OVERVIEW OF SOIL FERTILITY RESEARCH IN ONTARIO, 1991

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The major areas of focus in soil fertility research at the Department of Land Resource Science, University of Guelph over the past year have concerned increased nutrient use efficiency and environmental impact. These studies have examined the development of nitrogen soil test for corn, nitrate movement to groundwater, the fate of manure N, the placement of phosphorus fertilizer and the role of VA mycorrhizae in plant phosphorus nutrition. The following is a summary of the projects being conducted in these areas and related fields at the University of Guelph.

Nitrogen Soil Test for Corn[1]

The increasing the efficiency of fertilizer nitrogen use is of economic and environmental benefit. In the past, nitrogen recommendations in Ontario have been based on yield goals adjusted to account for corn / nitrogen price ratio, N fertilizer response data for different regions of the province and manure / legume credits. Examination of yield data collected since 1962 indicated a strong negative correlation between check (no fertilizer N addition) yields and the maximum economic rate of N fertilizer (MERN) (Beauchamp et al., 1987; Kachanoski, 1987). The N supplying capacity of Ontario soils are sufficiently different that it cannot be ignored in determining recommended rates for N fertilizer and must be taken into account if increased efficiency of N fertilizer use is to be achieved. Ontario has been pursuing an effective nitrogen soil test, as a basis for nitrogen fertilizer recommendations, for several years. The soil nitrate test for corn was introduced in Ontario this year. The intent of the nitrogen soil test is to adjust fertilizer recommendations to account for nitrate present in the soil at the time of planting.

Soil test procedure - The soil test currently being used in Ontario involves a measure the amount of NO_3^-, expressed as kg N ha^{-1} in the top 60 cm, based on samples collected from

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[1]Work conducted by R.G. Kachanoski and E.G. Beauchamp in cooperation with Ontario Ministry of Agriculture and Food, Partners in Nitrogen and The Fertilizer Institute of Ontario.

either the top 30 or 60 cm of the soil at the time of planting. Following sampling the soil may be either air-dried, frozen or chilled (< 5 °C). It is important that samples not remain moist at temperatures exceeding 10 °C for longer than 12-24 hours as microbial activity may affect the soil NO_3^- concentration. Soil samples are submitted to an accredited lab for analysis.

Nitrogen fertilizer recommendations were based upon N response data collected since 1986. Fertilizer response data were fit, the using least-squares method, to a quadratic function.

$$\text{Yield} = A + BN_A - CN_A^2 \qquad [1]$$

where N_A = fertilizer N applied (kg ha^{-1}) and A,B, and C are regression coefficients. The maximum economic rate of N fertilizer (MERN) was found by taking the first derivative of equation [1] and setting it equal to the price ratio R (price per kg of N fertilizer / price per kg of grain), and then solving for MERN.

$$\text{MERN} = \frac{B - R}{2\ C} \qquad [2]$$

The proposed calibration model (MERN as a function of the N test) is,

$$\text{MERN} = a - b^*\text{NTEST} \qquad \text{NTEST} \leq NT_0$$

$$\text{MERN} = 0 \qquad \text{NTEST} > NT_0$$

where NT_0 = N soil test (kg ha^{-1} to 60 cm) where the MERN approaches zero (i.e. $NT_0 = a/b$). It has been found that for Ontario soils, NO_3^- content to a 60 cm depth can be approximated by multiplying the NO_3^- content of a sample taken to a 30 cm depth by 1.62. The values of a and b are coefficients obtained by regression MERN on NTEST for MERN values > 0. Once the values of a and b are obtained, the model above is used to obtain a predicted MERN for all NTEST values, and the r^2 (coefficient of determination) obtained between predicted and measured. The values for a and b derived for Ontario conditions for price ratios (R) of 0 to 10 are given in Table 1.

Using this approach the N soil test explained approximately 75 % of the variability of MERN across a range of price ratios from 3 -10. Considering the range in soil types (sand through clay), years (1986 - 1990), and locations (Ottawa to Ridgetown), the relationship is excellent.

Table 1: Regression coefficients fro the relationship between MERN and NTEST for different price ratios.

Price Ratio R	Intercept a	Slope b	NT_0* (kg ha^{-1} to 60 cm)
1	230	1.411	163
2	229	1.535	149
3	229	1.736	132
4	225	1.783	126
5	224	1.954	114
6	220	1.973	111
7	215	2.010	107
8	209	1.980	105
9	203	1.982	102
10	198	1.981	100

* NT_0 = N soil test (kg N ha-1 to 60 cm) where the MERN first goes to zero.

Another indication that the soil test is related to the N response is its correlation to check (no fertilizer N applied) yield. A quadratic equation was fitted (least squares) to the data.

$$\text{Check Yield } (Y_c) = 2395 + 73.8*\text{NTEST} - 0.2185*\text{NTEST}^2 \qquad [3]$$

$$n = 52,\ r = 0.71\ (\text{sig. } p \leq 0.001)$$

Data analysis of all existing N response curves indicated the check yield was highly correlated to MERN. The high correlation between check yield and the N test agrees with the conclusion that the N test can be used to significantly enhance our ability to estimate MERN.

Conclusion - A measurement of the amount of nitrate nitrogen in the top 60 cm of soil is highly correlated to both check (0 kg N applied) yield and the maximum economic N fertilizer rate across a range of price ratios. This relationship holds for a number of years (five) and a wide range of soil types and locations in Ontario.

Evaluation of Soil Nitrogen Test Kits[2]

Several soil test kits are available for the on-farm testing of available nitrogen and may provide an alternative to a soil testing laboratory for NO_3^- analysis. Several soil test kits were compared with a laboratory method for NO_3^- analysis (Technicon Method # 824-89T). The

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[2]A summary of E.G. Beauchamp, D.L. Burton and R.G. Kachanoksi (1991) Evaluation of soil nitrogen test kits 1991. Ontario Agriculture College Publication #0991.

standard lab method is still the preferred method. The kits were evaluated on the basis of 1) their accuracy (as compared a standard method) and 2) their ease of use. Twenty soil samples providing a range of NO_3^- concentrations were collected from across Southwestern Ontario. Three soils having high nitrate levels (> 40 kg N ha^{-1} to 30 cm) were excluded. The seventeen remaining samples had nitrate levels within the range where fertilizer recommendations would be made and were used for comparison of the kits.

While test kits generally approximated results of the standard method, there was considerable variability in the accuracy and the ease of use of the kits examined. The standard lab method is still the preferred method of soil NO_3^- determination. Of the methods tested, the Cardy, N-TRAK, LaMotte STC-NA and QUICK TEST methods most closely corresponded with the standard lab method with r^2 values from 0.72 to 0.96 (Table 2). The QUICK TEST results corresponded most closely to those obtained with the standard lab method. The relationship between the test kit estimate and the value obtained by the standard lab method deviated from the 1:1 line and as a result a correction factor must be applied. Estimates of the maximum economic rate of N fertilizer (MERN) based on this method are anticipated to be within 26 kg of fertilizer N ha^{-1} of the true value 19 times out of 20, given a price ratio of 5.

Table 2: Mean test values and reliability analysis results for six soil NO_3^- test kits.

Method	Mean Test Value (kg NO_3^--N ha^{-1})*	Correction Factor**	r^2	Reliability (19 of 20)† (kg NO_3^--N ha^{-1})
LaMotte-STC-NA	45.6	1.16	0.95	13.6
LaMotte-SL-NA	51.2	0.95	0.64	63.2
Cardy	56.8	0.96	0.92	19.2
Chemetric	45.6	1.06	0.71	46.4
N-TRAK	52.0	1.15	0.72	20.8
QUICK TEST	47.6	1.10	0.96	12.8
Standard Lab (2M KCl)	54.8			

* Values expressed as kg N ha^{-1} to 60 cm

** Perfect agreement between the standard lab method and the test kits would result in a correction factor of 1.00.

† Test kit estimates will not differ from the standard lab method by more than the value specified 19 out of 20 times.

Laboratory analysis by the standard method remains the best approach for determining soil nitrate. The timeliness and possible ease of use of these kits may justify their use to assist in appropriately managing soil nitrogen.

Fate of Manure Nitrogen[3]

This study demonstrated the importance of 1) understanding manure nitrogen transformations and losses from the time of excretion by the animal through to its long term effects on the soil and crop, and 2) understanding manure nitrogen in the context of overall nitrogen management on the farm.

Data from the literature indicate that nitrate leaching from manured soils is usually lower than leaching from fertilized soils amended with similar amounts of N. Field experiments in this study strongly support this conclusion. Field experiments with manure and fertilizer indicated that leftover soil nitrate contents were lower with manure applications than with fertilizer applications at similar rates of mineral N (based on NH_4^+ content of the manure). Rates of N mineralization were slightly but not significantly higher in manured soil than in fertilized soil, indicating that there was no increased risk of nitrate leaching in the fall in manured soils even though N recoveries by the plants were much lower.

The amounts of NO_3^--N that were observed leaving an experimental water shed at the Elora Research Station in water flow varied from 26 kg ha^{-1} to 49 kg ha^{-1} in the calendar years 1986 through 1990. In the 12 months from March 1990 through February 1991, a very wet period, the amount was 78 kg ha^{-1}. Nearly all the NO_3^--N was removed in the outflow from the buried pipe system that drains this watershed.

The concentrations of nitrate-N in the drainage water from the buried-pipe system was above the drinking-water standard of 10 mg NO_3^--N L^{-1} in all seasons except winter and early spring. Highest concentrations in this flow, up to 30 mg NO_3^--N L^{-1}, occurred in late June through early July . The lowest concentrations of NO_3^--N were measured in the piezometers 1 metre below the depth of the drainage pipes and were consistently less than the concentrations measured in the buried-pipe outflow.

At Elora a substantial depth of low-permeability till lies between the watertable and the bedrock aquifer used for water supply. The concentrations of NO_3^--N in the deeper groundwater (15 and 25 m below the surface) were low (≤ 1 mg NO_3^--N L^{-1}) and there was no

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[3]A summary of J.W. Paul, E.G. Beauchamp, H. Whiteley and J. Sakupwanya (1991) Fate of manure nitrogen at the Arkell and Elora Research Stations. Final Report Ontario Ministry of Agriculture and Food: Special Contract # SR8710-SW001.

evidence of nitrate movement from the watertable to deeper groundwater. In this stratigraphic setting the outflow of the buried-pipe system is by far the major pathway for nitrate removal from the watershed.

Nitrate Leaching in a Coarse-textured Soil[4,5]

The role of tillage, nitrogen application rate and irrigation on nitrate leaching in a coarse-textured soil is the focus of a study being conducted at the Agriculture Canada Research Station in Delhi, Ontario[4]. Nitrogen fertilizer application rates ranging from 0 to 200 kg NH_4NO_3-N ha^{-1} were examined. Yield response curves indicate that the MERN rate ranges between 125 and 150 kg N ha^{-1}. The 150 kg N ha-1 treatment was instrumented with suction lysimeters to allow monitoring of porewater NO_3^- concentration. Examination of mineral N content is soil solution samples collected from a one metre depth in relation to soil moisture content indicate that the NO_3^- concentration often exceeded the recommended drinking water standard of 10 mg N ha^{-1} (Fig. 1). In particular there was a major leaching event in the fall of 1989 corresponding to a period of high rainfall in November of 1988. This emphasizes the sporadic nature of nitrate leaching and the difficulties in producing yearly estimates of loss. Tillage had little impact on the concentration of NO_3^- in porewater at this site.

Nitrogen management on coarse-texture soils of this nature must embrace their high nitrate leaching potential. Management strategies which minimize the accumulation of mineral-N will help to reduce nitrate movement. The use of fall cover crops in reducing nitrate movement and availability to the subsequent crop has been examined on coarse-texture soils at study sites in Ayr and Woodstock[5]. Red clover, annual rye grass, winter rye and oil seed radish are being examined as cover crops for corn, barely and winter wheat. Cover crop establishment and growth was satisfactory following barley and winter wheat, but not following corn. N fertilizer application on cereal crops affected biomass and N content of oil seed radish but not of other cover crops. Nitrate in the soil solution at 75 cm was affected by fertilizer N rate in soils cropped to corn but not with other crops. Oilseed radish was the most

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[4]A summary of Alternative crop management and nitrate contamination of groundwater with sandy soils used for tobacco production. D.L. Burton, E.G. Beauchamp, R.G. Kachanoski, D.M. Brown and D.E. Elrick. Funded by Agriculture Canada's Tobacco Diversification Plan.

[5]A summary of studies conducted by M.H. Miller , E.G. Beauchamp and T. J. Vyn on cover crops and nutrient conservation funded by Agriculture Canada, INCO, NSERC and Department of Supply and Services (SWEEP).

effective cover crop for reducing NO_3^- concentration in the soil solution at the Ayr site. Red clover did not reduce the NO_3^- concentration in the soil solution compared to no cover crop at Ayr.

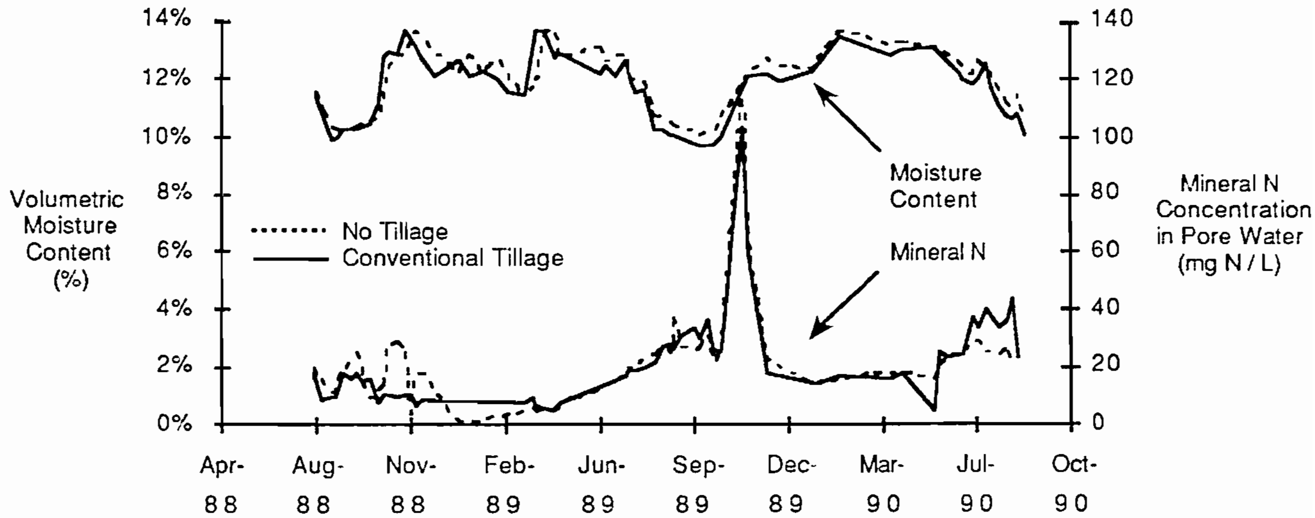

Figure 1: Mineral N concentration in soil solution samples collected from a one metre depth using suction lysimeters in a soil cropped to maize under conventional (spring plow) and no tillage management and receiving 150 kg N ha^{-1} of NH_4NO_3 annually in relation to soil volumetric moisture content.

Increasing the efficiency of phosphorus use by corn[6]

Contribution of phosphorus from cropland to surface water has been a major concern in Ontario for the past 10 years. This concern has lead to major programs to reduce erosion and to increase the efficiency of phosphorus use to avoid unnecessarily high concentrations of P in runoff. Nutritional studies have shown that P concentration in corn shoots at the 5-6 leaf stage has a significant effect on grain yield. Studies are being conducted to develop more effective means of obtaining the desirable P concentration at this stage. Two approaches are being used. On the first, two new placements of fertilizer P are being investigated. One placement being tested is to place fertilizer in two strips, one on either side slightly below the seed. These strips will intercept more of the seminal roots emerging from the seed and should result in a more

[6] A summary of work conducted by M.H. Miller, T.P. McGonigle and W.A. Mitchell

rapid early absorption of P. Early results show some promise. A second system being tested for the first time in 1991 is the cross-slot planter developed by Baker in New Zealand. This planter disturbs the soil to a much lesser extent than other no-till planters and places the fertilizer slightly below and to the side of the seed.

The second approach involves the potential to increase early P absorption by corn through increasing the effectiveness of the vesicular-arbuscular mycorrhizal symbiosis. Studies at Guelph have shown that the effectiveness of VA mycorrhizae increase as the degree of soil disturbance decreases. In a tillage experiment in 1990, P absorption from a ridge till treatment between 25 and 32 days after planting was 9 times that from a mouldboard plow treatment. This increased P absorption was closely related to more rapid VA-mycorrhizal development on the ridge till system. This suggests that there is a potential to use the indigenous VA-mycorrhizal fungi more effectively and hence reduce the soil phosphorus level required for profitable yields.

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