SITE-SPECIFIC N APPLICATION – THE SOIL MANAGEMENT FACTOR

David Franzen[1] and Dan Long[2]
[1]North Dakota State University, Fargo, ND
[2]USDA-ARS Soil and Water Conservation Research Unit, Pendleton, OR
david.franzen@ndsu.edu 701-231-8884

ABSTRACT

Fields within a site in North Dakota and one in Montana were investigated using variable-rate N based on zone delineation tools. Limited response was observed at either location. Closer examination of the soils within the fields showed that at the ND site, sandier, low organic matter soils might best be managed not through preplant rate, but through a top-dress or sidedress application of N, using lower rates adequate for the lower productivity of the soils. Higher organic matter, heavier textured soils with the field might be expected to sustain their higher inherent yield potential with lower preplant N rates than are currently recommended for general soils in the region. In Montana, an N-rate study was conducted by landscape position. Yield responses to N were observed on hilltops and slopes, but not on higher organic matter landscape positions. Zone delineation tools provide a template for N rate based on residual N, however, consideration of soil characteristics would increase the value of identifying these zones through additional site-specific management techniques.

INTRODUCTION

Site-specific nitrogen management has focused largely on varying N rate in response to soil productivity (i.e. yield goal) differences, residual soil nitrate differences based on grid or zone soil testing (Franzen et al., 1998; Khosla et al., 2002), or differences in previous crop mineralization potential (Franzen, 2004). Although in many studies these approaches have been advancements in fertilization of fields over the one-rate-fits-all approach of the past, they are based on the assumptions that the method and timing of N application is optimized by a preplant N approach, and that the response of soils within the field is the same for all.

The objective of this study originally was to test zone delineation tools and methods for use in variable-N application. As the study progressed, it became evident that rate alone based on what we thought was known was not sufficient to explain the results in crop yields or residual N levels following variable-rate N application and cropping. The objective of this paper was to introduce additional factors that probably need to be considered to further advance the effectiveness of variable-rate N application in the Great Plains.

METHODS

A four-year study was initiated in the fall of 2000. Included within the study was a site near Valley City, ND (lon. 97.910ºW, lat. 46.873ºN), and a site with two fields near Malta, MT (107.588W, 48.430N). The site in Montana was an alternate hard red spring wheat-fallow rotation. The Valley City site was in a spring wheat, barley, sunflower rotation.

Use of topography resulted in zone boundaries that compared well relative to other methods at all locations. In the west, soil EC sensors developed better boundaries than in the east. Yield maps were useful sometimes individually, but use of a yield frequency map that combined different years using a normalization of data placed into three classes was even more useful. Use of satellite imagery (Landsat 5/7, NDVI) was generally better than aerial photography (Ektochrome 200, flown at 5,000 ft. nadir) at most locations.

Most fields were divided into large subplots and variable rate N applications were imposed based on three treatments; uniform based on a field composite analysis, variable based on the researchers favorite method, and variable based on a combination of methods, usually developed by one of the three automated methods. Results showed a general yield and/or quality advantage to the zone-based approach. Residual nitrate was determined after harvest each year by grid sampling to 4-ft in depth at Valley City and 3-ft. at Malta.

RESULTS AND DISCUSSION

Valley City

Despite significant variability of beginning residual nitrate levels, variable-rate N based on weighted, classified zones only resulted in a significant yield increase in one of four years, and a significant protein increase in the same one of four years in spring wheat. Residual nitrate levels following variable-rate were not different between treatments in any year. Figure 1 shows an aerial photo of the Valley City site at an early June date.

In Figure 1, the areas with the "1" designation are eroded, deep sandy loam soils. Organic matter levels are 2% or less. The areas have relatively low residual nitrate levels following harvest, despite having some of the lowest yields and highest preplant N applications within the

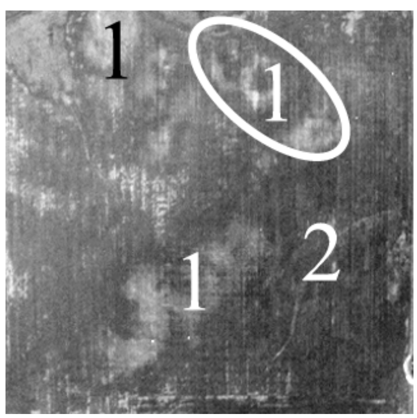

Figure 1. Valley City, 2002 aerial photograph, early June in spring wheat showing two zones with very different responses to variable-rate preplant N urea application. The "1" areas are sandy, the "2" areas are heavy loam textured with higher organic matter.

field. The area designated "2" is characterized by heavy loam surface textures, an argillic horizon (Hopkins and Franzen, 2003), and organic matter levels of about 3.5%. Area 2 has some of the highest residual N levels and the highest yields within the field, despite receiving lower preplant N rates than Area 1. In 2001, barley in Area 1 yielded less than 20 bu/acre, while barley in Area 2 yielded 100 bu/acre. In the same year, residual nitrate in Area 1 was about 30 lb /a, and in Area 2, 60 lb/a.

If the characteristics of the soils in this field were not considered, little improvement might be expected with variable-rate application in the future. The soils in Area 1 are subject to leaching, but are also subject to drought. Application of high rates of preplant N would not be expected to remain in the rooting zone of most crops, and high N rates would not be appropriate for soils with limited yield potential in most years. Therefore, these soils might better be managed if only limited N were applied preplant, and the majority of N applied in small grains through the season using stream-bars. N applications might better be conducted using limited preplant N, followed by a sidedress application.

In Area 2, the heavier, higher organic matter soils, with adequate soil water fed over the argillic horizon from water leached from Area 1 and surrounding soils, appear not to need high N rates to achieve high yields. These soils would better be managed with lower N rates than currently being applied.

Malta

Soils at the Malta site are deep and well drained, and formed on hummocky morainal hills, till plains, and glacial till. They are mapped as Scobey (fine, smectitic, figid Aridic Argiustolls) and Kevin (fine loamy, mixed, frigid Aridic Argiustolls) and have clay loam surface textures. June satellite imagery recorded spatially variable crop growth differences resulting from this soil/landscape variability (Fig. 2). According to nearby weather station data (Malta 7E, Western Region Climate Center Data), about 11.6-in of rain (91% of long term) fell during the 2004 growing season resulting in an average grain yield of 41 bu/a. The amount of total rain that fell during the growing season (May to July) was 6.2-in (93% of long-term).

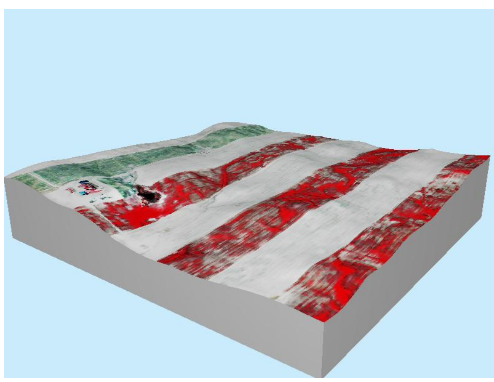

Figure 2. Crop growth patterns typical of hummocky morainal land features in northern Montana as recorded for the study site on a June 2004 satellite image, and location and size of study site for field experiment.

The N rate study was conducted by landscape position. Terrain modeling procedures were applied to a digital elevation model (DEM) that had been constructed from elevation measurements obtained with a survey-grade GPS receiver along a series of parallel transects. These elevation data were fit to a 10-m regular grid using the contouring software Surfer (Golden, CO) and the inverse distance interpolation procedure. The resulting grid was then imported to the landscape analysis program LandMapR (LandMapper Environmental Solutions, Edmonton, AB) that uses a fuzzy classification procedure to identify 15 landscape elements for each cell in a DEM. These elements were generalized into three classes of upper, middle, and lower slope positions (Fig. 3).

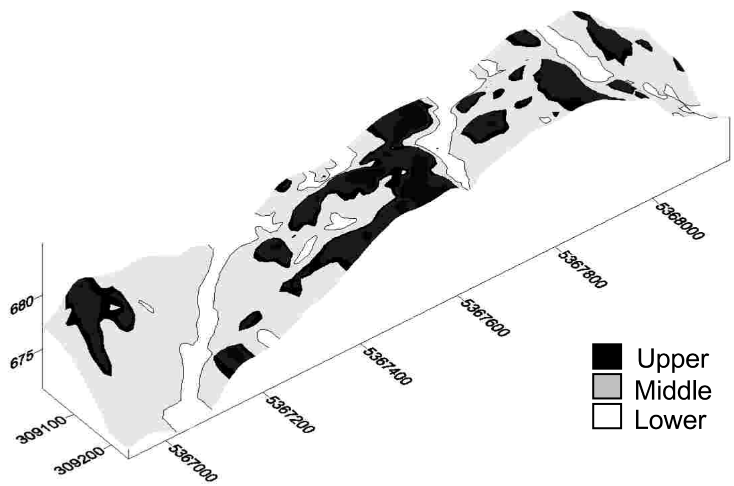

Figure 3. Management zones derived from a DEM and landscape analysis for upper, middle, and lower slopes.

A randomized block design was used with seven replications of four N treatment rates (0-, 20-, 40-, and 60-lb N/a) as illustrated in Fig. 4. These treatments were applied as liquid N fertilizer along the length of the field using a 40-ft Concord air till drill equipped with a variable-rate application system. At flowering, a 20 lb N/a foliar top-dress application of 28% N was applied in alternating passes across the field using an aircraft, which effectively divided each N treatment strip into a series of treated and untreated plots (Fig. 2). The slope class map derived from the DEM allowed each yield measurement to be associated with upper, middle, or lower slopes as needed to ascertain the yield response to applied N within these zones.

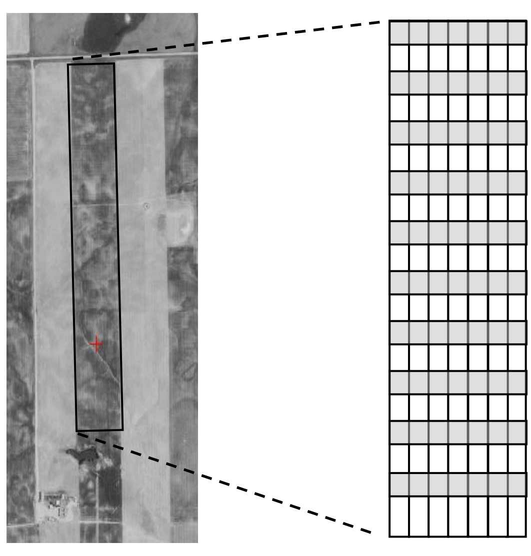

Figure 4. Size and location of randomized experiment at Malta study site (left), and experimental layout of seven replications of four N treatment rates lengthwise with field and series of 10 topdress treatments across field (right).

Applied N caused significant differences in grain yield, grain protein, and flag leaf N on a whole field basis (Table 1). Grain yield, protein, and flag leaf N increased in value with applied N, but topdress of N had no effect likely because of dry growing conditions during anthesis in late June.

Table 1. ANOVA summary for Malta in the entire experiment without regard for landscape positions.

Treatment	Yield†	Protein	Leaf N
lb ac^{-1}	bu ac^{-1}	%	%
0	40.6 a	14.2 a	2.5 a
20	40.5 a	14.8 a	2.6 ab
40	41.5 b	15.5 b	2.7 bc
60	42.2 c	15.8 b	2.8 c
Zero topdress	41.5 a	15.1 a	2.6 a
Topdress	40.9 a	15.1 a	2.7 a

†Means followed by the same letter in a column are not significantly different at P<0.05.

Nitrogen treatments significantly differed in grain yield, grain protein, and flag leaf N within upper and middle slopes where these named variables increased with increasing N rate (Table 2). In contrast, applied N had no significant effect on grain yield in lower slope positions. Grain protein significantly increased with applied N within each slope class, however, top-dress application had no effect. Test weight largely was not significantly different among N rates and slope classes. Leaf N concentration significantly increased with applied N on all landscape positions, but was not affected by top-dress application.

Significant yield responses to applied N were observed on upper and middle slopes, but not on lower slopes where soils are deeper and more productive. Nevertheless, the small range in values of mean grain yield among N treatments (40 to 43 bu/a) of each slope class indicated that the yield response to applied N was modest at best. Grain yields were also similar in value (40 bu/a) at an optimal protein concentration between 14-15%, which corresponds to an N rate of ≤ 20 lb/a in each slope class. Thus, there was little practical difference in grain yield response to applied N and optimum yield points among landscape positions. Consequently, variable rate N application based on upper, middle, and lower slopes might not have been appropriate in this case.

Soil testing revealed that the field site averaged 113 lb N/a within the profile, which compared with the N recommendation of 112 lb N/a computed for a yield goal of 40 bu/a (108 = 2.8 × 40) using Montana State Univ. fertilizer guidelines (Mont. State Univ., 2001). At conclusion of the study, 77 grid sampling points were soil sampled to the 3-ft depth. When divided into landscape positions, upper slopes contained 42 lb N/a, middle slopes 59 lb N/a, and lower slopes 82 lb N/a. Therefore, it is likely that excess residual soil N at the start of the growing season was available for the crop and this accounted for the small yield response to applied N. This also suggested that even though more N was taken up by the crop in depressions, as indicated by slightly higher yield, additional N was available in the soil following harvest compared with other landscape positions. Mineralization rates could have been higher in depressions than in other landscape positions.

Table 2. ANOVA of treatment differences on yield, protein, test weight, and flag leaf N by slope class.

Treatment	Yield†	Protein	Test Weight	Leaf N
lb/ a	bu/a	%	lb/ bu	%
		Upper Slopes		
0	40.4 a	13.7 a	63.0 a	4.02 a
20	40.8 ab	14.7 b	62.5 b	4.22 a
40	42.0 b	15.5 c	62.2 b	4.44 ab
60	42.0 b	16.0 c	62.0 b	4.63 b
No topdress	42.1 a	14.9 a	62.4 a	4.31 a
Topdressed	40.4 a	15.0 a	62.0 a	4.36 a
		Middle Slopes		
0	40.5 a	14.5 a	62.8 a	4.25 a
20	40.2 a	14.8 a	61.6 a	4.34 a
40	41.4 ab	15.5 b	61.4 a	4.50 b
60	42.2 b	15.9 b	61.4 a	4.61 ab
No topdress	41.8 a	15.1 a	62.1 a	4.44 a
Topdressed	40.3 a	15.2 a	61.6 a	4.41 a
		Lower Slopes		
0	41.9 a	13.8 a	59.5 a	4.20 a
20	41.5 a	14.4 ab	58.9 a	4.31 ab
40	42.9 a	15.5 b	62.5 a	4.40 ab
60	41.3 a	15.7 b	62.5 a	4.52 b
No topdress	40.8 a	15.1 a	62.7 a	4.37 a
Topdressed	43.0 a	14.6 a	59.0 a	4.34 a

†Means followed by the same letter in a column are not significantly different at $P<0.05$.

SUMMARY AND CONCLUSIONS

Review of the lack of response to variable-rate N fertilizer compared with uniform N application at sites in Valley City, ND and Malta, MT prompted investigation of the reasons for the lack of performance of the practice. At Valley City, more highly productive areas were linked to higher organic matter and might be eligible for reductions in N rates below the level applied in the variable-rate treatments. The sandier, lower producing soils would not only benefit from lower N rates, but a change in N application timing may be justified, since preplant N was not efficiency utilized in these soils.

In Montana, an N rate study imposed on a field previously unresponsive to variable-rate N showed that the productive, higher organic matter soil was unresponsive to N, while the hilltop and slope landscapes both responded to N. Future N management would benefit from the realization that the N response curves for different soils may not be the same. Some soils are able to provide more native N release to crops, while others would benefit from a higher rate of N.

Clearly, site-specific N management should be more than changing rates due to residual soil N levels. It appears that some identification and consideration of the differing response to N for different soils is necessary. In addition, site-specific N management might also need to include site-specific N application timing if preplant N was found to be unacceptable in part of the field and acceptable in other areas.

REFERENCES

Franzen, D.W. 2004. Delineating nitrogen management zones in a sugarbeet rotation using remote sensing – a review.

Franzen, D.W., L.J. Cihacek, V.L. Hofman, and L.J. Swenson. 1998. Topography-based sampling compared with grid sampling in the northern Great Plains. J. Prod. Agric. 11:364-370.

Hopkins, D.G., and D.W. Franzen. 2003. Argillic horizons in stratified drift: Luverne end moraine, eastern North Dakota. Soil Sci. Soc. Am. J. 67:1790-1796.

Khosla, R., K. Fleming, J. Delgado, T. Shaver, and D. Westfall. 2002. Use of site-specific management zones to improve nitrogen management for precision agriculture. Jour. of Soil and Water Cons. 57:513-518.

ACKNOWLEDGEMENTS

This project was supported by Initiative for Future Agriculture and Food Systems Grant no. 00-52103-9652 from the USDA Cooperative State Research, Education, and Extension Service.