Impact of Spring Flooding on Soil Fertility in Manitoba

Spring flooding may cause large losses of fall-applied nitrogen (N) fertilizer and residual nitrogen left over after the previous crop or fallow year (Figure 1). The following topics deal with losses of residual soil N, fall-applied N fertilizer, other nutrients, and how to determine the extent of N loss.

Figure 1. Early spring flooding on Manitoba farmland

With flooded soil conditions, farmers may be concerned about the fate of N fertilizer applied last fall and residual soil N left in the soil after last year's crop. Losses of N occur mainly in two ways: 1) by leaching below the rooting zone on sandy soils and 2) by denitrification on poorly drained, depressional clay soils. In both instances, only N in the nitrate form is subject to loss. Nitrogen present in the ammonium form will not be affected, initially.

Leaching is a physical process. If soils are unfrozen enough to allow water percolation, downward movement of nitrate will occur. Coarse, sandy soils with low water holding capacity are at greatest risk of nitrate leaching below the root zone, especially in low-lying areas of fields.

Denitrification is the microbial conversion of the nitrate form of N (NO_3-) to nitrogen gas (N_2O or N_2), which is lost to the atmosphere. This is the greatest threat of N loss in the Red River Valley, since the soils are predominantly fine-textured clays that become easily waterlogged.

The amount of nitrate N that is lost depends upon the soil temperature (because it's a biological process) and the length of time during which the soil remains saturated. Below 5^{o} C the loss occurs slowly; loss is

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greatest at 25° C. A general rule of thumb for N losses due to denitrification is about two to four lbs. of lost N per acre per day when soil temperatures are 5° C. If a soil is under water for a week at this temperature, then 15 to 30 lbs. of nitrate - N per acre could be lost. This spring, soil temperatures at two-inch depth in central Manitoba have remained at about 0° C for the last two weeks of April, 2022, so the rate of denitrification has probably been slow.

Effect of flooding on residual soil nitrate N

Residual nitrate-N (the type of N measured in soil tests) that was unused by the previous crop may also be affected by flooding. Following the drought of 2021, very high levels of nitrate-N were measured across much of Manitoba (Figure 1) with the intention that fertilizer applications in 2022 could be reduced accordingly.   Residual nitrate-N is subject to the same leaching and denitrification losses as fertilizer nitrate-N. Therefore, this form of N loss may also be significant under flooded conditions. Residual N in the organic form (e.g., in volunteer or cover crops or legume crop residues or humus) is not affected.

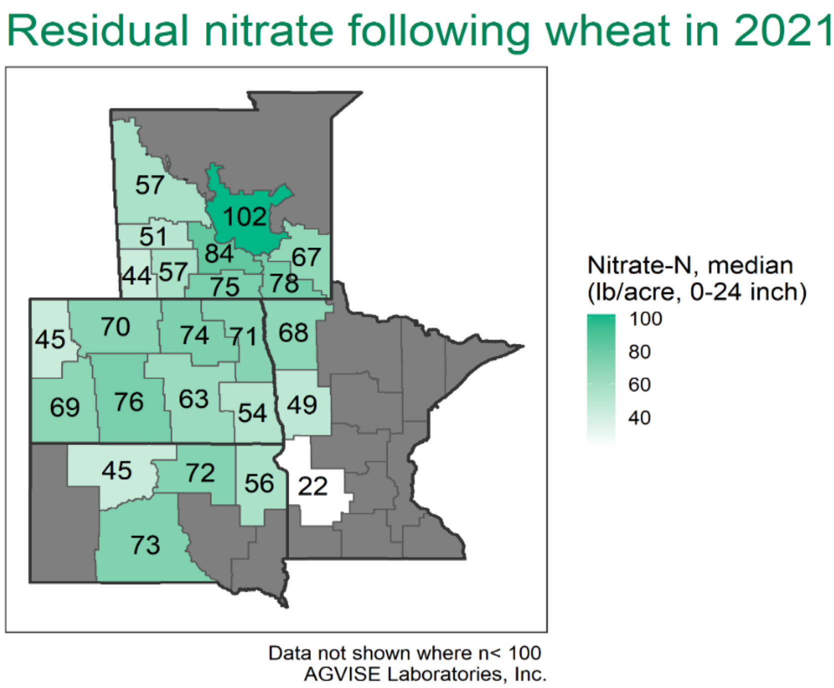

Figure 2. Median residual lb nitrate-N/ac in 0-24”

Effect of flooding on fall-applied fertilizer

For fall-applied fertilizer to be lost, it must first nitrify (or convert) from ammonium (NH4+) to nitrate (NO3-). Nitrification is an aerobic process, thus requiring high levels of soil oxygen. Conditions that reduce oxygen supply, such as waterlogged soils, may actually inhibit nitrification and keep N in the ammonium form. Likewise, warm conditions are needed for the microbial conversion to nitrate, so if ammonium form N is banded late in the fall into cold soils, this conversion is very slow (Table 1).

As soils warm in the spring, any remaining ammonium-N from fall-applied ammonia or urea will eventually convert to nitrate-N. If soils become waterlogged after this conversion, leaching losses will increase. And if waterlogged soils are also warm after this conversion, denitrification losses will increase.

Table 1. Temperature effect on rate of nitrification of banded urea to nitrate in Manitoba (adapted from Tiessen et al., 2006)

Average soil temperature at band depth	Days for 50% conversion to nitrate	Days for 100% conversion to nitrate
1^{o} C	190	380
5^{o} C	40	80
10^{o} C	20	40
15^{o} C	13	25
20^{o} C	10	20

It is difficult to predict denitrification losses, since several factors are involved. The following table summarizes the estimated impact of individual factors on denitrification potential of flooded soils (Table 2). If the fertilization practices and soil conditions for a flooded field were all rated as having a low impact (e.g., late season band application of anhydrous ammonia onto soil that was briefly flooded while the soil was cold), then the overall potential for N loss would be low.

Table 2. Denitrification and Leaching Losses for Fall-Applied Nitrogen Fertilizer

Factors	Risk of denitrification /leaching loss
Application Time in Fall	
• early - warm soils	High
• late - cool soil (<5° C)	Low
Fertilizer Source/Product	
• UAN solution	High
• urea or anhydrous ammonia (46-0-0 or 82-0-0)	Low
• ESN	Lower
• Use of nitrification inhibitor such as N-Serve, eNtrench, Centuro, SuperU	Lower
Application Method/Placement	
• broadcast	High
• banded	Low
Soil Temperature During Flood	
• cold <5° C	Low
• warm >5° C	High
Duration of Flooding	
• brief - a few days	Low
• several weeks	High

Other Nutrient Losses from Soil

Phosphorus (P) is not seriously affected by periodic, short-term wetness. Long-term, repeated flooding can release P and might result in somewhat inflated soil P test levels. However, in early spring, wet soils are often cold and restrict crop root growth and soil P availability that increases crop response to P fertilizer. Keep in mind that if excess water delays seeding, that delay also allows soils to warm, reducing the response to fertilizer P.

Potassium (K) is not directly affected by soil wetness. Indirect effects are similar to P with early spring soils often being cold which slows K diffusion rates and root exploration for K.

For **sulphur (S)**, the plant available form of S, sulphate-S, is moderately susceptible to leaching in sandy soils. It tends to leach less than nitrate-N, owing to its combining with soil calcium and forming less soluble gypsum in many soils. In theory, sulphur volatilization may occur, similar to nitrate denitrification, if soil is flooded and the oxygen supply is exhausted. Sulphate S can be used by bacteria for respiration, producing hydrogen sulphide gas (H_2S) which is lost to the atmosphere. However, this occurs only in extreme cases of prolonged flooding, such as in marshes or wetlands.

Micronutrients may also be influenced by soil wetness. Soluble manganese (Mn) concentrations may "explode" in flooded soils, interfering with iron (Fe) nutrition and causing iron chlorosis, especially in flax. Flooding of alkaline (high pH or high lime) soils also causes a buildup of bicarbonate, which interferes with iron uptake and causes iron deficiency chlorosis (IDC) of soybeans.

How to Determine the Extent of Nitrogen Losses

It is difficult to determine how much fall-applied N fertilizer or residual N might be lost on soils, which are flooded prior to seeding. Ideally, one would soil test prior to seeding, and this may be done in a few targeted spots to access any trend in losses from the fall test. However, in many cases, seeding the crop should be the most urgent priority. Furthermore, much of the N from fall-applied ammonia (either as anhydrous ammonia or urea) may still be in the ammonium form at planting and will not show up in a nitrate soil test, especially if the fertilizer was applied close to freeze up.

Another option is to seed the crop and then test the soil within a couple weeks of seeding, while the crop is still small. Lab turnaround is generally fast at this time of year, so if additional N is required, it can still be top-dressed onto the crop. By waiting until after seeding, much of the ammonium from the fertilizer should have converted to nitrate, and the tillage and seeding operations should have mixed the fertilizer bands sufficiently with the soil to reduce sampling "hot spots."

Sample the soil from 0-6 and 6-24 in. to determine if extra N is needed. On fields where fertilizer was banded, ensure that many subsamples (>15 per field or management zone) are taken to get a representative sample that is not extremely biased toward, or against, the location of a band.

Spring soil sampling may not always be feasible. For fields fertilized in the fall, carefully observe crop growth. If N deficiency (yellowing of lower leaves) appears, be prepared to top-dress the crop with additional N. Another tool for detecting N deficiency is to apply a substantial rate of N to a “N rich strip” in a portion of the field to serve as a check for full N supply and any deviation in colour from this high N strip would signal the need for an in-season application.

Nitrogen fertilizer that is top-dressed during the growing season is susceptible to volatilization losses or being stranded at the soil surface if the weather is dry. Ideally, midseason applications of N should be timed in advance of significant rainfall, to reduce both of these risks. In addition, farmers who apply granular urea or UAN solution should consider adding a urease inhibitor. UAN solution should also be dribble banded to minimize leaf burn and volatilization losses.

References

Tiessen, K., D. Flaten, P. Bullock, D Burton, C A. Grant and Rigas E. Karamanos. 2006. Transformation of Fall-Banded Urea: Application Date, Landscape Position, and Fertilizer Additive Effects Agronomy Journal 98:1460-1470.

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