVER CROPS

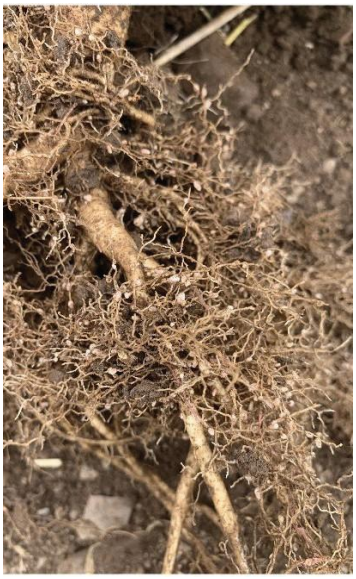

Figure 1. Nodulation on red clover.

The unique advantage of legumes in agricultural systems is their ability to form symbiotic relationships with specific bacterial species (see Table 1) that have the ability to convert atmospheric nitrogen into ammonium, which the plants can then use. The nitrogen fixation happens in nodules that form on the plant roots (Figure 1), where the plants share some of the sugars created during photosynthesis with the bacteria in return for nitrogen.

Nitrogen fixation and biomass accumulation go hand in hand for legume cover crops; more foliage equals more photosynthesis, which supplies more sugars to the nodules to support N fixation and, in turn, support more leaf growth. This feedback depends on good growing conditions for the cover crop, which can be challenging during the window between harvest of the cash crop and the planting of the next cash crop – especially as winter sets in. This will limit the species that are suitable for planting in Nova Scotia or Newfoundland and Labrador, and also the cropping systems where legume cover crops will fit.

Table 1. *Rhizobium* species required by legume crops.

Legume species	Rhizobium species
Pea, lentil, faba bean, chickling vetch	*Rhizobium leguminosarum*
Chickpea	*Rhizobium ciceri*
Dry bean	*Rhizobium phaseoli*
Soybean	*Bradyrhizobium japonicum*
Alfalfa, sweet clover	*Rhizobium meliloti*
Clovers	*Rhizobium trifolii*
Birdsfoot trefoil	*Mesorhizobium loti*

Resources such as SARE's **Managing Cover Crops Profitably** (**https://www.sare.org/resources/managing-cover-crops-profitably-3rd-edition/**) have excellent tables that give an estimation of cover crop growth, but, dependent on the crop, can range from zero to 7 tonnes per hectare of dry matter. This all depends on weather conditions and cover crop management. Nitrogen accumulation generally follows the amount of cover crop biomass. A lot of the variation in the estimated biomass of a cover crop arises from the time available for cover crop growth, particularly for the annual legumes. One study in Estonia showed a decline of nearly 70% in growth and N accumulation of Berseem clover, faba bean and field pea when planting was delayed from August 3 to 18 (Toom et al., 2019). For most forage legumes (i.e., alfalfa, red clover), seeding in the spring under a cereal crop seems to provide the most consistent growth as the seedlings were able to begin rapid growth as soon as the main crop was harvested. Annual legumes such as field peas, as well as hairy vetch, were better suited to planting immediately after cereal grain harvest. Perennial legumes left to grow until spring generated more biomass and N accumulation, provided there was good winter survival. Brandsæter et al. (2008) showed that winter survival was the most important factor for N accumulation in Norway. In order to maximize nitrogen credits from overwintered legumes such as red clover and hairy vetch, it is important to allow the cover crop sufficient time in the spring to grow before the cover crop is terminated for planting the cash crop.

.

Table 2. Measured yield and N content of above-ground biomass for three cover crops in Nova Scotia, planted in pure stands on July 14, 2022, and sampled October 25, 2022.

Cover Crop Species	% Dry Matter	Nitrogen (%)	Carbon (%)	C:N Ratio	kg DM/ha	kg N/ha	kg C/ha
Hairy Vetch	11.3	5.1	44.3	8.8	2,590	131	1,150
Red Clover	14.5	3.9	43.7	11.3	2,230	86	974
Forage Peas	18.0	3.1	38.6	12.5	8,780	271	3,470

As a rough rule of thumb, you should be looking for an above-ground biomass accumulation at the time of cover crop termination of at least 1 ton/acre (2.2 tonnes per hectare), such as that provided by a vigorous stand of red clover. Less than this, and there generally won't be enough N accumulation to make a meaningful difference to the fertilizer requirements of the following crop.

NITROGEN RELEASE FROM LEGUME COVER CROPS

Once the N has accumulated in the cover crop, it must be released into the soil at a time and place where the following cash crop can absorb it. Rapid mineralization of the cover crop N before the crop needs it can result in N losses, while slow mineralization may mean that the N supply may not meet the needs of the following crop. This synchrony between N availability and N requirement depends on the C:N ratio of the cover crop residues, the weather conditions, the timing of cover crop termination and the dynamics of cash crop nitrogen requirements.

Grain versus forage legumes
Annual legumes, grown primarily for harvest of the seed portion (i.e., field peas, soybeans) can produce large amounts of above-ground biomass when planted in late summer, but with relatively little nitrogen accumulation below the soil surface. If left to maturity, almost all of the N fixed by the plant will have been translocated into the grain. Perennial forage legumes, in contrast, retain more N in the root system, so a forage legume (i.e. clovers, vetches, alfalfa) with the same amount of top growth as a grain legume will add more nitrogen to the cropping system.

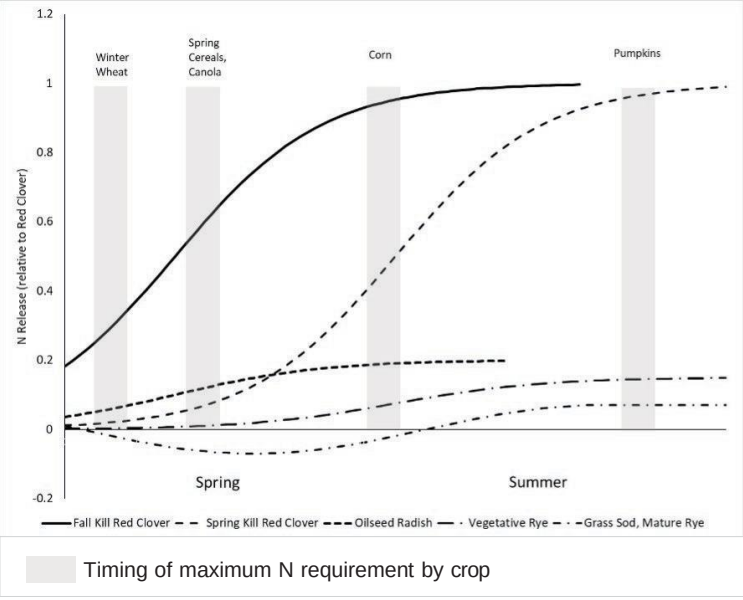

Figure 2. Conceptual illustration of N release from cover crops, relative to the timing of maximum crop requirement for N (represented by the vertical bars).

Most legume cover crops have a narrow C:N ratio, so they will degrade quickly and release mineral N into the soil under warm, moist conditions. If the legume is mixed with a grass or other non-legume (i.e., hairy vetch with cereal rye), the C:N ratio will be higher, and N release will be delayed. This becomes more of an issue with spring-killed cover crops; both legumes and grasses will have higher C:N ratios as they mature, but this will happen to a much greater degree with the grasses.

Residue decomposition and N release, will be much slower during the winter when the soil is cold, so most of the N from a cover crop terminated in late fall should stay in the organic form until the soil warms in spring. If the cover crop is terminated in early fall, however, most of the N could be mineralized when there is no growing crop to use it and be lost over winter.

Managing the timing of N release from the cover crop will not give precise results each year because so much depends on the weather between cover crop termination and crop uptake. As a rule, however, pure legume stands that are terminated in late fall or early spring will be more reliable N sources for cereal or canola crops that require much of their N supply early in the season. Grass-legume mixtures, with termination delayed until just before planting, should more closely match the N requirements of a full-season crop such as corn or late-crop potatoes.

APPARENT FERTILIZER N VALUE OF LEGUME COVER CROPS

There is good evidence that legume cover crops, when there is sufficient growth, can supply significant amounts of nitrogen to the following crop. However, there are uncertainties about precisely how much N is available (Bourgeois et al., 2022). We can apply rules-of-thumb to account for this nitrogen. The easiest approach is to apply a single N credit for any legume that is planted and terminated in the same year; Ontario recommends a credit of 45 kg N/ha to the crop following legume cover crops (80 kg N/ha if the crop is corn) (Ontario Ministry of Agriculture Food and Rural Affairs, 2017). Similar average N credits would be expected in Nova Scotia and Newfoundland.

The drawback to the simple approach is the failure to account for exceptional management that generates large amounts of nitrogen accumulation in the cover crop. From the yield responses in corn to various levels of cover crop N, it appears that the corn crop is absorbing between 40 – 50% of the N in the cover crop biomass, with higher percentages in the highest N cover crops. Estimating the above-ground biomass and N concentration can allow a closer approximation of N that would be available to the following crop.

Table 3. Nitrogen in above-ground biomass at various levels of biomass accumulation and N concentration, showing typical ranges for various legume types for biomass and N concentration.

		N Concentration					
		2.5%	3.0%	3.5%	4.0%	4.5%	5.0%
Biomass							
2.0 T/ha		50	60	70	80	90	100
2.5 T/ha		63	75	88	100	113	125
3.0 T/ha		75	90	105	120	135	150
3.5 T/ha		88	105	123	140	158	165
4.0 T/ha		100	120	140	160	180	200
5.0 T/ha		125	150	175	200	225	250
6.0 T/ha		150	180	210	240	270	300

Legend:

Grain Legumes (Peas, Soy, Beans)
Red Clover, Alfalfa
Hairy Vetch
Vegetative
Full Bloom

Table 3 shows the calculation of the amount of N accumulated in the above-ground biomass to the time of cover crop termination for various levels of crop growth and N concentration. Nitrogen concentrations decline as the plants mature, but biomass production typically increases as the plant reaches full bloom. If the N concentration is less than 2.5%, there is unlikely to be any N credit to the following crop, regardless of the N accumulation, since the C:N ratio will be high enough to inhibit N release. The ranges of biomass and N concentrations are rough estimates; much will depend on the planting dates and growing conditions, particularly for grain legumes planted after cereal harvest. For the most accurate results, weigh the biomass from a known area, and send the biomass to a local lab to be analyzed for nitrogen content.

Table 4. Expected N credit to the following crop at various levels of N accumulation in the cover crop above-ground biomass. The credit from grain legumes is lower because there is less N in the root biomass.

N in cover crop biomass (kg N/ha)	Expected available N (kg N/ha)	
	Forage Legumes	Grain Legumes
60	24	15
90	36	22
120	54	32
150	68	41
180	81	49
210	105	63
>240	120	72

Table 4 estimates how much N is expected to be available to the following crop given the N accumulated in the cover crops. Grain legumes are assumed to be about 40% less than forage legumes because the forage legumes retain additional N in the root biomass; this root N is not measured but forms part of the available N pool. The amount of available N will be less than predicted if weather conditions are extremely cool or dry or if there is a long delay between the cover crop termination and the N uptake by the following crop. If you send a biomass sample to the lab for analysis, Oregon State has a handy calculator that can determine just how much N you can expect to be plant-available for your cash crop (**smallfarms.oregonstate.edu/calculator**).

FREQUENTLY ASKED QUESTIONS ABOUT THE IMPACT OF COVER CROP MANAGEMENT ON NITROGEN CREDIT

Should I terminate the cover crop in the fall or wait until spring?

There is no single answer to this. Leaving a perennial legume until spring will give the opportunity for more N fixation, but in a no-till system, it may be challenging to kill the actively growing cover crop before planting the main crop. In a tilled system, not all soils respond well to spring primary tillage, although the soils that do are also the ones that benefit the most from cover over the winter. There does not appear to be a difference in the proportion of N in the cover crop that transfers to the following crop between a late fall or spring termination. However, killing the cover crop in early fall will increase the risk of N loss over winter. Each farm will need to balance the risks and benefits of its own production system.

Does the tillage system make a difference to the N availability from the cover crop?

There are mixed results to tillage. In an analysis of N requirements for corn in Ontario, the optimum N rates following a red clover cover crop were about 15 kg N /ha lower in tilled systems than in no-till (Ontario Ministry of Agriculture Food and Rural Affairs, 2017), although there is actually a timing effect here as well since most of the comparisons were between fall tilled and spring termination in no-till. A meta-analysis of many studies across the temperate zone of North America and Europe, however, found no difference between no-till and tilled systems (Bourgeois et al., 2022).

Can I harvest the top growth and still get the N credit?

For legumes in the first year of growth, it appears that most of the fixed N is in the top growth, so harvesting this material as forage removes the N that would have fed the following crop (Bowren et al., 1969). The exception appears to be grazing systems, where a large part of the N consumed by livestock is excreted back into the field and so remains available. For this system to be successful, there needs to be sufficient N fixed by the cover crop (>100 kg N/ha) and intensive enough grazing to evenly distribute the manure back over the field (Cicek et al., 2014).

INCORPORATING LEGUME COVER CROPS INTO A CROP PRODUCTION SYSTEM

The biggest factor in N accumulation in cover crops, and therefore in N credits for the following crop, is adequate growth of the cover crop. This means there are a limited number of places in a crop rotation where there is a window to allow cover crop growth (following cereals, canola or early vegetables). Unlike the southern U.S., there is insufficient warmth and daylight to support adequate growth of legumes interplanted into or planted after corn or soybean harvest. These covers may help to reduce soil erosion but not provide N to the following crop.

Interseeding a small-seeded forage legume like red clover into cereal crops, either by planting at the same time as the spring cereal or broadcasting seed on the surface into the crop canopy, has the advantage of getting plants established so they can begin rapid growth as soon as the cereal is harvested. The species chosen must be quick to establish and tolerant of shading. The risk is that competition from a heavy grain crop, particularly if it lodges, can choke out the seedlings and result in a thin or patchy stand. **However, in a system where red clover is frost-seeded into winter wheat, your goal is really only one stem per square foot to achieve a 40- 70 lbs/acre N credit going into the winter.**

A second alternative is to drill cover crop seeds into grain stubble immediately after harvest. The most common limitation at this planting time is soil moisture; if the cover crop's germination is delayed until adequate rainfall, there may not be time for appreciable growth or N fixation before winter. Typically, in Nova Scotia, no-tilling the cover crop after grain is more successful than if the soil is worked, as tillage reduces the soil moisture needed for germination. The further north you are located, the shorter the growing season and, therefore, less cover crop N accumulation.

Planning for the termination of the cover crop is just as important as planning for planting. Any advantage to the following crop will disappear if the cover crop residue impedes planting of the following crop or if it becomes a weed.

Farmers who are successful with cover crops treat them as crops, with the same attention to management as the main crops. The yields they generate are carbon for the soil and nitrogen for the following crops rather than forage or grain, but they can be equally beneficial to the bottom line.

SUMMARY

Legume cover crops can provide a significant part of the nitrogen requirement for the following crops, although there is significant variability in how much N is supplied each year. Much of this variation is due to the amount of cover crop growth and N fixation along with soil and weather conditions; however, the N release from properly managed cover crop residues appears relatively consistent. Investing in the management of legume cover crops to maximize N fixation will pay immediate dividends to the farmer.

REFERENCES

Bourgeois, B., Charles, A., Van Eerd, L. L., Tremblay, N., Lynch, D., Bourgeois, G., Bastien, M., Bélanger, V., Landry, C., & Vanasse, A. (2022). Interactive effects between cover crop management and the environment modulate benefits to cash crop yields: a meta-analysis. *Canadian Journal of Plant Science*, 102(3), 656-678. **https://doi.org/10.1139/cjps-2021-0177**

Bowren, K. E., Cooke, D. A., & Downey, R. K. (1969). YIELD OF DRY MATTER AND NITROGEN FROM TOPS AND ROOTS OF SWEETCLOVER, ALFALFA AND RED CLOVER AT FIVE STAGES OF GROWTH. *Canadian Journal of Plant Science*, 49(1), 61-68. **https://doi.org/10.4141/cjps69-007**

Brandsæter, L. O., Heggen, H., Riley, H., Stubhaug, E., & Henriksen, T. M. (2008). Winter survival, biomass accumulation and N mineralization of winter annual and biennial legumes sown at various times of year in Northern Temperate Regions. *European Journal of Agronomy*, 28(3), 437-448.

Cicek, H., Thiessen Martens, J. R., Bamford, K. C., & Entz, M. H. (2014). Effects of grazing two green manure crop types in organic farming systems: N supply and productivity of following grain crops. *Agriculture, Ecosystems & Environment*, 190, 27-36. **https://doi.org/10.1016/j.agee.2013.09.028**

Ontario Ministry of Agriculture Food and Rural Affairs. (2017). *Agronomy Guide for Field Crops* [OMAFRA Publication 811]. Queen's Printer for Ontario. **http://omafra.gov.on.ca/english/crops/pub811/pub811.pdf**

Toom, M., Talgre, L., Pechter, P., Narits, L., Tamm, S., & Lauringson, E. (2019). The effect of sowing date on cover crop biomass and nitrogen accumulation. *Agronomy Research*, 17(4), 1779-1787. **https://doi.org/10.15159/ar.19.164**

Torbert, H. A., Reeves, D. W., & Mulvaney, R. L. (1996). Winter Legume Cover Crop Benefits to Corn: Rotation vs. Fixed-Nitrogen Effects. *Agronomy Journal*, 88(4), 527-535. **https://doi.org/10.2134/agronj1996.00021962008800040005x**