Predicting Fertilizer Nitrogen Requirements for Corn in Ontario

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INTRODUCTION

The nitrogen fertilizer requirement of a crop under field conditions is influenced by numerous factors including soil, climate and management variables. Most of these factors are very difficult, if not impossible to predict in advance. The major factors influencing nitrogen fertilizer requirement are (Goh and Haynes, 1986);

1. the requirement of the crop for N as determined by its yield (or yield potential),
2. the availability of fertilizer N or the fertilizer use efficiency, and
3. the amount of available mineral N from the soil.

It is generally believed that for high yielding crops such as corn, the N requirements are much larger than variations in the N supplying capacity of soil (Olsen and Kurtz, 1982). Thus, in many areas fertilizer N recommendations are often based on expected yield (yield goal) and some estimate of the amount of N required for different yield goals. This is the case in Ontario, where since 1973, N fertilizer requirements have been based on yield potentials.

If possible fertilizer requirements should also take into account major credits of N available for crop growth. In areas where leaching is minimal, the amount of residual soil NO_3^- to some control depth is usually considered to be equal to fertilizer N and recommendations are adjusted accordingly. As Keeney (1982) states, acceptable recommendations can be made with more or less subjective approaches taking into account expected crop uptake and residual profile NO_3^- where applicable.

However, subjective approaches will not be viewed favourably by an environmentally aware society concerned with ground water quality and pollution. In addition, economic pressures require producers to make optimum use of their input dollars.

The acceptance of any method, subjective or not, should be based on how well it describes the data, or fulfills the purpose it was devised for. The objective of this paper is to examine the concept of recommending N fertility rates on the basis of expected yield potential, in Ontario, Canada.

Methods

Data sets from 202 field N response trials conducted across Southern Ontario from 1962 to 1986 were obtained from a comprehensive review of nitrogen requirements for corn by Beauchamp et al. (1987). The study by Beauchamp et al. (1987) compiled extensive field trial data collected by themselves, C.K. Stevenson and C.S. Baldwin (Ridgetown College of Agriculture technology, W.E. Curnoe (Kemptville College of Agriculture Technology), T.E. Bates (Dept. Land Resource Science, Univ. of Guelph) and others. The author would like to acknowledge the work by these researchers as well as the summary of the data into a most useful format by Beauchamp et al. (1987).

Beauchamp et al. (1987) fit a quadratic polynomial equation to each of the 202 field N response data sets, of the form;

$$Y = a + bN_A + cN_A^2 \qquad (1)$$

The nitrogen rate for maximum yield N_m' and the rate for most economic yield Ne were obtained by setting the first derivative of equation (1) equal to zero and the price ratio R respectively, and then solving for N. The price ratio is the estimated price of corn per kg divided by the estimated price of nitrogen per kg. For this analysis a price ratio of 0.214 was used. The economic yield, Ye was obtained by setting N_A = Ne in equation (1).

The quadratic equation was chosen because it adequately represented the data and tended to give the highest coefficient of determination r^2 for the individual data sets (Beauchamp et al. 1987) Beauchamp et al. (1987) also fit a square root and log model to the data. However, the Ne and Ye values calculated by each model were highly correlated ($r>0.9$), thus the trends in the data set can be interpreted using equation (1).

The following criteria were used by Beauchamp et al. (1987) to accept or reject data sets.

1. Only data sets were accepted where manure was not applied or forage legumes were not grown in the previous year.
2. Only the data set from the first year of a long term trial on a given site was used. It was noted that crop response to residual N from previous applications may affect the yield response to applied N fertilizer to the same plots (Richards et al., 1983, Can. J. Soil Sci. 63: 547-556; Beauchamp, 1987, unpublished data). There can be considerable carry-over of residual fertilizer N from the previous year. Similarly, the availability of N with the control treatment may decrease. Thus data sets were accepted from sites where "normal" N fertilization practices had been followed the previous years.
3. At least three levels of applied N with associated corn grain yields were required to provide a suitable data set. It was felt that fewer levels or rates may result in biased response relationships.
4. A considerable number of trials showed no response to N fertilization. These data sets were included if there was no other criterion for their exclusion.
5. In some cases, the data set did not provide a maximum or economically optimum N level because yield continued to increase beyond the highest level of N applied. These data sets were accepted because it was thought that their exclusion would bias the overall relationship of yield to N fertilization. In these cases,

the yield obtained with the highest applied N rate was considered to be maximum yield.

The data sets were grouped into three classes or regions of origin; Southwestern, Central, and Eastern Ontario. The data set classes were significantly different according to a t test (0.05 probability level) (Beauchamp et al. 1987). In addition, the Southwestern Ontario class was further subdivided into preplant N applications and sidedress N applications. The four classes of data will be used in this analysis.

Results

The correlations between maximum yield Ym, most economic yield Ye, most economic nitrogen rate Ne, and check yield Yc are given in Table 1. As indicated, the maximum yield (yield potential) explained only 7.3%, 0.5%, 25%, and 10.2% of the variability of the most economic rate of nitrogen Ne, for the four data sets respectively. A graph of economic rate of nitrogen Ne versus maximum yield Ym for eastern Ontario is shown in Figure 1 and illustrates the scatter of the relationship.

The most economic yield Ye was, as expected, related to maximum yield Ym with correlation greater than r = 0.98. The most economic yield was approximately 90-95% of maximum yield. However, the relationship between maximum yield and the most economic yield does not increase the ability to predict the rate of N required to give the most economic yield. The correlations between yield Ye and economic rate of nitrogen Ne are as poor as between Ym and Ne.

The poor correlation between maximum yield (yield potential) and economic rate of nitrogen Ne is rather disturbing. The large scatter in the data (Figure 1) suggest that recommended rates of N are not very well predicted by an estimated yield goal. The philosophy behind using a yield goal for estimated N requirements is that for high yielding crops such as corn the requirements of N are much larger than variations in the N supplying capacity of soil (Olsen and Kurtz, 1982). In areas where substantial N supplying capacity of soil is present, suitable soil tests such as the amount of residual mineral nitrate are used to adjust recommended rates. In Ontario, a suitable soil test for N has not been found. It is generally believed that because of the high amounts of precipitation in Ontario, significant drainage and leaching negates the possibility of using residual nitrate N as a useful soil test. However, in most areas where residual nitrate is used, there is, as expected, a high correlation between it and the check yield (0 kg N applied). Thus a correlation of the check yield Ye and the recommended rate of N implies a strong dependence between the nitrogen supplying capacity of the soil and the shape of the nitrogen response curve.

The data in Table 1 indicate a very strong relationship between the check yield Ye and the most economic rate of nitrogen Ne. The check yield explained 25%, 56%, 49%, and 20.0% of the variation of Ne in the four data sets. In addition, in all four data sets, the check yield Yc explained <u>more</u> of the variation of the recommended rate of nitrogen Ne than the maximum or economic yield did. This suggests that in Ontario, the nitrogen supplying capacity of the soil is so different from location to location or from one year to the next, that it significantly reduces the usefulness of using only the maximum or economic yield goal as an estimate of fertilizer N requirement.

For other nutrients, it is well known that actual yields usually do not correlate with soil test results because of variations among locations attributable to climate, and soil (Nelson and Anderson, 1977). In these cases yield increase (ΔY) over check yield is used and has the advantage that direct economic interpretations can be made. Correlation analysis between maximum yield gain over check yield ΔYm and not most economic rate of nitrogen Ne were carried out. The maximum gain in yield over check ΔYm explained 72.%, 91.0%, 68%, and 76% of the variability of Ne in the four data sets. The economic yield gain over check yield Ye explained 87.0%, 93%, 74%, and 84% of the variation of Ne in the four data sets. The high correlation between yield gain over check and Ne, and the low correlation of check yield Yc to yield potential (Ym and Ye) illustrates once again the poor ability to predict Ne from only maximum or economic yield goals.

In the absence of a soil test to estimate the soils N supplying capacity (and thus check yield) there seems to be little hope in refining the recommended rates of N. However, the low predictive capability using only a yield goal, and the high correlation between check yield and economic N rate suggests research on developing a soil test is necessary. The fact that residual N from a previous years application of fertilizer may affect the yield response to applied N on the same plots in Ontario also suggests considered N carry-over from year to year. If N carry-over is occurring to the extent that it is affecting N response curves, than it should be possible to measure an index of this carry-over with some sort of soil test. A possibility which is currently being examined is a spring nitrate test at time of seeding.

SUMMARY

A very poor relationship was found between estimated yield potential based on either maximum yield or most economic yield, and the most economical rate of nitrogen fertilizer on 202 N response data sets. A higher correlation was found between check yield and most economic rate of nitrogen suggesting the N supplying power of Ontario soils are sufficiently different that it overrides the N requirement for crop growth in determining the recommended rate of N fertilizer. The yield gain (ΔYe and ΔYmax) over check was very highly correlated to the recommended rate of N. More research is needed on estimating the N supplying capacity of Ontario soils.

Acknowledgements

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Table 1: Correlation matrix of nigrogen response parameters.

A. Eastern Ontario (Data sets = 37)

	Ne	Yc	Ye	Ym
Ne	1.0	-0.50*	0.27	0.27
Yc		1.0	0.59*	0.60*
Ye			1.0	0.99*
Ym				1.0

B. Central Ontario (Data sets = 31)

	Ne	Yc	Ye	Ym
Ne	1.0	-0.75*	0.03	0.08
Yc		1.0	0.52*	0.59*
Ye			1.0	0.98*
Ym				1.0

C. Southwestern Ontario - preplant (Data sets = 57)

	Ne	Yc	Ye	Ym
Ne	1.0	-0.70*	0.45*	0.50*
Yc		1.0	-0.08	-0.15
Ye			1.0	0.99*
Ym				1.0

D. Southwestern Ontario - sidedress (Data sets = 74)

	Ne	Yc	Ye	Ym
Ne	1.0	-0.44*	0.38*	0.32*
Yc		1.0	0.44*	0.48*
Ye			1.0	0.99*
Ym				1.0

Ne = economic rate of nitrogen (price ratio = 0.214)
Yc = check yield (0 kg N)
Ye = most economic yield (N=Ne)
Ym = maximum yield
* = significant ($P<0.05$)

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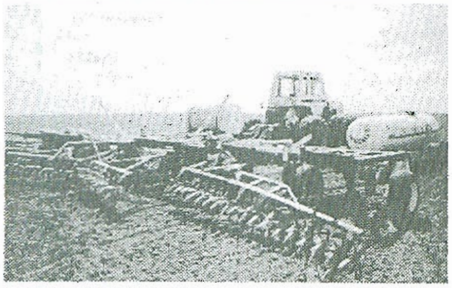
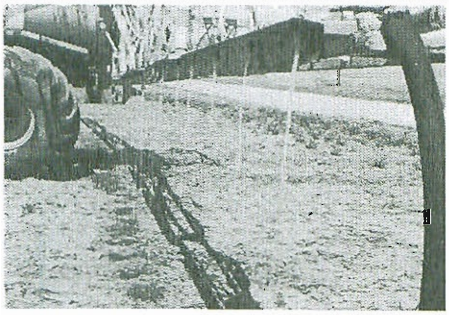

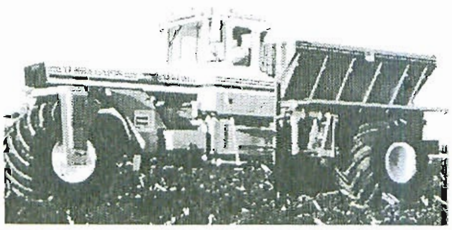
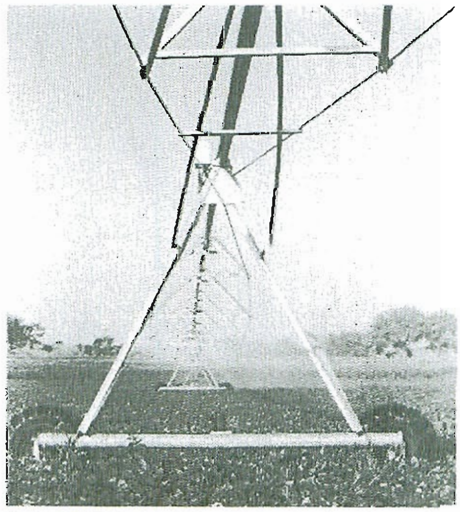
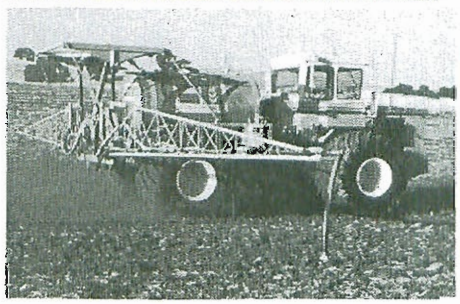

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