Spring Options for Applying Nitrogen Fertilizer in 2020

With the wet conditions and delayed harvest experienced in parts of Manitoba in fall 2019, very few farmers were able to complete their fall fertilization program. Since early seeding is important for optimizing crop yield, producers will be looking for ways to apply their nitrogen (N) requirements efficiently without delaying the seeding operation. In addition, soil reserves of N are variable, and although fertilizer prices are relatively modest, optimizing N use efficiency is important. In order to achieve these objectives for a spring fertilization program, the fertilizer source, placement and timing must be managed to minimize losses of fertilizer N to the environment and optimize crop access to the fertilizer.

Minimize Fertilizer Losses to the Environment

Fertilizer use efficiency will be greatest when a source, placement and timing combination is used that minimizes N losses by the following mechanisms:

1) Volatilization is the loss of N to the atmosphere as ammonia gas. Ammonium and ammonium-producing sources, such as urea or UAN solution, may be lost by volatilization when left on the soil surface, while nitrate sources are not. The ammonia travels in the water stream, so volatilization losses increase with factors that increase evaporation, such as warm air and soil temperatures and wind. Applying ammonium-based fertilizer when temperatures are cool, winds are light and rainfall is imminent helps to reduce volatilization losses.

Table 1. Conditions that Affect Volatilization Losses of N Fertilizer

High Loss Potential	Low Loss Potential
moist conditions, followed by rapid drying	dry conditions, followed by rainfall
high wind velocity	low wind velocity
high soil temperatures	low soil temperatures
high soil pH (> pH 7.5)	low soil pH (>7.5)
high lime content in surface soil	no lime at soil surface
coarse soil texture (sandy)	fine textured soil (clay)
low organic matter content	high organic matter content
high amount of surface residue (Zero Till)	low amounts of residue (intensive tillage)

2) Immobilization refers to the "tie-up" of N in the soil microorganisms as they decompose crop residues and use plant available N, such as ammonium and nitrate, for their own growth and reproduction. This is a temporary loss, since the N will become plant available when the microorganisms die and decompose, but it restricts N availability in the year of application. Immobilization losses are greatest for crop residues that have a low concentration of N or a high ratio of C to N (e.g., cereal crop residues) and when straw volumes are high (e.g. corn and wheat straw versus canola or soybean residue).

3) Denitrification is the conversion of nitrate-N to gaseous forms of N, which can be lost to the atmosphere. Denitrification occurs when available oxygen in the soil is limited, such as very wet or flooded conditions or when the soil is very compacted. Losses are higher on fine-textured soils (e.g., clay) and in depressional areas of the landscape where water ponds. Even when the soil is not completely flooded, there will be microsites in the soil where oxygen availability is limited and denitrification can occur. The rate of denitrification will be faster when soil temperatures are warm, because the activity of the microorganisms that cause denitrification increases with increasing soil temperature.

4) Leaching is the movement of N in the soil water down through the soil profile. When the N moves below the rooting depth, the plants can no longer reach the N, so it is lost for crop use and poses a threat to groundwater quality. Ammonium-N is normally bound to soil particles and is protected from leaching losses. Therefore, N in the nitrate form is much more susceptible to leaching losses than the ammonium form. Leaching will increase with increasing precipitation and is higher on light-textured soils with lower water holding capacity.

5) Runoff and Erosion is not generally a serious problem where fertilizer N is banded or incorporated. However, if fertilizer is applied onto snow, or if surface application is followed by heavy rainfall, losses may be substantial.

The potential for N loss from these pathways will depend on soil type and environmental conditions. Therefore, when selecting a fertilizer management program, the soil and environmental conditions should be evaluated to assess the relative risk of losses by volatilization, immobilization, denitrification, leaching and runoff or erosion.

Optimize Crop Access to Fertilizer

In addition to minimizing losses, an effective nutrient management program ensures that an adequate supply of N is present in a location where the crop can access it when it is needed by the crop.

1) Positional Availability and Surface Stranding - Under dry conditions, surface applied fertilizer that is not incorporated can become physically isolated or stranded in dry soil, unavailable to the active portion of the crop's root system. Conversely, banding of fertilizer N often increases the efficiency by improving access to fertilizer by roots, especially under dry soil conditions.

2) Timing for Increased Yield - Early applications, at, prior to or shortly after planting, will produce the greatest yield benefit since crop yield potential is determined early in the growing season. Ideally N should be applied to cereals at or before the 3-5 leaf stage and prior to bolting of canola. Later applications are most likely to result in a protein increase, rather than yield.

Options for Spring Application of N

Recent surveys of Manitoba farmers indicate that a high portion (32-45%) routinely apply fall N predominantly in a banded placement (Table 2). However, many other spring placement options are available and are routinely used by farmers. These options will be discussed further. Note that the same surveys found over 90% of wheat and canola crops are fertilized with phosphorus (P) at seeding.

Table 1. Nitrogen fertilizer placement and timing used by Manitoba farmers for spring wheat, canola and corn (based on % of acres or volume applied).

Practice	Wheat	Canola	Grain corn
TIMING	% of acres or volume applied		
Fall	**45**	**34**	**32**
Spring, preplant	11	13	48
At seeding	43	51	23
Post seeding, in crop	2	2	22
PLACEMENT			
Broadcast , no incorporation	0	2	11
Broadcast and incorporated	4	13	35
Preplant banded (including fall)	**52**	**40**	**39**
Sidebanded	12	12	13
Mid row banded	17	19	3
Seed placed	13	11	2
In crop applied	2	2	22

From STRATUS Ag Research Surveys conducted 2016-2018.

1) Pre-plant Banding – Banding N in concentrated rows below the soil surface tends to be the most efficient form of application under western Canadian conditions. Placing the fertilizer below the soil surface protects the ammonia portion from volatilization losses. Placing the fertilizer in a band limits the contact between the fertilizer and the soil microorganisms, reducing immobilization of both ammonium and nitrate. Banding also slows the conversion of urea to ammonium and ammonium to nitrate, which can reduce losses by denitrification and leaching. Ideally, bands should not be disturbed by pre-seeding tillage or seeding operations.

All forms of N fertilizer perform well when applied as a spring pre-plant band, provided that the fertilizer is separated from the seed. Anhydrous ammonia (NH_3) should be placed at least 4"below the soil surface and, if possible, seeding should be done perpendicular to NH_3 bands. There is no need to delay seeding after application if NH_3 is placed at recommended depths, especially on moist clay soils. However, pre-plant banding may potentially delay seeding and dry or disrupt the seedbed, especially in clay soils.

Where spring tillage will be required to manage ruts left from harvest operations, spring banding fertilizer with a cultivator-style air seeder may accomplish both jobs. Likewise, many farmers have low disturbance disk drill seeders that could be used to band granular fertilizer before or after seeding. Urea should be banded as deep as possible for seed safety and on an angle to seed rows.

With very good RTK guidance, some may wish to try fertilizing between seeded rows after seeding to band apply fertilizer N, but this is only practical in 10" or wider row spacings.

2) Surface Applications Immediately Before or After Seeding – Broadcasting is a very fast method of applying fertilizers, with applicators being able to cover as much as 1000 acres per day. However, urea or UAN solution sources of N can be lost by volatilization until they are incorporated or moved into the soil with precipitation. Tillage during conventional seeding operations is generally sufficient to incorporate urea or UAN solution to reduce volatilization. If either ammonium or nitrate sources are in close contact with crop residues, they may also be subject to immobilization as the residues decompose, since microorganisms will use N from the soil or fertilizer as they break down crop residues that may be low in N (e.g., cereal residues). Surface stranding of broadcast fertilizer, in dry soil above the active portion of the crop's root system may also be a problem in some weather conditions. High rates of broadcast urea-N applied without incorporation on drill-seeded fields may concentrate pellets in the seed-furrow and cause seedling damage to sensitive crops like canola.

Where fields are rutted and tillage is required, it is logical to broadcast fertilizer beforehand. Generally cultivators and disks will incorporate fertilizer to a 3-4" depth, but harrowing or shallow vertical tillage may be insufficient for full incorporation. Volatilization losses have been observed at shallow incorporation depths.

Because of the high potential for volatilization and immobilization losses, surface applications of N tend to be less efficient than in-soil banded applications. Efficiency of surface applications tends to improve in higher rainfall areas, since precipitation is more likely to move the fertilizer into the soil, reducing the risk of loss and/or stranding at the soil surface. Efficiency is lower on high pH soil, since high pH encourages the production of ammonia gas.

While often less efficient than in-soil banded or incorporated fertilizers, surface N applications without incorporation may play a role in fertilization of forages, winter cereals and for post-emergent N delivery. However, lack of N fertilizer incorporation will increase the risk of volatilization and immobilization losses. As a result, if dribble banded to reduce contact with crop residues and soil, UAN will generally be a better choice than broadcast urea for surface applications. Volatilization losses with dribble banded UAN will be lower than with urea, both because the UAN provides a portion of the N as nitrate and because UAN does not increase initial pH at the application site to the same extent as urea. Both of these factors reduce the proportion of N present as ammonia, thus reducing volatilization. Use of a dribble-band rather than a spray application also limits contact between the fertilizer and crop residue, reducing immobilization. As a result, in several field studies in Manitoba, surface dribble-banded applications of UAN were nearly as effective as in-soil banded applications.

Another option to reduce the risk of volatilization loss from broadcast fertilizer is to use a urease inhibitor, such as Agrotain with urea or UAN, or a product like SuperU. Urease inhibitors slow the conversion of urea to ammonium, allowing more time for the urea to move into the soil before being converted into ammonium and ammonia. Also, the slower conversion reduces the concentration of ammonia at the soil surface, reducing the rate of volatilization. The economic benefit of urease inhibitors will depend on the relative risk of volatilization loss and the cost of both the fertilizer and the inhibitor. As volatilization losses from UAN are generally lower than from urea, the benefit of using the urease inhibitor is likely to be lower with UAN than with urea.

While a higher rate of fertilizer may be required to compensate for the reduced fertilizer use efficiency for surface applications, this may be a practical compromise, particularly for producers who are not willing or able to purchase specialized equipment for in-soil fertilizer placement.

3) Placement in the Seed-row – Placement of fertilizer in the seed-row is an attractive option, since it eliminates an extra pass for fertilizer application. If the fertilizer is placed directly with the seed, it eliminates the extra expense, draft requirements and soil disturbance required to side-band the fertilizer requirements. Seed-row placement is a form of banding, so it is efficient in terms of reducing N losses.

Applying excess nitrogen with the seed, however, can lead to seedling damage due to combination of salt and ammonia toxicity. Such damage often reduces crop yields, limits crop response to nitrogen fertilizer and reduces nitrogen use efficiency. In addition, seedling toxicity may also delay crop emergence and reduce crop vigour (increasing potential losses from weed competition), delay crop maturity (increasing risk of damage from fall frosts), and lower crop quality. In all cases, the eventual impact of seedling toxicity on crop yield and quality at harvest is highly dependent on the type of growing season.

The amount of seed-placed fertilizer that can be safely applied depends on a number of factors including environmental conditions, crop grown, soil type, width of the seed/fertilizer band, row spacing and fertilizer source. Small seeded crops such as flax or canola are more sensitive to seedling damage compared to crops such as wheat or barley. With cereal crops, urea tends to be more damaging than ammonium nitrate, while UAN tends to be intermediate, since it is a blend of urea and ammonium nitrate. The rate applied with the seed must be decreased with light textured soils, low soil organic matter, cool growing conditions, low soil moisture, in the presence of salts or free lime, or with the use of wide row spacing. The use of air seeders with wide sweeps allows for increased rates of seed-placed fertilizer, since the concentration of fertilizer in contact with the seed is reduced as the seed and fertilizer are spread over a wider area. For more detail about determining safe rates of N fertilizer that can be applied with cereals and canola, please refer to Table 7 of the Manitoba Soil Fertility Guide (https://www.gov.mb.ca/agriculture/crops/soil-fertility/soil-fertility-guide/).

The amount of damage from seed-placed fertilizer can vary greatly from year to year, depending on conditions at seeding, so a rate that caused no problems one year may cause significant damage the next. A reasonable compromise may be to apply a portion of the fertilizer with the seed and broadcast or dribble-band the remainder.

The use of a controlled release product like ESN may increase the level of N that can safely be applied with the seed. The amount of safety is difficult to predict since the polymer coating may be fractured during handling, transport and air-seeder delivery, affecting the rate of N release. The suggested safe rate limits are based on the provincial guideline (Table 7, referred to above) and the proportion of ESN in the blend with seed-placed urea. At 100%, ESN can be used at 3 times the safe urea rate, and a 50% ESN:urea blend can be used at 1.5 times the safe urea rate.

4) Side-banding or Mid-row Banding at Seeding – Banding of N to the side and below the seed will decrease the risk of ammonia toxicity compared to seed-placing. Many commercial and home-manufactured openers have been designed for one-pass seeding and fertilizing. These include simple systems where fluid N is dispensed through a tube on the seed-opener and mixed with the soil as it falls back over the seed, combined seed and fertilizer boots which place the N in a band separated from the seed, and systems with separate openers for side-band or mid-row placement. Often the entire N needs of the crop can be met through sideband placement, but Manitoba research has shown that placement 1" to the side and 1" below may NOT be sufficient separation for crop safety. Therefore, if the entire N needs are to be applied, the side band should be at least 2" from the seed row for solution or dry fertilizer and at least 2-3" from the seed-row for anhydrous ammonia.

Mid-row banding the N between every second row at seeding maintains the greatest degree of seed safety. Less soil disturbance, and hence more moisture retention, would be achieved with a disk type mid-row bander unit compared to a shank-type.

Fluid sources are particularly good for one-pass systems, as application equipment for fluids is often easier to work with and cheaper to modify than equipment for granular or ammonia application. NH_3 is a relatively low-cost N source, but concerns exist as to its safety for application in a one-pass system. NH_3 can be safely applied using side-band or mid-row band equipment, as long as the seed-fertilizer separation is adequate. It is important to ensure that the NH_3 does not travel through soil pores or cracks to the seed, so adequate horizontal separation is important. Good opener wear-ability, good soil tilth, good moisture conditions, and reasonable speed of operations are also important to ensure that seed and fertilizer separation are maintained. Wing-tip injection of NH_3 on sweep openers has performed well for cereals on heavier soils. However, at the shallower seeding depths required for canola or flax, there may not be sufficient soil coverage to prevent ammonia escape to the surface.

Many of the commercial seeders do a very good job of side-banding or mid-row placement, but the cost of the equipment can be high. Draft requirement and seedbed disturbance may also increase and trash clearance may become a problem; however, the benefits of combining seeding and fertilization into one operation can be significant and may pay long term dividends.

Recently there have been concerns over shallow placement of urea or UAN in the soil and volatilization potential. Field studies in eastern Manitoba have shown urea placement at ½ to 1" depth had slightly more volatilization than at 1.5 to 4" placement, but yields were unaffected. Proper coverage and packing help to minimize any potential loss.

5) Banding Nitrogen Immediately After Seeding – Limited research and practice indicates that banding NH_3 immediately after seeding may have some advantages over topdressing in terms of cost and efficiency. Research was conducted on heavy clay soils seeded with diskers or air seeders. If such a strategy is attempted, ensure that NH_3 is placed perpendicular to the direction of seeding, using a narrow knife or low disturbance opener to minimize destruction of the seedbed. Also ensure that NH_3 is injected at the recommended depth to minimize the potential for seedling damage and to prevent ammonia escape from the trench.

As mentioned earlier, low disturbance disk drills could be operated after seeding to band urea into the soil with minimal stand disruption or injury.

6) Post Emergence or Midseason Applications – Historically, under Manitoba conditions, applying all or part of a crop's N requirement after emergence does not produce higher yields than pre-plant or one-pass applications. However, in some cases, producers may not be able band their N fertilizer prior to seeding due to time limitations or risk of poor seedbed quality. In other cases, producers may want to delay applying a portion of their N fertilizer until they have better estimate of their crop's yield potential.

In these cases, top-dressing is often a reasonably efficient method of applying N fertilizer if rain falls soon after application, which is common in the spring in much of Manitoba. However, post-seeding surface applications will be subject to the same considerations as surface applications prior to seeding. UAN is well-adapted to use for post-seeding N applications if it is dribble-banded, or injected using spoke-wheel or coulter applicators after crop emergence. Conversely, applying UAN in a full-coverage spray may result in leaf burning and significant losses of N.

Ideally, post-emergent N should be applied to cereals at or before the 3-5 leaf stage and to canola prior to bolting. Recent research on split N application produced highest spring wheat yield when 25-50% of the N was split applied at stem elongation – when more than 5mm of rain was received within 5 days of application.

Long season, wide row crops like corn or sunflowers have numerous opportunities for in-season N: in-soil bands as side dressing, broadcast top dressing, or surface banded (y-drop application of UAN).

As adverse weather may delay post-seeding applications, some N should be applied at seeding if available soil N is low. Volatilization losses will be higher on high pH soils. There may also be an enhanced risk of stranding of N at the soil surface with prolonged dry weather. Therefore, the likelihood of a benefit from post-seeding applications increases with the chance of significant in-season precipitation. This is because the crop is more likely to be able to use the applied N and, because if yield is primarily limited by available moisture, in-season rainfall increases yield potential and response to applied N. In addition, denitrification and leaching losses of N already present in the soil will be greater under wet conditions.

7) Enhanced Efficiency Fertilizers (EEF) – The directed use of EEFs has been mentioned above in regards to volatilization and seed safety. Several EEFs also are nitrification inhibitors, which tend to slow the process where ammonium is converted to nitrate, decreasing potential leaching and denitrification losses under wet conditions. These include nitrapyrin (N-Serve for NH_3 and eNtrench for urea and UAN) and DCD (SuperU and Agrotain Plus for UAN). Similarly, the controlled release N such as ESN slows the accumulation of nitrate-N. Such products may be beneficial when nitrate-N is exposed to prolonged excessively wet conditions and when crop uptake is low.

Summary

Ultimately, every N fertilization package has advantages and disadvantages. In selecting the optimum fertilization system, the balance between rate of application, cost and availability of equipment, soil disturbance, seedbed quality, moisture conservation, time and labour constraints and fertilizer use efficiency must be considered against the backdrop of the other demands in the overall operation. The objective is to improve farm management, not just fertilizer management. With competing and unique demands within each farm operation for time, labour, equipment and financial resources, flexibility in nutrient management is an important consideration. Often losses in efficiency in one area can be compensated for by improvements in efficiency in another; therefore, the "best" fertilization system is not universal, but will depend on the major limiting factors on each individual farm. By evaluating the potential risk of losses and the options available for their particular farm, producers can determine management options that will ensure effective crop use of the fertilizer, while allowing seeding to be completed in a timely and effective manner.

(Adapted from **Spring Options for Nitrogen Fertilization,** 2004 Manitoba Agronomist's Conference by Dr. Cynthia Grant.)

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