The Nitrate Soil Test: Is it Reliable?[3]

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In the fall of 2001, many soil test analyses for Manitoba soils indicated unusually high concentrations of nitrate-N and, therefore, a requirement for unusually low amounts of fertilizer N to be added for next year's crop. Farmers and agronomists have wondered whether they should be confident in these analyses and recommendations. Therefore, a brief review of development, benefits and limitations of the nitrate-N soil test may be helpful.

Development of the Pre-Plant Nitrate Test

The nitrate soil test is not new. One of the first scientists to analyze soils for water soluble nitrate-N as a means of estimating the plant available N pool was King in Wisconsin in 1901 (Dahnke and Johnson 1990). Almost 60 years later, Leggett found that nitrate-N was a useful indicator of plant available N in Washington soils (Dahnke and Johnson 1990) and Soper found similar results for Manitoba soils (Figure 1). Soper and Huang (1963) also examined the effectiveness of the soil organic matter test, an incubation test and a test for easily hydrolyzed N as methods for predicting the N supply for barley. However, the nitrate test had the best correlation with barley yield, with an excellent R^2 value of 0.90 compared to R^2 values of 0.06, 0.69 and 0.73 for the other tests, respectively.

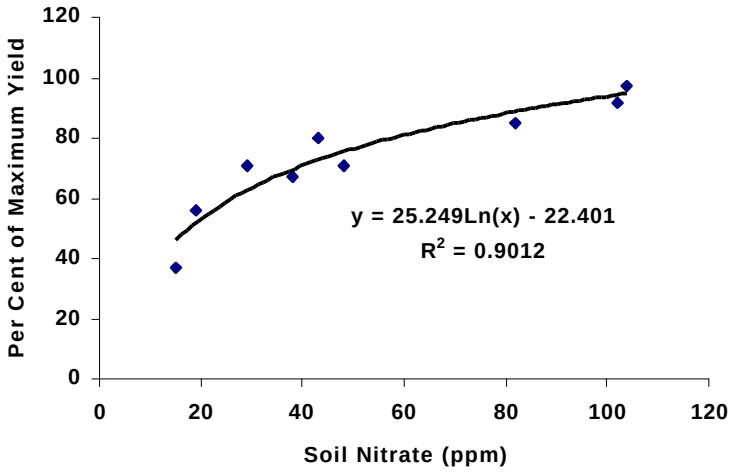

Figure 1. Effect of soil nitrate-N on relative yield of barley in Manitoba (Soper and Huang 1963)

Additional studies at the University of Manitoba also showed a high correlation between soil nitrate and N uptake in barley (Soper et al. 1970). These studies also demonstrated that a two-foot sample depth was optimum for determination of nitrate-N (Table 1).

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Table 1. Effect of soil sample depth on accuracy of nitrate soil test for predicting N uptake in barley (Soper et al. 1970)

Sample Depth	Correlation Between Extractable Nitrate-N and Uptake of N by Barley (R^2)
0-6"	0.32
0-12"	0.64
0-24"	0.84
0-48"	0.78

Limitations of the Nitrate Test

In spite of its overall success, the nitrate test fails periodically, especially in cases where the soil may contain large amounts of organic N that may be mineralized during the growing season. Therefore, when the nitrate test is evaluated across many different types of sites and years, the accuracy appears to less than that observed in some of the early research trials with the test (Figure 2).

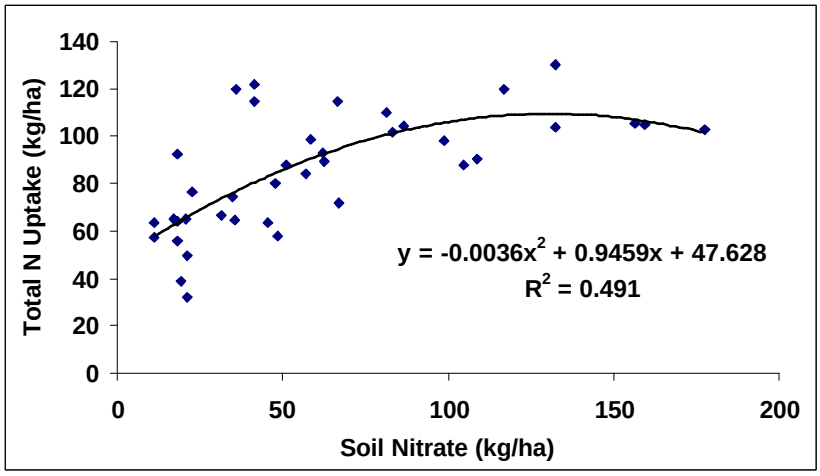
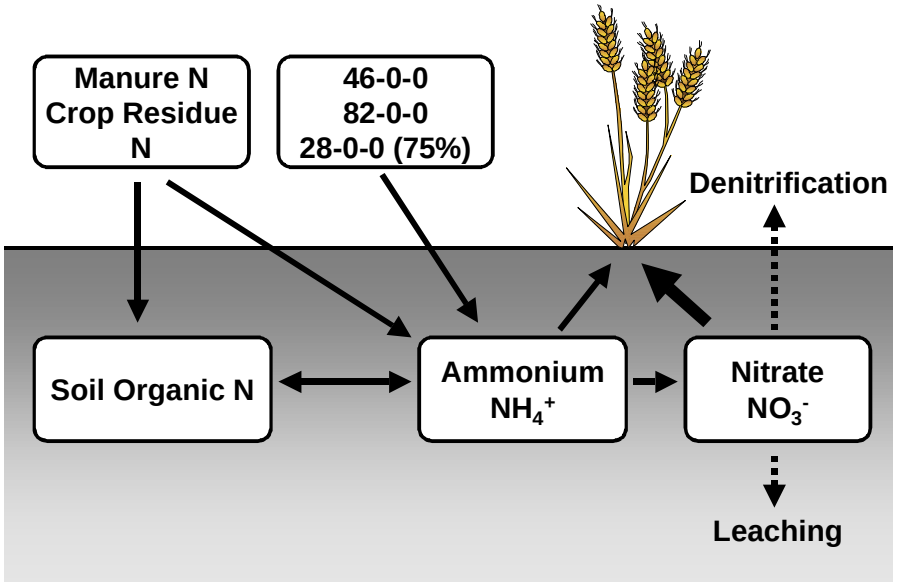


Figure 2. Effect of soil nitrate-N on N uptake by spring wheat for 10 site years of experiments in Alberta, Saskatchewan and Manitoba in 1999, 2000 (Unger and Flaten, unpublished)

To understand the limitations of the nitrate test, we need to examine the overall dynamics of N conversions in the soil and the role that nitrate plays in those conversions (Figure 3).

Figure 3. Nitrogen conversions in soil and uptake by crops



Crops can utilize ammonium or nitrate forms of N; however, annual crops, in particular, take up nitrate as their main source of N. Ammonium N still plays a very important role in crop nutrition, although that role is often indirect, as a result of bacterial nitrification of the ammonium to nitrate prior to crop uptake of the N. The soil's ammonium-N supply is regularly replenished from several sources, including soil organic matter, manure, crop residues and fertilizers. At the same time, some of the ammonium N can be immobilized into organic N by soil microorganisms. The processes of immobilization of plant available N and mineralization of organic N from soil organic matter, manure and crop residues are the "wild cards" that can make prediction of the soil's N supply very difficult, especially when using conventional soil tests, where only the nitrate form is measured.

To further complicate the process, nitrate-N is particularly susceptible to leaching and denitrification losses under wet conditions. These losses explain why the fall nitrate soil test is not reliable in humid climates such as in Eastern Canada or the American Midwest. However, these N losses are relatively minor in most years in most areas of the Canadian Prairies. Therefore, in the Prairie Provinces, any N that exceeds crop requirements usually accumulates as residual nitrate-N. The relatively stable, residual nature of nitrate in the Northern Great Plains has allowed the annual nitrate test to serve as an excellent tool to assess the overall dynamics of plant available N supply in this region.

Other Soil Test Procedures to Replace or Supplement the Nitrate Test
To overcome the limitations of using nitrate concentrations, alone, as an indicator of the supply of N available to a crop, other procedures might be used to replace or supplement the nitrate test.

Adjustments by interpretation of field information - A farmer or local agronomist can adjust the fertilizer recommendations from a nitrate test by simply observing a field to determine whether N recommendations may be too high or too low. Crop colour, yield, protein content, lodging and other indicators can be used to raise or lower subsequent fertilizer recommendations from the nitrate test. Soil testing laboratories may also use information submitted by the client (e.g., previous crop type and yield, manure history, etc.) to adjust fertilizer recommendations proactively, during the preparation of the soil test report.
Adjustments based upon fundamental soil properties, soil survey information - Many studies have shown a reasonably consistent and positive relationship between mineralizeable organic N in soil and

organic matter and clay content of that soil. Therefore, some labs will adjust fertilizer recommendations for the estimated release of organic N based on these parameters.

Extraction of mineralizeable N - Recent studies by Bremner in Iowa and by Campbell in Saskatchewan have shown that the N extracted by hot KCl or phosphate-borate may serve as a reasonable index of mineralizable N. In most cases, the laboratory estimate of mineralizeable N correlates quite well with the release of organic N under greenhouse or growth chamber conditions. However, the correlation under field conditions is often much poorer due to the biological sensitivity of mineralization to variability in combinations of soil moisture and temperature. Recent experiments by Mulvaney in Illinois with microdiffusion techniques to measure amino sugar N have shown considerable promise (the so-called "Mason Jar" soil test), since amino sugars are a very active fraction of the organic N pool.

Ion exchange membranes - Schoenau and Simard have examined the potential to use ion exchange membranes to estimate organic N release as NH_4^+ and NO_3- in Saskatchewan and Quebec soils, respectively. These membranes appear to be particularly useful in situations such as perennial forage, where N cycling is relatively tight and where nitrate is unlikely to accumulate in large quantities, except where N rates are grossly excessive. Western Ag Innovations markets a commercial probe and analytical service to support this type of test.

Methods used by AgVise, EnviroTest and Norwest Labs to Replace or Supplement the Nitrate Test
In late fall of 2001, the three main soil testing services used by Manitoba Farmers were asked five questions regarding if and how their lab attempted to account for the limitations of the nitrate test. The answers to those questions are summarized below (personal communication with B. Green, D. Keyes and J. Lee):

1. Does your lab account for potential immobilization of N by crop residues?

Agvise and Norwest: Not explicitly. The available data for yield responses are for typical residue levels and management practices in the region; data for other residue levels and practices are not available or very limited, so the yield responses for those situations are unpredictable.

ETL: Yes, immobilization is estimated from the lab's soil climatic zone database and client's residue management information.

2. Does your lab account for potential mineralization of organic N from legumes?

Agvise: Yes, legume benefits are automatically estimated and are increased for long season vs. short season crops in the subsequent season (mineralization is a time-consuming process that requires warm temperatures and is, therefore, assumed to be of greatest benefit for long season crops such as corn).

ETL: Yes, legume benefits are estimated from the lab's soil climatic zone database and client's yield and residue management information.

Norwest: No, such adjustments are very sensitive to local conditions and, therefore, should be made by a local agronomist.

3. Does your lab account for potential mineralization of organic N from manure?

Agvise: Not generally. Manure benefit is determined only when customer calls and provides enough detailed information so that a reasonable estimate can be calculated.

ETL: Not directly through the soil test report, but ETL provides software that enables local agronomists to adjust N recommendations for their customers, based on detailed information for the local situation.

Norwest: No. Adjustments are very sensitive to local conditions and, as such, should be made by a local agronomist.

4. Does your lab offer specialized extraction procedures for NH_4^+ or potentially mineralizable N?

Agvise: Yes, upon request, AgVise will test for ammonium-N (NH_4^+), but does not provide an interpretive recommendation for such an analysis. AgVise does not offer a routine test for potentially mineralizeable N, but is currently evaluating Mulvaney's amino sugar N test from Illinois.

ETL: Yes, ETL can analyze for NH_4^+ and can extract potentially mineralizable N with hot KCl. However, they do not provide a fertilizer recommendation based on these analyses.

Norwest: Yes, Norwest offers a mineralizeable N test, using phosphate_borate as an extract.

5. Does your lab account for net changes in nitrate N from fall to spring?

Agvise: No, but late fall sampling is recommended for canola and bean stubble in all soils and spring sampling is recommended for sandy and flood-prone soils where late fall or early spring losses of N are a hazard.

ETL: No, not generally, but the lab assumes that mineralization could increase available N concentrations after early fall samples are taken. Therefore, ETL encourages local agronomists to decrease N recommendations from early fall soil tests by 5_15 lb/ac, depending on soil organic matter content and local weather conditions.

Norwest: Yes, Norwest estimates that soil N will increase by up to 20 lb/ac for soil that is sampled early in fall.

Performance of the Nitrate Test Under Current Conditions in Western Canada

Very little research has been conducted to examine the accuracy of the nitrate test or any recently developed N tests under current Manitoba conditions. However, in a recent study on the effects of N and S fertilization on wheat quality, Unger and Flaten gathered information on the value of using the nitrate test and the phosphate borate test to estimate available and potentially mineralizable N, respectively, at sites across Alberta, Saskatchewan and Manitoba (Table 2). These data show that the correlation of soil test extractable N with N uptake in the crop was reasonable when the nitrate test was used on its own. However, the correlation was greater when the values of the nitrate test and the phosphate-borate test were added together than when either test was used individually.

Table 2. Correlation between soil test extraction method for N and N uptake in unfertilized red spring wheat (Unger and Flaten, unpublished)

Extraction Method	Correlation Between Extractable Nitrate-N and Uptake of N by Wheat (R^2)
Water Soluble Nitrate	0.49
Phosphate-Borate N	0.10
Water Soluble Nitrate Plus Phosphate-Borate N	0.62

Summary and Conclusions

To answer the question posed by the title for this presentation, yes, the nitrate test provides a useful prediction of the soil's N supply in most annually cropped fields in W. Canada. In particular, high soil test values for nitrate-N give a reliable prediction of nonresponsive sites, if the sample is representative and nitrates are not unstable due to excess wetness. However, low soil test values for nitrate-N may not always identify responsive sites, especially if large amounts of mineralizable organic N are present. Under such conditions, most alternative soil testing procedures appear to provide limited predictions of N release from the soil's reserves and local agronomists should try to adjust recommendations based on detailed information about soil and crop management history, as well as local weather conditions. Tests

for potentially mineralizable N would help, but actual mineralization rates in the field are very sensitive to environmental conditions.

Due to the stable, residual nature of nitrate under Western Canadian conditions, the nitrate test is a very effective tool for regular, annual monitoring of the net effect of all N additions, removals, and losses (i.e., using the nitrate test as a tool to audit the N budget on an annual basis). If, for example, the nitrate test underestimates the pool of available N due to its inability to account for mineralizable organic N, the resulting excess in recommended fertilizer N should appear as excess nitrate in a post-harvest soil test and the fertilizer rate recommended for the next crop can be adjusted downwards, accordingly.

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