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FACT SHEET

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NITROGEN MANAGEMENT PRACTICES TO INCREASE NUTRIENT USE EFFICIENCY

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Introduction

Nitrogen fertilizer is the largest single expense in many crop production systems. It provides a good return on investment since an adequate supply of N is critical to high grain and forage yields. Sharp operators, however, are looking to get even better returns on their N fertilizer investments by implementing practices to increase their Nutrient Use Efficiency (NUE). Even better, these practices will reduce nitrogen losses to the environment (See Factsheet Fertilizer Nitrogen Use Efficiency).

The key to improving NUE is to follow the principles of 4R Nutrient Stewardship: Use the Right Source of N at the Right Rate, applied in the Right Place and at the Right Time. Individually, these components are not necessarily new or unique, but the power of the 4R approach is the recognition that these "Rights" all interact. There is no "best" 4R program; each farm, or each field, could have a different combination of practices that account for economics, soil types, crops being grown, and more to maximize the NUE for that situation.

Right Source

From a strictly economic perspective, the right source is the one that supplies N to the crop at the time when it most needs it, as cheaply as possible. There is added complexity, however, when you add in the considerations of crop safety, ease of handling and application, and potential environmental losses. The price per pound of N is only one part of choosing the right source for your farm.

Conventional mineral fertilizers are all quickly available for crop uptake, particularly during warm, moist conditions when crops grow rapidly. Urea or ammonium-based fertilizers are less prone to leaching than nitrate fertilizers if applied under cold conditions, but this advantage disappears once the soil warms up. If there is a long delay between fertilizer application and crop uptake, an enhanced-efficiency fertilizer can manage the risk of loss through leaching or denitrification during this period. If it is broadcast on the surface of the soil, urea can lose significant amounts of N to the air as ammonia gas. This is literally dollars evaporating into the air.

Compare price per pound of N, not price per ton!
The nitrogen content of various fertilizers varies greatly, so buying the material with the lowest price per ton won't always get you the lowest price for your N.
To compare materials, divide the price per ton by the kilograms of N in each ton:

Material	Divide price by:
Urea	460
Ammonium Nitrate	340
UAN	280
CAN	270
Ammonium Sulfate	210
This formula gives the price in $/kg. Divide this by 2.2 to get $/lb.	

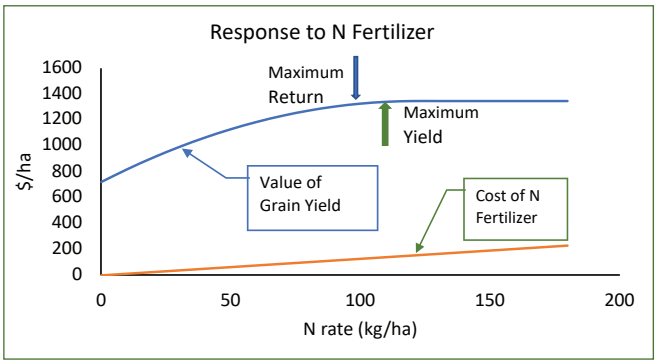
The specific type of N fertilizer will have a bigger impact on how easily the material can be spread and how safe it is for the crop. It is much easier to get an even spread pattern with a solution like UAN (urea ammonium nitrate) applied with a sprayer than with any granular material. The trade-off is that the risk of leaf injury is much higher if sprayed post-emerge. Any fertilizer that contains urea carries the risk of root burn if it is banded near the seed. However, they are generally safe if broadcast (the exception being very high rates [>250 kg N/ha] applied on coarse textured soils where injury could occur under dry conditions).

Different fertilizers will also vary in the risk of nitrous oxide (N_2O) emissions, which is one of the contributors from agriculture to greenhouse gas emissions (Burton, 2018). The greatest losses as N_2O tend to be from nitrate fertilizers. Some studies have shown that banded urea has less N_2O loss, but this has not been consistent (International Fertilizer Association, 2022). The materials that do show consistent reductions have both urease inhibitors and nitrification inhibitors (also known as dual inhibitors; SuperU or Agrotain Plus). See the factsheet on **Enhanced Efficiency Nitrogen Fertilizers** for more information.

Manure is often ignored in the discussions of the right source, but the same 4R principles apply. Manure N is a combination of ammonium-N and organic-N, with a wide range of proportions depending on the livestock species and the water content of the manure. The ammonium-N is exactly the same as fertilizer-N, while the organic-N will need to be mineralized before plants can use it. The mineralization may not be fast enough to meet the needs of rapidly growing crops, and it may continue after the crop has matured, so the recovery of N from manure is often less than from fertilizer.

Right Rate

The rate of fertilizer application is probably the decision we have the most control over, and it is one of the most challenging because soil N keeps changing among different forms, and soil tests for N are not as reliable as for P or K. Too little N, and crop yields will suffer. Too much adds unnecessary production costs and increases nitrate leaching and nitrous oxide emissions. There are two pieces of good news, however; losses to the environment only increase significantly when we apply above optimum rates, and there is a fairly large window on either side of optimum where the net returns to fertilizer are similar.



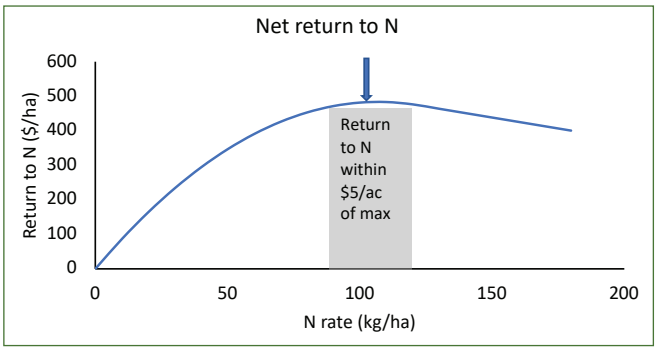


Figure 1: Crops generally show a diminishing response to added N, so the N rate that gives the maximum return is less than the rate that gives maximum yield.

Figure 1 shows an example of grain corn response to added N fertilizer. The rate that gives the maximum economic return to N (MERN) is approximately 110 kg/ha, but any rate within the range of 90-125 kg N/ha (gray box) will give returns within $5/acre of the maximum. This provides some assurance that being a little off the mark will not severely limit the profitability of the crop, but it also underlines the importance of trying to be within that range.

The "big picture" of finding the right rate of N is understanding how much N your crop needs (since there are huge variations in N uptake between different crops and different yield potentials within crops) and how much is already available from the soil. The relatively wet winters in Atlantic Canada mean there is not usually much residual N from previous fertilizer applications. Still, there can be a lot of N released from previous legume crops or manure applications. Not accounting for this is leaving money on the table.

Soil N Tests: Tool or Toy?

Nitrate in the soil solution is the same as fertilizer, and lab testing for soil nitrate can be done accurately. The trouble is that nitrate is so mobile that any testing in Atlantic Canada would need to be done near planting time in the spring, and on a deeper sample than for standard soil tests. This test only measures what is already in the nitrate form, and not what is available for release from soil organic matter, so there is uncertainty what the results mean for crop N requirements. If the test shows there is already more available N in the soil than you were planning to apply, however, you can be pretty sure you don't need to fertilize.

Every N recommendation includes an allowance for the inevitable losses of N between fertilizer application and uptake by the crop. There have been times in the past when fertilizer was inexpensive, so adding extra N to ensure there was enough for the crop made economic sense, but this ignored the impact of N losses on the environment. Following the 4Rs can reduce these losses through better timing and placement or through using an enhanced efficiency fertilizer, so our fertilizer rates need to reflect this. Otherwise, we are incurring unnecessary expenses.

A rough starting point for determining N rates for grains or vegetables, particularly where recommendations for a specific crop are not available, is the amount of N removed in the harvested part of the crop. The soil can generally supply the N for the plant parts that are cycled back to the soil at the end of each growing season. The link between crop yield and N requirements is not as strong as you might expect; in a review of N response in grain corn in Ontario over 40 years, variation in yield only explained about 10% of the variation in N requirements, while soil type and the previous crop had bigger impacts. High-yielding crops will need more N to maintain yields, but this does not mean that adding more N will automatically increase yields. Fertilize for the productive capacity of your fields (the average yield of the best three out of the last five years). Remember, as well, that legumes like soybeans, alfalfa or red clover fix their own nitrogen out of the air and so do not require additional N fertilizer.

Right Time

The correct timing of fertilizer applications should provide N during the period when the crop is actively acquiring and utilizing N for growth. This gives the crop the best opportunity to access the N before it can be lost. In Atlantic Canada, most N losses occur outside of the growing period of the crop (October to May). The period of greatest N uptake varies by crop, although it generally coincides with the time of maximum vegetative growth. In most situations where a crop grows in the fall and winter, demand for additional N is limited, and the N supplied by the soil is sufficient for any crop requirements during this time. Fall applications of N have low plant uptake and are much more prone to loss, resulting in lower crop NUE (NUE_{crop}). During the spring and summer when plants are rapidly growing and the uptake of N is at its peak, the demand for N exceeds the amount supplied by the soil, and plants will utilize additional N supplied as fertilizer.

One tool to ensure N is available exactly in the period of N uptake by the crop is to split application between pre-plant and side dress. A single application of N pre-plant or at the time of planting requires the N to remain in the soil until the crop has established a root system and can fully utilize the N provided. Under ideal conditions, N losses during this time can be minimal, so split applications do not always show an advantage, but wet weather after planting is all it takes to change the equation. Providing a small amount of starter fertilizer and following with a side dress at the optimal time for the crop can reduce the risk of N losses and increase NUE_{crop} by ensuring more of the N is available at the right time for the crop.

Right Place

Nitrogen placement is a balance between crop safety and the reduction of ammonia volatilization from the applied fertilizer. Incorporation or in-soil banding of N fertilizer will reduce gaseous losses of N compared to surface broadcasting. When banding fertilizer, the band's location relative to the plant can be optimized so plant roots will grow into it when crop requirements are high, but not so close that concentrated nutrients in the band can damage seedlings. This increases NUE_{crop} by maximizing the uptake of fertilizer N by the plant.

Foliar application of N can efficiently target the delivery of fertilizer for direct absorption by the plant, bypassing the soil altogether. However, the amount of N that can be applied this way without injuring leaf tissue is quite small, (in the range of 5-10 kg N/ha, depending on environmental conditions), so it is not appropriate for meeting the full N requirements of any crop.

Using 4R as a system

The power of 4R nutrient stewardship is the combination of the four aspects of nutrient management that can compensate for one being less than ideal. These examples will help to illustrate this:

- **Situation**: Established grass hay, so N fertilizer must be surface broadcast. Soil is moderately acidic. **Response**: Change the source of N from Urea to ammonium sulfate or ammonium nitrate, or use a urease inhibitor with urea. This reduces the amount of ammonia volatilization, so the N is available to the grass. Split the applications to match grass growth, with one at spring green-up and following applications after each cut.

- **Situation**: No-till corn, with all the N applied at planting time because of no capacity for sidedress N. The corn planter is set up to apply liquid starter fertilizer with the seed and to band granular fertilizer 4" to the side of the seed row. The previous crop is spring barley underseeded to red clover. **Response**: The agronomist's recommendation is for a total N rate of 120 lb/ac for corn following barley. Since there is a good stand of red clover, this is reduced by 55 lb/ac for an application rate of 65 lb N/ac. The liquid starter (4.5 gallons/acre of 6-24-6) supplies 3 lb N/ac. The remaining 62 lb of N is banded as SuperU (product rate of 135 lb/ac); the combination of distance from the seed row and delayed release from the urea makes this rate safe for the crop and will ensure the N is available during the time of maximum vegetative growth.

- **Situation**: The farmer must apply liquid dairy manure in the fall so there is enough storage to last the winter. The manure will be incorporated within a day after application, and it is intended to fertilize a crop of silage corn the following spring. **Response**: To retain as much N as possible until next spring, application should be delayed until the soil has cooled down below 10˚C, but this may not allow timely incorporation. The alternative is to apply in mid-fall, but to mix Instinct® nitrification inhibitor in with the manure. This will keep the ammonium in this form so it can bind to soil particles rather than convert to nitrate which will leach below the root zone over winter.

And finally, good farming is part of good nutrient management

This factsheet has focused on the management of N fertilizer, but every farmer knows that this is only one part of crop production. Paying attention to good crop management is foundational to getting good returns to fertilizer, for two reasons.

The first is that poor conditions for crop growth can also be conditions that reduce the availability of N to the crop. Weeds in the field are very efficient scavengers for N, so poor weed control also leads to poor N availability to the crop (Lindquist et al., 2010). Excessive soil moisture from poor drainage will increase N losses through denitrification. Soil erosion will preferentially carry away the richest soil, so the soil that is left behind will have less available N as well as other nutrients.

The second consideration is that good agronomy leading to high yields (proper variety selection, timely planting, good stand establishment, insect and disease control, etc.) will increase the amount of fertilizer-N that is turned into harvestable yield. This not only improves your bottom line, but also reduces the N that is available to be lost to the environment.

Summary

Using the Right Source of nitrogen at the Right Rate, applied at the Right Place and Right Time, is the key to 4R Nutrient Stewardship. Following these principles will ensure more of the fertilizer you use ends up in the crop, improving your NUE and reducing the amount of N that is lost to the environment. These are not "one size fits all" recommendations but are flexible enough to be tailored to individual circumstances. Following 4R principles takes on new importance as farmers are tasked with reducing N_2O emissions from agriculture.

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