PRINCE EDWARD ISLAND FEDERATION OF AGRICULTURE

Nitrogen Management Reference Guide

To assist with applications to the On Farm Climate Action Fund

Nitrogen Management Reference Guide:

Ramsay, Matt

2022

Published by:

PEI Federation of Agriculture
1-159 Sherwood Road
Charlottetown, PEI
Canada C1E 0E5
Tel: (902) 368-7289
Fax: (902) 368-7204
E-mail: info@peifa.ca
Web: www.peifa.ca

Nitrogen Management on PEI Soils

Managing Nitrogen on PEI soils presents unique challenges given our weathered, sandy loam soils. Nitrogen can exist in many different states in the soil and the nitrogen cycle is quite complex. The following table outlines different sources of nitrogen in cropping systems:

Table 1 - Sources of Nitrogen in Cropping Systems

Chemical fertilizers	Industrially fixed urea, nitrate (NO_3), and ammonium (NH_4) from atmospheric nitrogen (N_2)
Manure and composts	Organic nitrogen (proteins, organisms, etc), nitrate (NO_3), ammonium (NH_4)
Biologically fixed nitrogen	Organic nitrogen fixed by bacteria on legume roots (clover and alfalfa) converted to nitrate (NO_3) and ammonium (NH_4) from decomposing crop residues
Biologically mineralized nitrogen	Organic nitrogen (proteins, organisms, etc) converted into ammonium (NH_4) and nitrate (NO_3) through the breakdown of organic matter

If not already in nitrate form, nitrogen fertilizers generally convert to nitrate quite quickly and are therefore in an exposed chemical state and subject to leaching loss through the movement of water. Therefore, it is increasingly imperative, given higher intensity rain events and elevated nitrate levels in water, that farmers make the most of every unit of Nitrogen available from *all* sources and follow an integrated nutrient management approach to Nitrogen. Generally speaking, the efficiency of supplied nitrogen can be measured as:

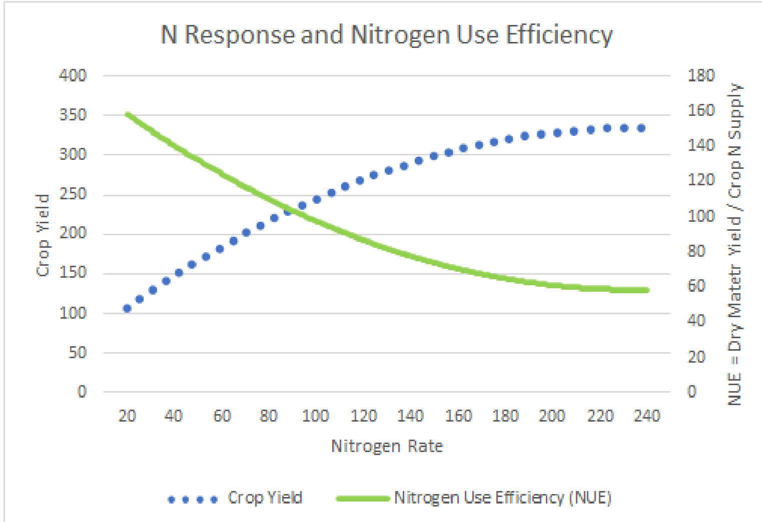
Nitrogen Use Efficiency (NUE) = Dry matter yield / Crop N Supply

Several processes affect variation in NUE. On the yield side of the equation, the efficiency with which the plant takes up the Nitrogen supplied and the efficiency with which the plant makes dry marketable yield with that Nitrogen can impact NUE (Zebarth, 2004, Fageria 2005).

In terms of Crop N supply, it can be challenging to estimate given that soil nitrate is so mobile and may not be accurately captured with soil nitrate testing. Applied fertilizer, manure, legumes, nitrate levels at planting, and an estimate of mineralized Nitrogen should be factored into an estimate of crop N supply (Zebarth 2004). A combination of multi-depth nitrate tests together with biologically available Nitrogen testing (BNA Soil Health Metric) would provide a reasonable estimate in addition to applied Nitrogen fertilizer.

Generally speaking, Nitrogen use efficiency (NUE) will decrease with increasing rates of Nitrogen fertilization while yield growth will slow and eventually plateau (see Figure 1). Therefore, it is important to take a balanced approach to N management so that equal emphasis is placed on minimizing economic, environmental, and social risk.

Figure 1 - Generalized Relationship Between Nitrogen Use Efficiency & Crop Yield



Source: PEI On-farm data, Zebarth et al. 2003

Integrated Nitrogen Planning

A 4R approach to nitrogen must include a wider consideration of all nutrients in order to ensure plant function is maximized and N uptake is not impaired. This can be combined with knowledge of soil texture, structure, and biological status to approach a more refined estimate of how much nitrogen needs to be supplied. Therefore, a Nitrogen Management Plan includes a basic 4R framework with respect to chemical fertilizers (source, rate, time, place), but also includes soil health metrics, crop rotation history, manure and compost testing. Additionally, topography and proximity to watercourses need to be taken into account when planning operations and working around buffer zones (see Table 2).

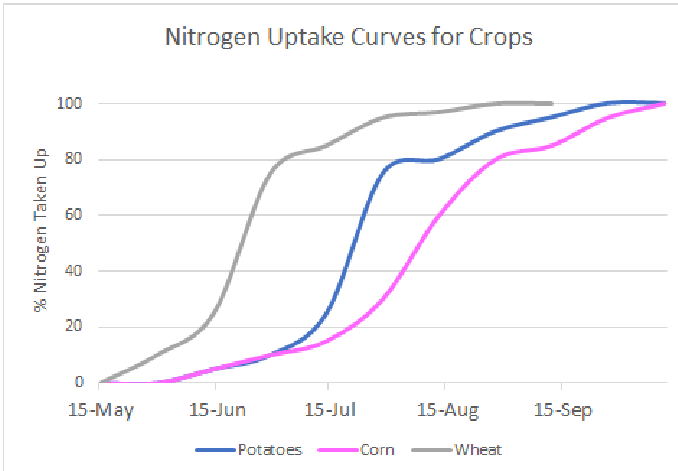
Table 2 - Components of an Integrated Nitrogen Planning Process

Crop / Variety Uptake & Removal	Determine the crop & varietal N uptake & removal
Soil analysis & biological status	Estimated Nitrogen mineralized from organic matter levels and general soil health, multi-depth nitrates
Field history, rotational plan, & legume credits	Estimate legume N credits, soil quality
Manure credits and incorporation approach	Estimate Nitrogen value of applied manure
Economic optimum rate analysis	Maximize economic efficiency of Nitrogen
Source, timing, and placement planning	Slow release, split application, banding or topdress
Source specific loss mechanisms	E.g. Urea vs. nitrate, standard vs. slow release
Triple bottom line risk assessment	Identify environmental, social, and economic risks
Greenhouse Gas Emissions	Consider lower rates in terms of GHG reduction

Crop/variety Nitrogen uptake and removal

Different crops require different rates and some cultivars are more nutrient efficient than others; either due to breeding selection or natural genetics. Ask your seed sales rep or local agronomist for an estimate or range on nutrient uptake and removal. AgPHD FertRemoval is a free app for generalized removal rates as a starting point or refer to this localized factsheet. The more you can match your nitrogen supply (using *all* sources listed) to crop uptake over the season, the higher the probability you will convert N dollars into crop yield (see Figure 2)

Figure 2 - Examples of Typical Nitrogen Uptake Curves by Crops



Source: https://umanitoba.ca/faculties/afs/MAC_proceedings/proceedings/2006/heard_hay_nutrient_uptake.pdf

Soil analysis & biological status

Currently, no reliable chemical test (except multi-depth nitrate testing) exists for Nitrogen, largely due to the rate at which nitrate moves through the soil profile. More recently, the Biological Nitrogen Availability (BNA) test was introduced as part of Soil Health testing at the PEI Analytical Lab. PEI soil testing has shown that the lower range for BNA is ~20-30lbs/a whereas the higher range is ~110lbs/a.[1] BNA represents an opportunity to reduce nitrogen and local research is suggesting reductions based on the BNA test can reduce N_20 emissions and better target optimal N rates.[2]

[1] Burton, Zebarth, Styles (2016, March). Developing a soil nitrogen test for potato production in Prince Edward Island. Data presented at the PEI Soil and Crop Improvement Association Annual Conference, Summerside, PE.

[2] Burton, D., Stiles, K., Watt, S. (2022). Implementation 4R Nitrogen Management Practices to Reduce N_2O Emissions from Rainfed Potato Production [Report]. Submitted to Fertilizer Canada.

Legume credits, cropping system, and field history

This credit is highly dependent on the quality of the stand and whether or not forage was removed. Credits can range from 10lbs/a to 100lbs/a. This factsheet provides a useful starting point. This calculator will help to estimate Nitrogen content of forage harvest removal. The timing of forage termination and plough-down affects nitrogen retention in the following crop. (Jiang, 2019). The following table provides published estimates from various sources.

Table 3 - Estimates of Nitrogen Credits for Various Scenarios

Forage Type	**Minimum % Legume**	**Yrs Established**	**N Credit (lbs/a)**			
			Stand Fair (PEI)	Stand Good (PEI) [1]	OMAFRA [2]	Gov Manitoba [3]
Legumes	50%	1			40	
Legumes	20%	>1			20	
Legumes	30%	>1			50	
Legumes	50%	>1			100	
Alfalfa	50%	2	36	71		
Alfalfa	50%	3	36	71		
Alfalfa	50%	4	36	71		70
Red Clover	50%	2	18	36		20
Red Clover	50%	3	18	36		
Rye Grass		1	0	-13		

1 http://peipotatoagronomy.com/wp-content/uploads/2018/01/Nutrient-Mgmt-Factsheet-Jan17.pdf

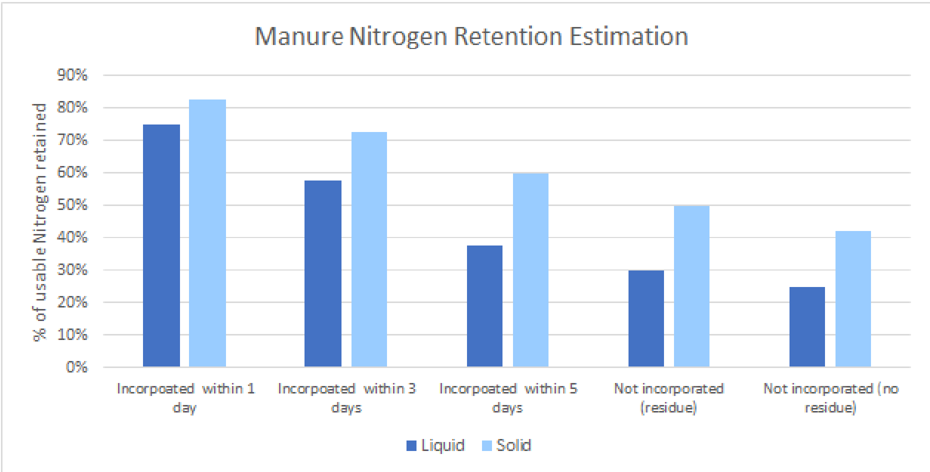
2 http://www.omafra.gov.on.ca/english/crops/hort/soil_fruit.htm#Nitrogen

3 https://www.gov.mb.ca/agriculture/crops/soil-fertility/soil-fertility-guide/nitrogen.html#pulse

Manure credits and incorporation method

A worksheet is available through the PEI Potato Agronomy nutrient management website for calculating these credits using manure tests. In the absence of manure tests, OMAFRA as well as PEI Soil and Crop have published factsheets with estimations. A range of 1-2 Kg ammonium (NH_4) per metric tonne of manure is common for solid beef and dairy with swine and poultry ranging from 2-8Kg NH_4 per metric tonne. The sooner manure is incorporated the more nitrogen is retained (see Figure 3).

Figure 3 - Estimated Nitrogen Retained in Soil After Manure Application



Target the Economic Optimum Nitrogen rate

While maximizing yield is important, many response trials show that the Nitrogen rate which achieves maximum yield is generally less profitable than finding the rate at which additional nitrogen starts to return less and less yield. It's more economical to maximize revenue per N dollar spent than to chase every last unit of yield (see Figures 4 & 5).

Figure 4 - Example Nitrogen Response Trial Data (Grains)

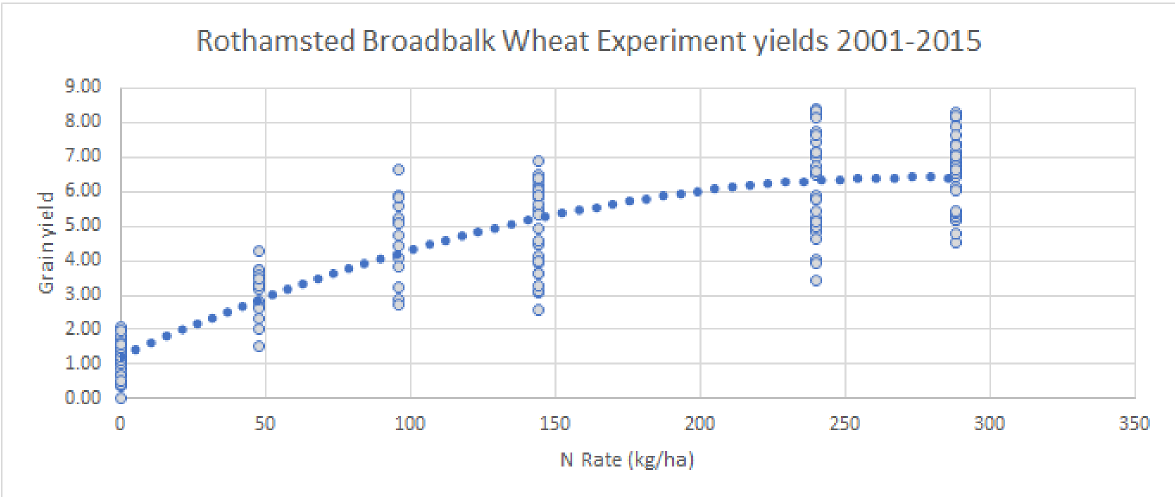
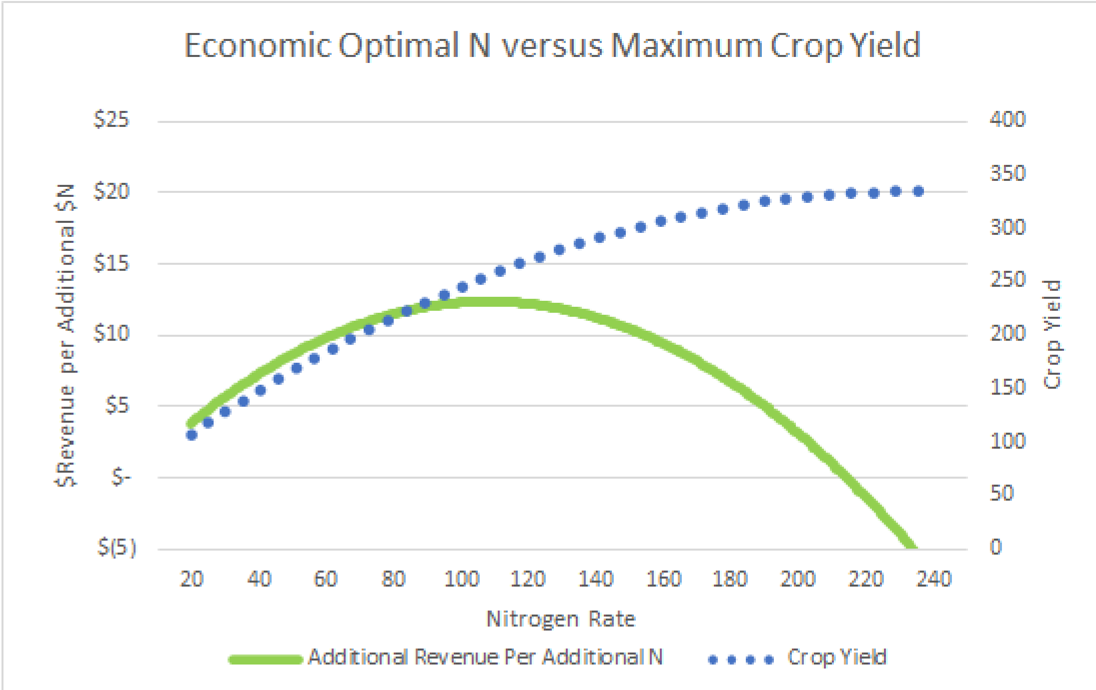


Figure 5 - Example of Economic Optimal N Rate vs. Maximum Yield Response (Potatoes)



Slow release and/or split applications can buy time

Because nitrogen uptake doesn't peak until later on in the growing season, applying all of a crops nitrogen at once doesn't match its needs in time. Consider how you can utilize either split applications or slow release nitrogen sources to better match crop needs in time.

- Delaying the application of a portion of the total crops N requirements may reduce nitrate exposure but not necessarily N_20 emissions (Zebarth et. al., 2012).

- Preplant applications of slow release nitrogen can reduce nitrate exposure and provide a similar effect of a post-planting application of regular nitrogen. Past research has suggested controlled release products may reduce nitrate exposure but increase N_2O emissions when applied at similar rates to conventional nitrogen. Recent research is demonstrating that slow release products can reduce N_2O emissions from PEI soils and reductions are further improved with reduced rates of N[3]. Types of controlled release N:
    - Polymer coated urea (PCU) - also known as ESN. Specially coated to delay the exposure of urea to the environment where it will begin to convert into other nitrogen forms (NH_3, NH_4, $N0_3$)
    - Urease inhibitor - A spray on coating that delays the conversion of urea to ammonium. Ammonium (NH_4) quickly converts to nitrate ($N0_3$) once converted from Urea.
    - Nitrification inhibitors - These slow the conversion of ammonium (NH_4) to nitrate ($N0_3$). When paired with a Urease inhibitor, such as in Agrotain or Super U, Nitrogen conversion can be managed.

[3] Watts S. (2022) Investigation of Reducing Nitrogen Application Rates Using Enhanced Efficiency Nitrogen Sources on Performance of Commercial Potatoes in Prince Edward Island Canada.

- Foliar applications of nitrogen can also provide smaller amounts of nitrogen later in the season and reduce the initial amounts of exposed nitrate. More research is needed on testing protocols to guide foliar programs.

Delaying N application, reducing initial rates and/or using controlled release fertilizers can buy time to decide if more Nitrogen is required based on plant tissue testing or changes in the weather outlook. Ensure delayed surface applications (such as topdresses on cereals) are timed to catch late spring rains. If topdress applications are delayed too long and rainfall is limited, they may not become soluble enough to be plant available, reducing NUE.

Consider source specific loss mechanisms when placing nitrogen

If Urea is not incorporated and conditions are dry, it can be lost to the air through volatilization. However, when incorporated, it can delay the conversion to nitrate and create a subtle slow release effect whereas nitrate products are highly soluble and prone to leaching immediately after application. Generally speaking, incorporating Nitrogen fertilizers (including slow release products) is best practice. But incorporating too much nitrate containing fertilizer too early in the season creates an elevated risk for leaching. If Nitrogen sources are not placed with consideration to risk of loss, it may not count towards actual crop nitrogen supply and create both economic and environmental losses which reduces NUE.

Evaluate environmental and social risk with economic risk.

There are sufficient resources available through local agronomists and technicians to identify topological risks and map concentrated flows of water. Spreading Nitrogen or manure when there is a raised probability for movement with water has to be considered at the outset of crop planning. Where possible, planting more nitrogen efficient cultivars in sensitive areas can help prevent nitrate movement to surface and groundwater by using lower rates. Adding margin for error on broadcasters and investing in section control equipment can help keep applied nitrogen within cropped areas. Variable rate maps can adjust rates on the fly when entering areas where environmental risk on nitrate loss outweighs the financial risk of underfeeding the crop in a small area. Given that elevated nitrates continue to be reported in our water, a triple bottom line approach is the only way to ensure a sustainable food supply doesn't come at the cost of safe and sustainable water.

Greenhouse Gas Emissions and Nitrogen Management

According to Angers (2005), "Many management factors, including tillage, legume cropping, crop residue management, and type and rate of mineral N fertilizer application, also contribute to N2O emission." Better use of manure, optimized fertilizer rates, and legume credits can all work towards reducing N_2O greenhouse gas emissions. Since Nitrous oxide (N_2O), methane (CH_4) have carbon dioxide (CO_2) equivalencies, nitrogen management is part of a larger initiative to slow down global warming by minimizing net greenhouse gas emissions from all sources. Focusing on metrics such as NUE and EONR in the context of greenhouse gas (GHG) emissions is intended to pair two, often differing, perspectives such that best practices can be assessed in terms of economic, environmental, and social value dimensions. As noted above, Living Labs data has demonstrated reduced rates using biological nitrogen availability testing as well as enhanced efficiency fertilizers can reduce N_20 emissions.

Further Reading

Angers, D. (2005). Greenhouse gas contributions of agricultural soils and potential mitigation practices in Eastern Canada. Soil and Tillage Research.

A review of how agriculture contributes to greenhouse gas emissions in Eastern Canada. Of note, no-till practices don't always increase soil carbon in Eastern Canada. In cool temperate climates N_20 emissions represent the majority of greenhouse gas emissions related to crop production. Manure is a significant source of N_20 emissions in crop production, whereas CH_4 is associated with animal production.

Brown C. (2013). Available Nutrients and Value for Manure From Various Livestock Types. [Website]. OMAFRA. http://www.omafra.gov.on.ca/english/crops/facts/13-043.htm

Very detailed sets of tables useful in estimating the dry matter and nutrient value of many different types of manure. This can be used when manure tests are unavailable.

Burton D.,Nyiraneza J.,MacDonald E.,Stiles K. (2018). Nutrient Management in Potato Production http://peipotatoagronomy.com/wp-content/uploads/2018/01/Nutrient-Mgmt-Factsheet-Jan17.pdf

This factsheet was the product of a nutrient management workshop hosted in 2018. It provides a good overview of general nutrient management concepts as well as crop removal rates and legume Nitrogen credit suggestions.

Burton, Zebarth, Styles (2016, March). Developing a soil nitrogen test for potato production in Prince Edward Island. Data presented at the PEI Soil and Crop Improvement Association Annual Conference, Summerside, PE.

Data collected on Prince Edward Island show substantial variation in soil nitrogen supply across regions and and farms. Potentially mineralizable N ranged from approximately 95kgha-200kg/ha and actual, mineralized N ranged from 30kg/ha - 110kg/ha.

Burton, D., Stiles, K., Watt, S. (2022). Implementation 4R Nitrogen Management Practices to Reduce N_2O Emissions from Rainfed Potato Production [Report]. Submitted to Fertilizer Canada.

This research demonstrates that the Biological Nitrogen Availability (BNA) test as part of the PEI Analytical Laboratories Soil Health testing can be used to optimize Nitrogen rates and reduce N20 emissions without statistically affecting crop yields. A second component to this work looked at enhanced efficiency nitrogen and found a reduced rate of Super U (urease and nitrification inhibitor coated Urea) reduced N20 emissions without statistically affecting yield.

Clark, Jason & Fernández, Fabián & Veum, Kristen & Camberato, James & Carter, Paul & Ferguson, Richard & Franzen, Dave & Kaiser, Daniel & Kitchen, Newell & Laboski, Carrie & Nafziger, Emerson & Rosen, Carl & Sawyer, John. (2019). Predicting Economic Optimal Nitrogen Rate with the Anaerobic Potentially Mineralizable Nitrogen Test. Agronomy Journal. 111. 10.2134/agronj2019.03.0224.

This research was out of the US midwest and looked at using potentially mineralizable nitrogen (PMN) as a predictor for economic optimal Nitrogen rates in grain crops. While the study found that looking at biologically mineralized nitrogen (approximate to BNA on PEI soil health tests) did not provide adequate prediction of the economically optimal nitrogen rate (EONR), it did find on most sites that the EONR for split applications was less than for single applications, indicating possible N reduction benefits of using split N applications. It also found that the ability of the PMN test to predict EONR varied with soil texture and could be combined with other factors to help determine optimal N rates using soil health tests such as PMN or BNA.

Cornell University Cooperative Extension (2017). Nitrogen Uptake by Corn. [Fact Sheet] http://nmsp.cals.cornell.edu/publications/factsheets/factsheet98.pdf?msclkid=9a64eafdc4b611ec959e5b9 219bf158a

This fact sheet provides an example of the nitrogen uptake curve for corn in season. While some nitrogen is required to initiate growth, most of the nitrogen uptake doesn't occur until later on in the growing season.

Fageria, N.K. & Baligar, V.. (2005). Enhancing Nitrogen Use Efficiency in Crop Plants. Advances in Agronomy. 88. 97-185. 10.1016/S0065-2113(05)88004-6.

This paper discusses various metrics for measuring nitrogen efficiency. Generally, formulas include a measure of gain in yield compared to an unfertilized control divided by the amount of nitrogen either applied or taken up by the plant relative to the unfertilized control. It also reports on optimal N concentrations in the shoot dry matter for corn, beans, rice and soybean.

Heard J., Hay D., (n.d.) Nutrient Content, Uptake Pattern and Carbon:Nitrogen Ratios of Prairie Crops. [Fact Sheet] Manitoba Agriculture, Food and Rural Initiatives. https://umanitoba.ca/faculties/afs/MAC_proceedings/proceedings/2006/heard_hay_nutrient_uptake.pd

This provides good examples of Nitrogen uptake curves in season. Note that for most crops, 100% nitrogen uptake does not occur until mid-summer, suggesting the window of opportunity available to better tailor nitrogen management to crop demands.

Jiang, Y., Nyiraneza, J., Khakbazan, M., Geng, X., & Murray, B. J. (2019). Nitrate leaching and potato yield under varying plow timing and nitrogen rate. *Agrosystems, Geosciences & Environment*, *2*(1), 1-14.

This local research demonstrates the importance of approaching Nitrogen management as a double pronged approach. While it's important to provide sufficient Nitrogen to crops in order to avoid limiting yield, applying too much nitrogen not only increases the risk of nitrate leaching, but it can also decrease yield; especially when season length is cut short by frost or crops are planted late. Increasing vegeatative top growth doesn't always translate into higher harvested yield.

Liang, K., Jiang, Y., Nyiraneza, J., Fuller, K., Murnaghan, D., & Meng, F. R. (2019). Nitrogen dynamics and leaching potential under conventional and alternative potato rotations in Atlantic Canada. *Field Crops Research*, *242*, 107603.

This local research looked at two different potato rotations over a 4 year period. Potato-barley-clover and potato-soybean-barley rotations were compared for nitrate leaching potential and yield difference. Trials were conducted at the Harrington research farm. The data showed nitrates were generally lower under the potato-soybean system, and in 2017, the potato-soybean-barley system generated higher yields than the potato-barley-clover (on a fresh weight basis). This research demonstrates the importance of consideration of rotation in the management of nitrogen; but also highlights a challenge in research cycles: only one cycle of the rotation was measured, and it coincided with a drier than normal potato year using a less nutrient efficient variety with no legume credits applied to nitrogen rates. As such, it serves as a good case study for outlining the parameters to consider when managing nitrates across different rotations, weather conditions, varieties, and management practices (N rates & sources used, differences in tillage intensity and soil health).

Lebender, U., Senbayram, M., Lammel, J., & Kuhlmann, H. (2014). Impact of mineral N fertilizer application rates on N2O emissions from arable soils under winter wheat. Nutrient Cycling in Agroecosystems, 100(1), 111–120. https://doi.org/10.1007/S10705-014-9630-0

This research looks at the impact of mineral N fertilizer rates on $N_2$0 emissions and crop yield. $N_2$0 emissions increase linearly with increasing rates of mineral N fertilizer. In terms of yield response, applying nitrogen to meet crop demands actually lowers yield scaled $N_2$0 emissions but they quickly increased again once too much nitrogen has been applied. This metaanalyis is a good reference for other $N_2$0 emissions research.

PEI Potato Agronomy. (2022). Soil & Fertility. https://peipotatoagronomy.com/topic-soil-fertility/

As part of the PEI Agronomy Initiative for Marketable yield (AIM), this online resource was developed to host primary information produced through AIM research and trials as well as secondary research from various sources including conference presentations, factsheets, and webinars.

Rothamsted Research (2022). Broadbalk Wheat Experiment yields and N uptake Section 1, 2001-2015. Electronic Rothamsted Archive, Rothamsted Research, Harpenden, UK 10.23637/rbk1-yldS10115-01

Located in the UK, this one of a kind long term experiment research farm provides open access data from a selection of experiments conducted there going back as far as the late nineteenth century. Data from this collection is used in the winter wheat response chart above.

Watts S. (2022) Investigation of Reducing Nitrogen Application Rates Using Enhanced Efficiency Nitrogen Sources on Performance of Commercial Potatoes in Prince Edward Island Canada. [Report] Submitted for AAFC Living Labs BMP 7

Local research confirms that reducing rates by factoring in the soil health metric 'Biological Nitrogen Availability' or BNA reduces nitrous oxide (N_20) emissions. Additionally, the use of enhanced efficiency fertilizers allows for reduced rates with no statistically significant yield reductions, allowing farmers to afford more expensive products by applying them at lower rates.

Zebarth, B. J., Tai, G., Tarn, R. D., De Jong, H., & Milburn, P. H. (2004). Nitrogen use efficiency characteristics of commercial potato cultivars. *Canadian Journal of Plant Science*, *84*(2), 589-598.

This paper provides localized Nitrogen Use Efficiency estimates for various potato cultivars commonly grown in Eastern Canada. Nitrogen efficiency is measured as Nitrogen Use Efficiency (NUE), defined as dry matter production per unit crop N supply, N uptake efficiency (NUpE), defined as whole plant N content per unit N supply and N utilization efficiency (NUtE), defined as plant dry matter content per unit plant N content.

Zebarth, B. J., Leclerc, Y., & Moreau, G. (2004). Rate and timing of nitrogen fertilization of Russet Burbank potato: Nitrogen use efficiency. Canadian Journal of Plant Science, 84(3), 845-854.
This research reports on the nitrogen use efficiency of Russet Burbank potatoes. At moderate levels of inorganic fertilization (120-160 kg/ha), nitrogen use efficiency was 50%. Nitrogen use efficiency decreased with increasing rates of nitrogen fertilizer. As whole plant dry matter increased, harvest index (the ratio of tuber dry matter to plant dry matter) decreased.

Zebarth, Bernie & Snowdon, Emily & Burton, David & Goyer, Claudia & Dowbenko, Ray. (2012). Controlled release fertilizer product effects on potato crop response and nitrous oxide emissions under rain-fed production on a medium-textured soil. Canadian Journal of Soil Science. 92. 759-769. 10.4141/cjss2012-008.

This research compared split N application with polymer coated urea (PCU) sold as ESN commercially. Split N application did not reduce N_20 emissions but did reduce nitrate exposure. Authors note "Previous studies on timing of fertilizer N application in eastern Canada and Maine also reported limited benefits from split N application compared with all N banded at planting with respect to tuber yield or crop N Uptake" (pg 766 para 3). Regarding PCU, both plant uptake and N_20 emissions increased in some cases and it was advised that further research be done to examine using lower rates with controlled release products; which is generally one of the selling points for these products.