Precision Management Zones Increase Sugar Production in North Dakota and Minnesota

By David Franzen, Greg Richards, and Tom Jensen

Use of variable rate N field management zones – based on sugarbeet leaf color differences derived from satellite imagery – has successfully increased crop yields and the amount of refineable sugar produced per acre of land where sugarbeets are grown in rotation in eastern North Dakota and western Minnesota. The development of a system to subdivide fields into three differentially managed zones is based on research and field experience looking at N management for sugarbeet production. The three management zones are simply characterized as low, medium, and high available N zones, and N and other nutrient rates are adjusted for each zone, based on soil test results.

Management of N, although important for most agronomic crops, is especially critical when growing sugarbeet to achieve desired yields and refineable sugar quality of the beet roots. Sufficient N is needed early in the growth of the beets to grow adequate leaf canopy to make maximum use of photosynthesis and then to store the photosynthetically produced sugars in a sufficiently developed root structure. If excess N is available later in the growing season, the root yield of sugarbeet can be high. But undesirable concentrations of nitrate (NO_3^-) and ammonium (NH_4^+) N compounds, as well as protein, are present in the roots. This reduces the amount of quality sucrose-sugar produced per acre when the beets are refined.

Research examining the relationship between available N and sugarbeet root yield and quality has been on-going for almost 130 years. The earliest recorded studies were in Bernburg, Germany, in 1882 at an experimental research station investigating the mineral nutrition of sugarbeet (Winner, 1993). Numerous studies have subsequently increased the knowledge of how to manage N to achieve desired yields and quality of sugarbeet. One example is the research reported by Bauer and Stevenson (1972) that shows sucrose yield reaching a maximum at a moderate rate of N (100 lb N/A), but decreasing if a higher N rate is applied…even though root yield continued to increase **(Table 1)**. To accurately manage the N supply for a sugarbeet crop, the first step is to determine the amount of available residual N in the soil following the previously harvested crop, and supplement this residual N with added N as fertilizer required for the target yield of sugarbeet. Residual N can be estimated by taking soil samples in the fall after harvest of the previous crop, and having them analyzed for mineral N content, usually NO_3-N. Initial depth of sampling was 24 in., but subsequent research has shown sampling to a depth of 40 to 60 in. is useful because of the deep rooting nature of sugarbeet (Franzen et al., 1999a).

This method of soil sampling can be used to help determine the appropriate rate of fertilizer to add for each crop in the crop rotation used. However, it was observed that field variability usually resulted in sugarbeet growth such that some areas of a field appeared deficient in N, some moderate in N, and some excessive in N. Soil testing these three areas separately determined that residual N levels increased from levels of relatively low to medium, and high. Smith (1996, 1997) conducted site-specific N application studies for sugarbeet in rotation, and found that when whole field soil NO_3^- average

Abbreviations: N = nitrogen; ppm = parts per million; USD = U.S. dollar

Table 1. Effect of N application over three sugarbeet varieties on sugarbeet yield, sucrose concentration, impurity index, and sucrose yield, Oakes, North Dakota.

N rate, lb N/A	Root yield, ton/A	Sucrose concentration, %	Sucrose yield, ton/A	Impurity index, ppm
0	21.8	17.0	3.7	429
51	22.3	16.7	3.7	482
100	24.0	16.4	4.0	534
200	24.6	15.3	3.7	750

Initial soil nitrate-N to 24 in. was 50 lb N/A

levels were used to develop fertilizer rate applications, the same soil N variability level patterns persisted through the crop rotation. He suggested that sugarbeet leaf N content should be used to prevent excessive N application within the rotation. Considerable N is present in the sugarbeet leaves or tops and the greener the color of the leaves the greater the N present. Most of the N present in the leaves is returned to the soil after harvest of the sugarbeets, and it becomes available to a subsequent crop (Franzen, 2004).

Satellite imagery was used to distinguish between "high-N" and "low-N" tops in commercial fields (Moraghan and Smith, 1996). Three reflectance bands... representing low N status, medium N status, and high N status sugarbeets... were used to form the image. Moraghan et al. (1997) separated sugarbeet canopy color from images obtained from late August through early October into yellow, yellow-green, and green. Moraghan subsequently indicated (Sims et al., 2002) that providing N credits to "green" sugarbeet tops was practical.

Franzen et al. (1999b) used Normalized Difference Vegetative Index (NDVI) imagery from the Landsat 5 satellite to delineate zones for applying sugarbeet top credits against N recommendations for wheat following sugarbeet in rotation. NDVI is the ratio of the reflectance of infrared minus red light, divided by infrared plus red light. NDVI is related to relative biomass, crop type, plant health, and nutrition. Yields of areas where credits were given were similar to yields in areas where credits were not needed. Careful attention to N application rates to crops within the rotation, directed by soil sampling, application of N, and sugarbeet top N credits within these image-based zones, resulted in improved sugarbeet quality. In 2002, approximately 20% of the 2002 sugarbeet acreage in the Red River Valley (of crops immediately following sugarbeet) were given a N credit based on this research, with a reduction in fertilizer costs of about USD50/A. Other benefits

Table 2. Effect of zone fertility management on yield, 2003-2007 (ACSC Database).

Management method	Refineable sugar, lb sugar/A	Refineable sugar, lb sugar/ton fresh beets	Revenue, USD/A
Zone	7,567	388	1,022
Conventional field	7,315	338	986
Advantage for zone over conventional management	252	50	36

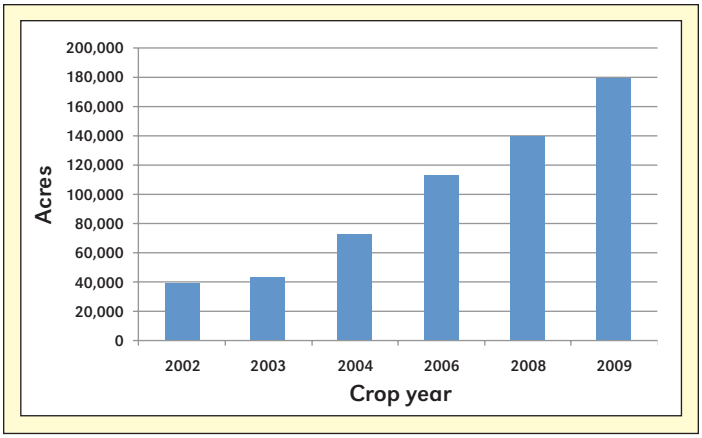

Figure 1. Use of zone management from 2002 to 2009 in eastern North Dakota and western Minnesota (American Crystal Sugar Company 2007, and personal communication 2010).

included reduced lodging of small grains and lower residual N levels in fields returning to sugarbeet in 2 to 3 years.

The use of the sugarbeet leaf color management zones based on satellite imagery has continued to increase since the initial development and use in 2002 **(Figure 1)**. It is estimated that in the crop year 2009, approximately 43% of the 425,000 acres of sugarbeet grown under contract for the American Crystal Sugar Company (ACSC) in eastern North Dakota and western Minnesota used zone management as described above. Sugarbeet growers have the fertilizer variable-rate applied on their fields, usually by their custom fertilizer retailer using prescription variable rate files developed using zone management technology. As growers and ACSC agronomists have worked with using this method of N management, they have found that the management zones could be further refined by using not only the sugarbeet leaf imagery, but also digital topographic maps, and yield maps of all crops in rotation. Many fields are separated into variable rate fertilizer application zones using a combination of the three data information sources mentioned above (ACSC, 2008). It is important to mention that all fields grown under contract with ACSC are managed at the very least using conventional soil sampling on a field average basis to develop fertilizer rate recommendations. The advantage to using the zone management system is that it results in more refinable sugar per acre and per ton of beets, and results in increased revenue per acre for growers **(Table 2)** (ACSC, 2008).

Use of precision variable rate technology applied to management zones based on sugarbeet leaf color has been used effectively in eastern North Dakota and western Minnesota.

A sugarbeet production field as seen by eye (left) compared to the satellite-derived leaf color image on the right. (Source: ACSC).

It is expected that variable rate fertilizer technology will continue to increase in use by growers having sugarbeet contracts with ACSC. There is consideration to further refine the three management zones now used (up to five management zones) to more effectively supply the appropriate N rate to zones requiring intermediate N rates in between the existing zone categories. This will help to maximize sugar production and further increase grower revenues.

Another use being considered for zone management technology is to increase or decrease planting rates of the sugarbeets. For example, the high residual N zones are often consistently higher-yielding compared to the other zones in all crop phases of crop rotations. By increasing plant populations or stands of sugarbeets in these zones, there may be incremental increases in sugarbeet yield and refined sugar per acre of crop. Conversely, in consistently lower yielding management zones, lower than average plant stands may save money on seed costs and not decrease attainable yields. This variable rate planting technology is part of on-going research (ACSC, 2010). BC

Dr. Franzen is Extension Soil Specialist, North Dakota State University, Fargo, North Dakota. Mr. Richards is Ag Strategy Development Manager, American Crystal Sugar Company, Moorehead, Minnesota. Dr. Jensen is IPNI Northern Great Plains Regional Director, located at Saskatoon, Saskatchewan; e-mail: tjensen@ipni.net

References

American Crystal Sugar Company, Moorehead, MN. 2007. Ag Notes – Issue #500, 26-July-2007. http://www.crystalsugar.com/agronomy/agnotes/files.500.asp

American Crystal Sugar Company, Moorehead, MN. 2008. Ag Notes – Issue #513, 23-July-2008. http://www.crystalsugar.com/agronomy/agnotes/files.513.asp

American Crystal Sugar Company, Moorehead, MN. 2010. Personal communication 10-May-2010.

Bauer, C.S. and C.K. Stevenson. 1972. North Dakota State Univ. Ext. Ser. 2: 49-56.

Franzen, D.W., A.J. Landgraff, J.F. Giles, N.R. Cattanach, and L.J. Reitmeier. 1999a. North Dakota State Univ. Extension Ser. 30: 117- 126.

Franzen, D.W., L. Reitmeier, I.F. Giles, and A.C. Cattanach. 1999b. Aerial photography and satellite imagery to detect deep soil N levels in potato and sugarbeet. p. 281-290. *In* P.C. Robert et al. (ed.). Precision Agriculture, Proceedings of the 4th Intemational Conference, 19-22 July, 1998, St. Paul, MN.

Franzen, D.W. 2004. Journal of Sugar Beet Research 41: 47-60.

Moraghan, J.T. and L.J. Smith 1996. Agron. J. 88:521-526.

Moraghan, J.T., K. Horsager, L. Smith, A. Sims, and J. Holland. 1997. 1996 Sugarbeet Res. and Ext. Rep., North Dakota State Univ. Ext. Ser. 27:121-133.

Sims, A.L., J.T. Moraghan, and L.J. Smith. 2002. Spring Prec. Agric. 3:283-295.

Smith, L.J. 1996. North Dakota State Univ. Ext. Ser. 26: 117-119.

Smith, L.J. 1997. North Dakota State Univ. Ext. Ser. 27: 88- 91.

Winner, C. 1993. History of the crop. p. 1-35. *In* D.A. Cooke and R.K. Scott (ed.), The Sugarbeet Crop-. Chapman & Hall, NY.