

The Plant Available Nitrogen Network in Ontario

How cover crops can PAN out in the soil

By Sarah Larsen

As farmers know, cover crops don't just disappear when they're terminated. What happens next—at and beneath the soil surface—is determined by many factors which influence whether nutrients are captured, released, or temporarily locked away.

Understanding these outcomes begins with the role cover crops play in nutrient cycling. While growing, cover crops capture excess nutrients and reduce leaching. After they are terminated and during decomposition, soil microbes mineralize the residue into plant-available nitrogen (PAN). This is especially true for legumes like clover, vetch and peas that partner with bacteria to capture atmospheric nitrogen (N) in their tissues.

During decomposition, soil microbes can also take up available N before crops can access it—temporarily tying it up in a process known as immobilization. This effect is especially pronounced when decomposing materials have a high carbon-to-nitrogen (C:N) ratio, which drives microbes to scavenge available N from the soil. Whether nutrients are released through mineralization or temporarily locked away through immobilization impacts how much fertilizer the next crop will need.

The timing of N release depends on cover crop type, and also growth stage. Young, leafy tissues tend to be higher in N and more readily mineralize into PAN. More mature tissues, particularly stems, contain less N and decompose more slowly.

That's the challenge, says Jesse Way of Milky Way Farm near Woodstock. "Cover cropping adds complexity to our management. You can do everything right with establishing a cover crop, but if our residue management and the timing of N release doesn't line up with your cash crop, you're not getting the full benefit."

Given this, a central management question for farmers is: how much N is actually supplied by cover crops—and when does it become available? Jesse's 2022 farmer-led research trial took that question to the field, comparing cover crops with low versus high legume content before carrots. This project was partly inspired by Oregon State University Extension research linking N concentration in cover crop dry matter to PAN release after incorporation (see sidebar).

After a year of data collection, Jesse and EFAO expanded the trial, enlisting other farmers and partnering with the Living Lab – Ontario project, a federally funded program connecting farmers, scientists and partners to co-develop and test ideas in-real world conditions. Together they formed the PAN Network, a multi-year, multi-farm, farmer-led research initiative with the goal of building a locally calibrated N management tool and detailing PAN from different cover



crop mixes across Ontario. Contributing farmers include: Ines Lacarne, Norm Lamothe, Glen Young, Adam Kramer, Hailey Mayfield, Steph Goodyear, and Larry Dyck.

The N management tool is now available through EFAO at efao.ca/research/pan, with more data to come.

"Farmers have so many cover crop options, and the cover crop's impact on PAN is highly variable, so we're trying to take some of the guesswork out of it", says Jesse. "If we can better predict when N is available, we can make better decisions in the field."



Table 1. Version 1 of the Ontario N Management Tool of PAN from Cover Crops, also available online at efao.ca/research/pan.

Initial database of % dry matter and % N of cover crops in Ontario. As expected, cereal crops and older cover crops are drier and have less % total N than legumes, mixed and less mature cover crops. Current research is investigating the effect of termination method on PAN.

Cover Crop	Seeding Date	Termination Time	Days to Maturity	% N	% Dry Matter	Maturity, Type
Peas	April 18, 2024	Early June 2024	46	5.1	14.9	Young legume
Oats, peas and sunflowers	August 12, 2024	Late October 2024	72	4.7	19.6	Mature summer/fall mix
Oats and peas (high legume ratio)	April 13, 2022	June 22, 2022	70	4.6	18.1	Mature 75/25 legume/cereal mix
Red clover	Spring 2024	Spring 2025	Spring to spring	4.3	16.1	Full year legume
Oats, peas and hairy vetch	April 30, 2025	Early July 2025	64	4.3	19.3*	Mature 50/50 cereal/legume mix
Oats and Peas (low legume ratio)	April 13, 2022	June 22, 2022	70	3.8	19.0	Mature 25/75 legume/cereal mix
Oats and peas	Apr 10, 2024	Mid June 2024	71	3.2	15.5	Mature 50/50 legume/cereal mix
Crimson clover and hairy vetch	Fall 2024	Spring 2025	Fall to spring	3.0	20.9	Overwintered legume
Oats	May 15, 2024	Mid June 2024	40	3.0	15.0	Young cereal
Mix (volunteer wheat, crimson clover, radish, etc.)	Aug 12, 2023	Spring 2024	Summer to spring	2.0	23.1	Overwintered mix
Rye	Sep 23, 2023	Spring 2024	174	1.4	27.5	Overwintered cereal
Rye	Fall 2022	May 2023	Fall to Spring	1.0	23.3	Mature overwintered cereal

* When sampling in the heat, especially for high biomass cover crops that must be cut into smaller pieces before sending to the lab, there is more potential for moisture loss between time of sampling and lab analysis. For this reason, this 19.3% DM is likely unnaturally elevated. In all situations, it is best practice to sample earlier in the morning.

Populating the database with on-farm data

Just prior to termination, farmers took biomass samples of their cover crops from a known area (e.g. quadrat of 30" x 30", or hula hoop of known diameter). They recorded the fresh weight and then mailed the samples to A&L Laboratories for analysis of %N, C:N, and % moisture, which was then converted to % dry matter.

How to use this database for an example cover crop of mature oats and peas (spring planted)

Example data:

- Sample area of your quadrat or hula hoop = $6.25 \text{ ft}^2 = 0.5806 \text{ m}$
- Wet weight that you measure on the farm = 7 lb = 3.18 kg
- Dry matter, estimated from the database based on cover crop type and maturity = 15.5%
- N, estimated from the database based on the cover crop type and maturity = 3.2%

Based on fresh weight, you can use the N management tool to calculate dry weight, total N and PAN, as detailed in Tables 2 and 3.

Note that **estimated values** assume cover crop incorporation, and adequate soil moisture and temperature for N mineralization. Actual PAN will vary under variable field conditions.

You can take soil N data to support PAN predictions.

Table 2. Example input and output using the OSU free online Organic Fertilizer and Cover Crop Calculator: smallfarms.oregonstate.edu/calculator.

Cover crop	Area Sampled (ft ²)	Fraction of an acre sampled	Fresh Weight of field sample (lbs)	%N from lab	% Dry Matter from lab (inverse of %Moisture)	Fresh weight (lbs/ac)	Dry weight (lbs/ac)	Total N (lbs/ac)	4 Week PAN (lbs/ac)	10 week PAN (lbs/ac)
Mature oats and peas	6.25	0.00014348	7	3.2	15.5	48787	7562	242	87	105

Table 3. Example of how to use fresh weight of your cover crop to estimate PAN in imperial and metric units, using the example for mature oats and peas.

Step	Imperial units	Metric units
1. Convert wet biomass to dry matter (DM)	Dry weight of your sample: Wet weight x % dry matter = $7 \times 0.155 = 1.085 \text{ lb DM}$ This is dry matter from the 6.25 ft ² sample area.	Dry weight of your sample: Wet weight x % dry matter = $3.18 \times 0.155 = 0.493 \text{ kg DM}$ This is dry matter from the 0.5806 m ² sample area.
2. Scale up to per acre biomass	1 acre = 43,560 ft ² Scaling factor: $43,560/6.25 = 6,969.6$ Dry matter per acre: $1.085 \text{ [from Step 1]} \times 6,969.6 = 7,560 \text{ lb DM/acre}$ Convert to tons: $7,560/2,000 = 3.78 \text{ ton DM/acre}$ This is dry matter in tons per acre.	1 hectare = 10,000 m ² Scaling factor: $10,000/0.5806 = 17,215$ Dry matter per acre: $0.493 \text{ [from Step 1]} \times 17,215 = 8,487 \text{ kg DM/ha}$ Convert to tonnes: $8,487 / 1,000 = 8.49 \text{ t DM/ha}$ This is dry matter in tonnes per hectare.

Step	Imperial units	Metric units
3. Calculate total N in cover crop dry matter from %N	From Table 1, total % N = 3.2% 7,560 lb DM/acre [from Step 2] x 0.032 = 242 lb total N/acre This is total N in the cover crop biomass.	From Table 1, total % N = 3.2% 8,487 kg DM/ha [from Step 2] x 0.032 = 272 kg total N/ha This is total N in the cover crop biomass.
4. Estimate PAN	Option 1: Use the OSU online calculator Cover Crop Analysis tab (4) to calculate a more precise mineralization factor and estimate PAN. Plugging in the example data, the calculator estimates 10 week PAN at 2.4 lb/1000 ft ² = 105 lb/acre. Assuming 10 week PAN is the season's release to the crop, we can use the 105/242 [from Step 3] to calculate a mineralization factor of 0.43.	Option 1: Use the OSU online calculator Cover Crop Analysis tab (4) to calculate a more precise mineralization factor and estimate PAN. Plugging in the example data, the calculator estimates 10 week PAN at 2.4 lb/1000 ft ² = 117 kg/ha. Assuming 10 week PAN is the season's release to the crop, we can use the 117/272 [from Step 3] to calculate a mineralization factor of 0.43.
	PAN (lb/ac) = Total N x mineralization factor: 242 lb N/acre x 0.43 = 105 lb N/acre	PAN (kg/ha) = Total N x mineralization factor: 271 kg N/ha x 0.43 = 116 kg N/ha
	Option 2: Use the sidebar to find N mineralization factor ranges. Residue with 3.2% N is on the lower end of the 'High' range, so a mineralization factor of 40 – 45% is reasonable.	
	PAN (lb/ac) = Total N x mineralization factor: Lower estimate: 242 lb/acre x 0.4 = 97 lb/acre of PAN Upper estimate: 242 lb/acre x 0.45 = 109 lb/acre of PAN	PAN (kg/ha) = Total N x mineralization factor: Lower estimate: 271 kg/ha x 0.40 = 108 kg N/ha of PAN Upper estimate: 271 kg/ha x 0.45 = 122 kg N/ha of PAN
5. Determine your N needs, taking into account PAN from your cover crop	Use Table 3 as a guide to the total plant available N needed by your specific crops. Subtract the estimate of PAN for your cover crop to know if additional N is needed through compost, meal, etc.	

Table 4. N input requirements for vegetable crops in established organic cropping systems and transition to organic systems. Adapted from reference 3. The higher ranges for transition to organic systems reflect less N available from SOM mineralization. Note that these are approximate ranges that haven't been tested in Ontario, and actual N requirements will vary depending on site specific variables such as SOM and management history.

Crop N requirement	Transition to organic systems	Established organic systems
	lb/acre of PAN input from all external sources, additional to SOM N mineralization	
Low	60-100	< 50
Medium	100-150	50-100
High	140-200	70-140

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References

- Jesse's research report: <https://efao.ca/wp-content/uploads/EFAO-PAN-Cover-Crops-Research-Report-2022-Final-28Feb2023.pdf>
- Report on PAN: <https://extension.oregonstate.edu/catalog/pnw-636-estimating-plant-available-nitrogen-release-cover-crops>
- Resource bulletin about the online PAN calculator: <https://extension.oregonstate.edu/catalog/pub/em-9235-osu-organic-fertilizer-cover-crop-calculator-predicting-plant-available>
- Online calculator: <https://smallfarms.oregonstate.edu/calculator>

Funding for this project has been provided by Agriculture and Agri-Food Canada under the Agricultural Climate Solutions – Living Labs program and by the following partners: Beef Farmers of Ontario, Dairy Farmers of Ontario, Grain Farmers of Ontario, Ontario Federation of Agriculture, Ontario Pork and Ontario Sheep Farmers. The project is coordinated by the Ontario Soil and Crop Improvement Association.



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Sidebar: Mineralization factors for PAN over 10 weeks

Take from OSU Extension Services (4)

Low %N (≤2%) → slow breakdown → low PAN (~10–30%)

Medium %N (2–3%) → moderate release (~30–40%)

High %N (>3%) → rapid release (~40–60%)

If you'd like to narrow down the mineralization factor for your specific situation, you can take soil nitrate tests in conjunction with biomass sampling and use OSU's online calculator (4).

Want to get involved?

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