VARIABLE NITROGEN RATE MANAGEMENT

Nicolas Tremblay and Carl Bélec
Research Center, Agriculture and Agri-Food Canada
St-Jean-sur-Richelieu, QC, Canada, J3B 3E6

Introduction

It is now more or less acknowledged that lime and N are potentially more profitable than P and K variable rate management. There is a lot of variability in optimal N rates within fields so that there is a need for variable N management.

The benefits related to variable N management are generally ranked as:

- Less N fertilizer used per unit yield. Savings of 15 USD/ac on average for small grains, up to 41 USD/ac.
- Greater uniformity in crop stand, yield, grain humidity, specific weight and protein content under variable than uniform N management (small grains).
- Less residual nitrogen left behind after harvest. Application of N using "best years" or "best areas of the field" as a basis for expected yield can result in over-application of N and increased residual soil N-NO_3 following harvest (Kitchen et al. 1995). The amount of residual soil N-NO_3 is a function of the difference between N applied and the optimum dose. Clearly, stringent environmental regulations will be adopted that will force a better use of N fertilizers.
- Higher yield
- More profits. For small grains, figures of 5 to 15$/ac of maximum potential benefits have been circulated.

Achieving a good distribution of N fertilizer is tough

Several approaches were initially proposed in order to achieve a sound distribution of N fertilizers according to soil and landscape parameters (Franzen and Kitchen, 1999). They were mostly based on soil chemical and physical attributes. Examination of results obtained so far indicate that the following parameters are not so good indicators of N requirements:

- Yield goals. High yield zones are often the least responsive to N fertilization.
- Yield maps (even with several years)
- Soil type
- Soil organic matter
- Soil electrical conductivity
- Landscape attribute
- Drainage class
- Satellite or airborne imagery

The N cycle in the soil is extremely dynamic and subjected to seasonal conditions (Franzen and

Kitchen, 1999). In dry years, there is very poor response to N fertilization; the opposite in wet years. Variation in the depth of maize residual soil nitrate acquisition is significantly influenced by year and attributed to differences in plant N demand as well as N fertilization and crop rotation.

This implies that the use of technologies that assess real-time plant N demand will improve variable rate technologies and most likely our ability to increase N use efficiency (Walters and Goesch 1999).

One trial in 2000

Corn (Zea mays L., variety DeKalb 389Bt) plants from 4 adjacent experimental fields located at the L'Acadie experimental farm of Agriculture and Agri-Food Canada (Lat. 45°17'47.90946", Long. -73°20'30.70798", altitude 45 m), were used for this study. The soils were of the clay-loam type, with 31% sand, 33% silt and 36% clay in the 0-30 cm layer. The median pH was 6.8; average phosphorus and potassium levels were 72 and 147 mg/kg of dry soil and considered as rich according to provincial standards. The 4 fields had various cropping histories so that actual N-NO_3 concentration at sowing varied as such: 52, 27, 51 and 37 kg N-NO_3/ha in the 0-60 cm layer for fields I, II, III and IV respectively. Each field was partitioned in 16 experimental plots (20 m x 20 m, each with 27 rows 75 cm apart), to which the nitrogen fertilizer treatments were randomly assigned. There were four nitrogen treatments: A, B, C, D. For each N level there were hence four replicates in each field. The nitrogen fertilization treatments were applied in two steps, one at sowing, and the other side-dressed (40 days after sowing) as indicated in Table I. At side-dressing, an excessive application of N fertilizer was made on field II by mistake, consequently, data from this field were neither statistically analyzed nor reported. The "A" treatment corresponds to the N deficiency. In the "B" treatment, the amount of N fertilizer required was applied in every plot without consideration of the actual chlorophyll status of the plot. In the "C" treatment, the same N fertilizer amounts, in average, were applied as in the "B" treatment. However, the actual amounts per plots were adjusted according to the chlorophyll status of the plot. The "D" treatment is considered as the over-fertilized reference treatment, the purpose of which was to establish a benchmark of chlorophyll condition under N sufficiency.

Table 1. Characteristics of the different nitrogen treatments applied to the four experimental fields at two steps during the crop growth.

Fertilization step	N treatment	Nitrogen quantities applied on different fields (kg N/ha)			
		Target: medium fertility		Target: low fertility	
		I	II	III	IV
Sowing (0 days)	A	0	0	0	0
	B	20	20	0	0
	C	20	20	0	0
	D	100	100	100	100
Side-dressing (40 days after sowing)	A	0		0	0
	B	94	Withdrawn	144	144
	C	var. 75 to 120	from the	var. 75 to 150	var. 165 to 180
	D	150	experiment	150	150

The fields contained all the other essential nutrients at sufficient levels as to rule out any other deficiency than N. However, the 2000 season was characterized by cooler conditions than previous years. Precipitations exceeded normal levels in May, August and September while June and July had lower than normal levels of precipitation. Overall, the 2000 season was not particularly well suited for the expression of N fertilization effects of treatment in corn fields because of the cool growing conditions limiting yield potential. Nevertheless, the effects of N treatments were apparent on the agronomical parameters measured.

Results

With low N applications, grain yield is variable and generally low; the opposite being true for high N applications (figure 1). At stage 37 days after sowing, the Hydro-N sensor recommended significantly higher (and more variable) N applications to N-deficient plots than N-saturated ones (figure 2). At harvest, N treatments differed in their grain protein (figure 3) and grain humidity (figure 4) contents. More desirable values were related to high N applications but there were no significant differences between uniform (treatment B) or chlorophyll-based (treatment C) fertilization strategies.

Conclusion

Under the new environmental reality, growers will certainly have to rethink their N fertilizers inputs to crops. Any reduced (blanket) application of N, however, would lead to an increase in crop stand variability. It is worth trying to gain knowledge from the canopy (chlorophyll status) in order to perform a better distributed N application.

What's the best we can do?

- First, make a relatively low blanket N application at or before sowing taking into account 1) a quick analysis of soil mineral nitrogen (sampling 12 to 20 cores/ha will provide estimates of field $N\text{-}NO_3$ content within plus or minus 20% of the average: Hergert et al. 1995); 2) the nitrogen supplying power of last crop residues.
- Install N saturated reference plots that will be used as checks at topdressing. Local research by our team has linked a "chlorophyll saturation index" to actual kg N/ha fertilizer requirements in corn.
- Apply topdress N according to chlorophyll status. Currently, the Hydro N Sensor is the only commercially available instrument for that purpose.

There's always a risk that the variation in chlorophyll status be due to another factor than nitrogen (drought, water logging, magnesium or sulfur deficiency). In such case, the variation of the nitrogen recommendation is of no use. However, most of the time, the primary factor for chlorophyll status variability is nitrogen availability.

Scharf et al. (2002) found little or no evidence of irreversible yield loss in corn when N applications were delayed as late as stage V11, even when N stress was highly visible. It is also our experience that corn can make-up for the lost time when an N deficiency is corrected, provided that sufficient moisture is available in the soil after the fertilizer is added.

References

Summaries of variable n rate application studies

- Franzen and Kitchen (1999). http://www.ppi-far.org/ssmg and head for SSMG-5
- Doerge (2001). http://www.ppi-far.org/ssmg and head for SSMG-36

Soil N-NO_3 quick analysis method

Tremblay N., H.C. Scharpf, U. Weier, H. Laurence and J. Owen. 2001. Nitrogen Management in Field Vegetables - A guide to efficient fertilisation. Technical Bulletin (651Ko). http://www.agr.gc.ca/science/stjean/recherche/azote_e.pdf or http://res2.agr.ca/stjean/publication/bulletin/nitogen-azote_e.htm

Hydro N sensor

http://www.hydroprecise.com/

The Hydro N Sensor sells in Europe for 18 800 euros. It is estimated that its costs can be covered within 5 years with 300 ha (Cultivar no. 534). In Canada, the Hydro N Sensor is marketed by SynAgri.

References

Hergert, G. W., Ferguson, R. B., Shapiro, C. A., Penas, E. J., and Anderson, F. B. (1995). Classification statistical and geostatistical analyse of soil nitrate-N spatial variability. In "Site-Specific Management for Agricultural Systems". ASA-CSSA-SSSA, Madison, WI.

Kitchen, N. R., Sudduth, K. A., and Birrell, S. J. (1995). Comparison of variable rate to single rate nitrogen fertilizer application: Corn production and residual soil NO_3-N. In "Site-Specific Management for Agricultural Systems". ASA-CSSA-SSSA, Madison, WI.

Scharf, P. C., Wiebold, W. J., and Lory, J. A. (2002). Corn Yield response to nitrogen fertilizer timing and deficiency level. Agronomy journal 94, 435-441.

Walters, D. T., and Goesch, J. E. (1999). Temporal and spatial variation in soil nitrate acquisition by maize as influenced by nitrate depth distribution. In "Fourth International Conference on Precision Agriculture". ASA-CSSA-SSSA, Madison, WI.

Figures

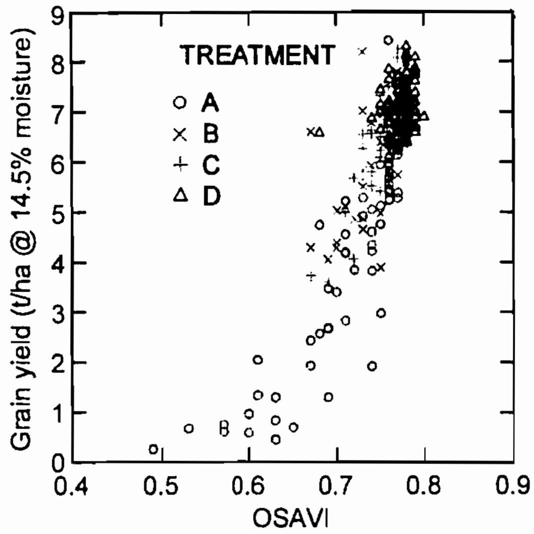

Figure 1. Relationship between corn growth (OSAVI; Optimized Soil-adjusted Vegetation Index) and grain yield, according to different N fertilization treatments.

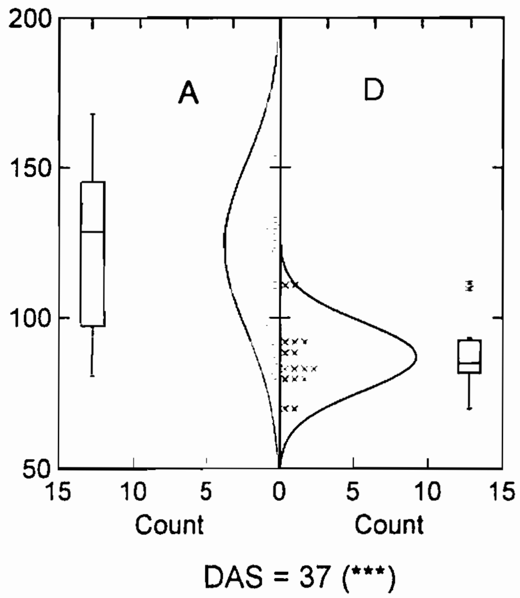

Figure 2. Distribution of N fertilizer by the Hydro-N Sensor on N deficient plots (A) and N saturated plots (D) 37 days after sowing.

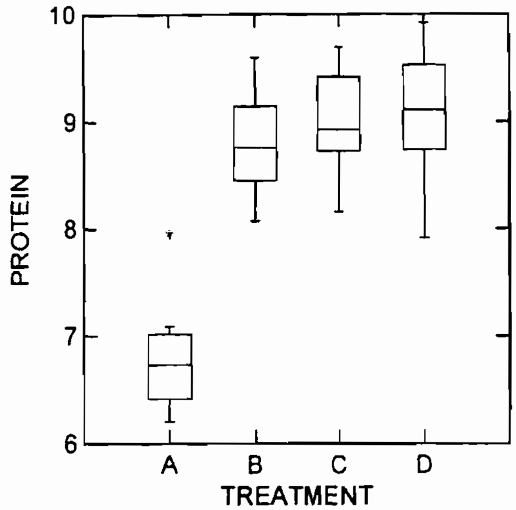

Figure 3. Box plot of corn grain protein content at harvest according to different N fertilization treatments.

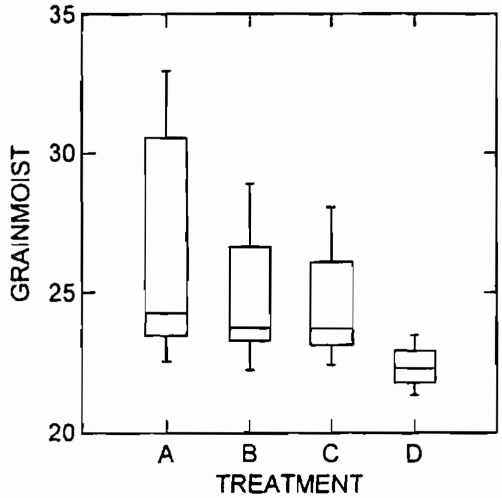

Figure 4. Box plot of corn grain moisture content at harvest according to different N fertilization treatments.

PROCEEDINGS OF THE

THIRTY-SECOND NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 18

November 20-21, 2002
Holiday Inn University Park
Des Moines, IA

Program Chair:
Larry Bundy
University of Wisconsin
Madison, WI 53706
(608) 263-2889

Published by:
Potash & Phosphate Institute
772 – 22nd Avenue South
Brookings, SD 57006
(605) 692-6280
Web page: www.ppi-ppic.org