ADV0253 Enhancing sugar beet storage quality.

Interim #1 Report
June 2006 - May 2007

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Agricultural Adaptation Council – CanAdvance Program
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Executive Summary:

Once harvested, the majority of Ontario sugarbeets are stored, typically over 120 days, in large piles until processed to extract raw white sugar. Even under ideal storage conditions, sugar losses occur in two ways: 1) sugar is consumed during respiration by the living beet root and 2) sugarbeets rotting within the pile. In the 2004/05 storage season alone an estimated $ 1.6 million (farmgate value) of sugarbeets were discarded. Observations during that winter suggested that production practices and/or varieties influenced sugarbeet storability. Little is known about the impact of crop fertility or crop variety on storage losses of sugarbeets in large piles.

The objective of this research project is to investigate the impact of crop fertility and variety on storage losses (sugar losses, losses due to rots) of sugar beets stored in large piles. A field nitrogen (N) fertility trial was established and throughout the growing season there were observable differences in plant growth and color between zero N treatments and the two highest rates (150 and 200 lb N/ ac). Yields in all plots were good, at approximately 42 t/ac. The most economic rate of nitrogen (MERN) was 97 lb N/ac, calculated based on sugar content. With increasing N (200 lb N/ac), yields, sugar and purity decreased, resulting in decreasing grower income. Soil and plant N analysis indicated no difference in nitrogen use efficiency when 100 or 200 lb N/ac was applied or when N fertilizer was applied at planting or at sidedress. An unexpected outcome of this research was the correlation between the SPAD® meter readings, which estimates chlorophyll content, and sugar beet parameters (yield, %sugar, purity and amino acids). However these relationships were only maintained at specific times during the growing season. This suggests that the SPAD® meter might be a useful decision making tool to estimate yield and profitability; however further research is necessary.

Difficult harvest conditions due to excessive rainfall and early hard frosts prevented the burial of experimental beets in large pile storage. Although alternatives were considered, there was no opportunity to put the trial samples in the large piles. Using the Euro Maus instead of front-end loader to remove beets from the pile for shipment will further facilitate storage this coming harvest season.

Project Details:

Objectives and Project Inputs:

1. **Nitrogen impact on storage**: To develop best management practices for nitrogen applications (rate and timing) that maximize sugar quantity and quality and minimize the incidence of rots over 120 days of large pile storage.

2. **Variety impact on storage**: To identify sugarbeet varieties which consistently have good storability, which will be characterized by high recoverable sugar and low incidence of rots over 120 days of storage in large piles.

Table 1. Project inputs from May 2006 to 2007.

Funding level		Cash	In-kind
AAC CanAdvance		$7 350	
OSGA		750	
Staff resources	Technical		$2600
	Professional		2000
Other resources used to date:			
Analysis	Nitrogen*		1100
	Sugar**		300
Total		**$8100**	**$6000**

*Note: based on $10.00 per sample, which is 50% of the commercial price of these analyses. Agri-Food Laboratories is contributing the balance of the cost as an In-Kind contribution to the project. Letter of support from Agri-Food Laboratories previously provided.
** Note: Sugar analysis (value of $18.00 per sample) provided as an In-Kind contribution by Michigan Sugar Company. Letter of support provided previously.

Methods:

CROP: Sugarbeet — Variety: Crystal 271
Plant population: 52000 plants/ac — Plant spacing: 4.2 in
Row spacing: 30 in

DESIGN: Randomized complete block design — Replications: 4
Plot width: 6 rows (15 ft) — Plot length: 26 ft

PEST CONTROL was according to typical Ontario production practices.

NITROGEN: Ammonium nitrate was broadcast applied by hand. Split applications were applied prior to row closure.

Table 2. Nitrogen treatments in sugarbeets.

N application	N rate (lb N/ac)
At planting	0
	50
	100
	150
	200
Split application	50+50
	75+75

Table 3. Site characteristics.

Characteristic		Dover
Planting date		28 April
Date of split application		6 June
Harvest date		14 November
Monthly rainfall mm	June	70
	July	153
	August	72
	September	110
	October to harvest	n/a
Soil characteristics:	pH	7.4
	Soil texture	Clay loam
	% sand:silt:clay	33:30:37
	% OM	4.4
	CEC (MEQ/1 00g)	38.9
Nutrients (ppm):	N	11
	P	24
	K	171
	Ca	6184
	Mg	765

Activities:

1. **Nitrogen impact on storage**:
   - Conducted field experiment in a commercial grower's field with various nitrogen rates (0, 50, 100, 150, and 200 lb N/ac) and timings(75 lb/ac preplant with 75 lb/ac sidedressed and 50 lb/ac applied preplant with 50 lb/ac sidedress)
   - Visual assessments of plant vigor over the growing season
   - Over the fall, estimate relative differences in crop senescence between treatments using a SPAD® chlorophyll meter.
   - At harvest, determine sugar beet yield and sugar quantity and quality.
   - For key treatments at harvest, plant (shoot and root) %N content and soil mineral N levels will be measured to assess N uptake

2. **Variety impact on storage**:
   - Industry-sponsored Sugarbeet Advancement Variety Trial was completed, but beet samples were not stored in large piles, due to reasons indicated earlier.

3. **Technology Transfer**:
   - Completed research reports
   - Presentation of results to the Ontario Sugarbeet Grower's Association and Michigan Sugarbeet Growers
   - Extension article written

Barriers:

Our project also included evaluating sugarbeet storage in response to various nitrogen rates as well as evaluating the storage characteristics of varieties included in the Sugarbeet Advancement Variety trial. The plan was to bury beets from these trials towards the back of the piles at the Dover Piling Station, assuming that beets would be removed as usual from front to back. This would give us time to have several removal dates over the winter. Fall 2006 was extremely wet, resulting in difficult harvesting conditions. Moreover, a hard frost in mid October and a second frost on November 2nd, resulted in a decision that the piles would be removed from the back to the front, as it was felt the frosted beets would not store well. There was no opportunity to put the trial samples in the front of the piles because this would cause too much damage to the beets in the pile. Small piles were considered, but they are not representative because they freeze solid. No large pile storage was possible in 2006, thus, the activities and the milestones associated with pile storage was not conducted. Discussions with the personnel at the Dover Piling Yard, have ensured that beets can be stored this season, should similar conditions occur. The approach to storing samples was revisited because beet removal will be done with a different machine (Euro Maus). (see 'next steps' section).

Results to Date:

SEEDLING EMERGENCE:

- N treatments had no impact on seedling emergence
- Excellent trial establishment and plant growth

OBSERVATIONS:

<u>9 August</u>

- Sugarbeet Research Tour was given August 9th to Michigan Sugar Inc, Sugarbeet Advancement, growers and OMAFRA
- Differences in plant color between zero N and 200 lb N/ac (light vs. dark green color)
- Perhaps smaller plants in zero N control, but difficult to assess visually

<u>23 August and 7 September</u>

- Differences in plant color between zero N and 200 lb N/ac (light vs. dark green color)
- Smaller plants in zero N control:
  plants do overlap in rows compared to higher N rates
  smaller leaves

<u>6 October and 3 November</u>

- Same as above
- Larger plants in 150 and 200 lb N/ac treatments:
  fuller canopy
  larger leaves

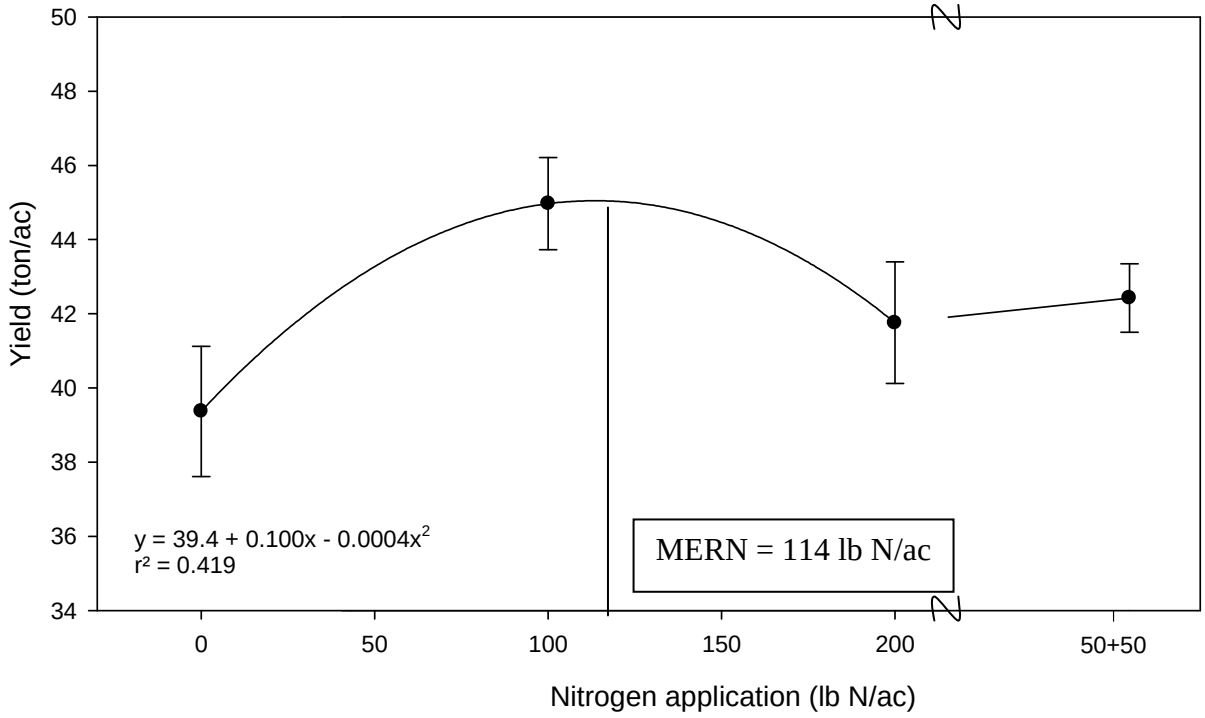

Figure 1. Sugarbeet yield response to ammonium nitrate fertilizer applied preplant. The 50+50 treatment was a split application of 50 lb N/ac applied preplant and 50 at sidedress.

YIELD: Yields were harvested by hand. There was a quadratic sugarbeet yield response to N fertilizer application. Based on tonnage, the most economical rate of N was 114 lb N/ac, based on $39.53CAN/ton and fertilizer cost of 45¢/lb. (Figure 1). By converting yield and sugar content for each treatment, the most economical rate of N was 97 lb N/ac based on the following equation price/ton sugarbeets = (3. 518 x % Sugar)–15.4 (Figure 2). Considering that new contracts are based on yield and sugar content, the optimal N rate was 97 lb N/ac. There was no yield advantage to split applying N in 2006. These results were similar to research from Michigan Sugar Company and elsewhere. Unfortunately, the other treatments were not harvested because of the wet fall conditions.

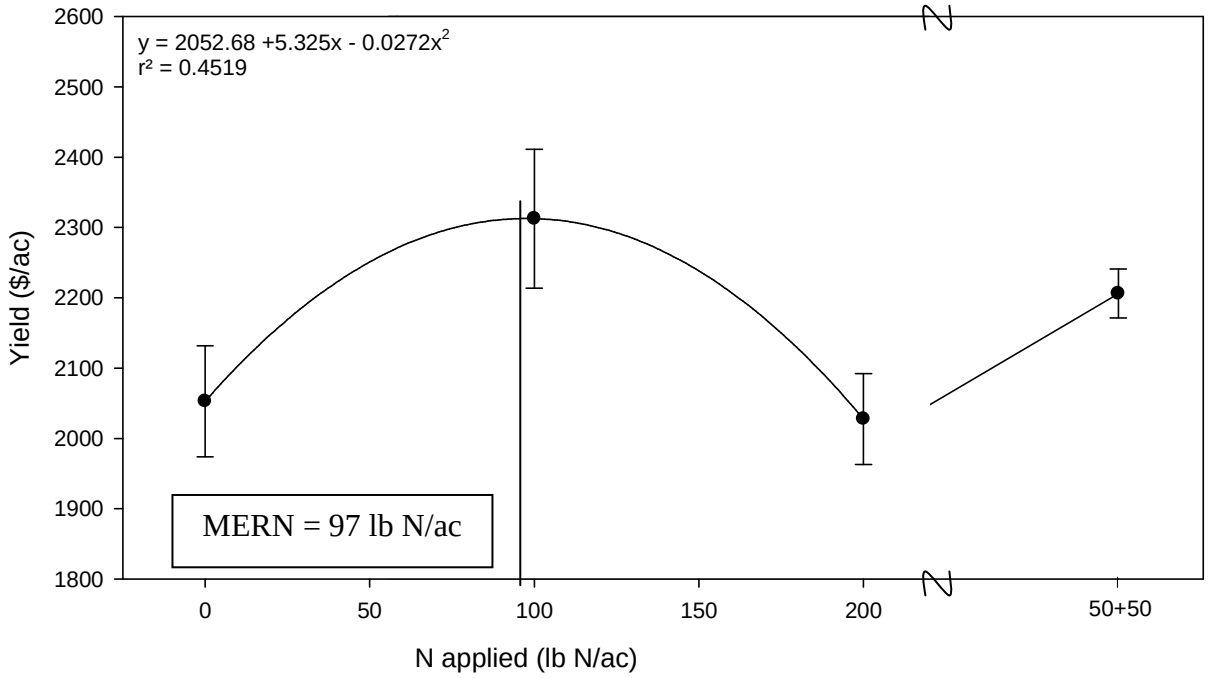

Figure 2. Sugarbeet yield response to ammonium nitrate fertilizer applied preplant. The 50+50 treatment was a split application of 50 lb N/ac applied preplant and 50 at time of sidedress application. The most economic rate of N was 97 lb N/ac based on 45¢ N fertilizer and price/ton sugarbeets = (3. 518 x % Sugar)–15.4.

QUALITY: All sugarbeet quality measurements (sugar, and % purity, and amino nitrogen) responded to N applications. As N applications increased, % sugar and % purity decreased (Figure 3A and 3B). Amino-nitrogen was higher at 200 lb N/ac and decreased with decreased amounts of N applied (Figure 3C). Thus, sugarbeet quality declined with increased fertilizer N. For all quality parameters, the split application was not different than the preplant N. These results were as expected and similar to research out of Michigan.

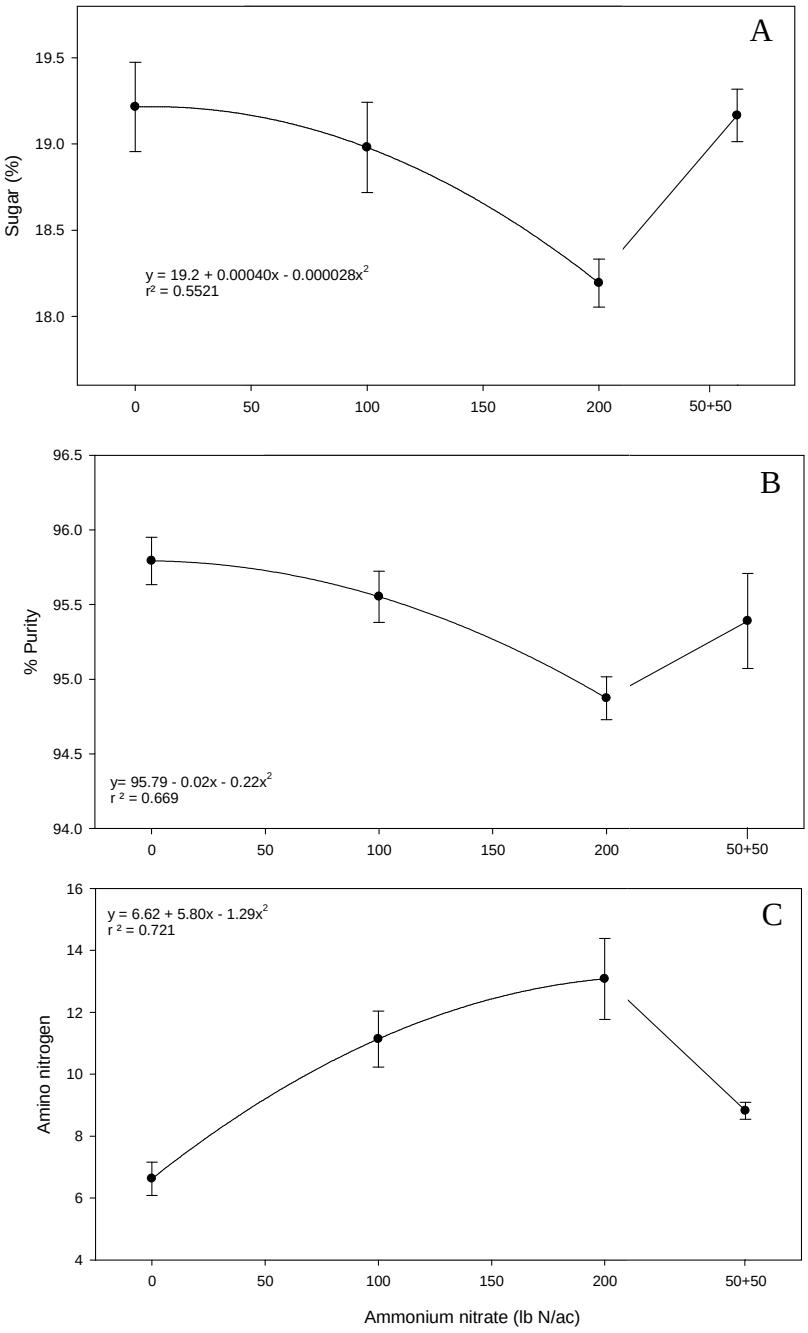

Figure 3. Sugar content (A), percent purity (B) and amino nitrogen (C) response to ammonium nitrate fertilizer applied preplant broadcast.

NITROGEN DYNAMICS: At planting, soil mineral N (nitrate-N and ammonium-N) was 49 and 129 kg N ha^{-1} at 0-30 cm and 0-90 cm depths, respectively(Table 4 and 5). Soil nitrate-N levels were constant with depth at the spring sampling date (Table 4). At harvest in the zero N control, soil nitrate-N levels were significantly lower than at planting (Table 4). However, there was no difference between all fertilizer treatments in soil nitrate-N (Table 4) or total mineral N. Both spring and harvest, nitrate-N and ammonium-N levels were typical for southwestern Ontario soils at this time of year.

Table 4. Soil nitrate-nitrogen concentration from zero N control in sugar beets.

Soil depth (cm)	Nitrate-nitrogen (ppm)				
	At planting	At harvest			
		Fertilizer applied			
		0	112	125	56+56
0-30	11.1	6.0	7.9	8.0	6.8
30-60	9.9	3.2	3.5	3.1	2.8
60-90	8.9	3.0	3.4	3.1	2.7

Nitrogen budgets were calculated based on N inputs and outputs. Inputs include fertilizer applied, the amount of soil mineral N, and the total N taken up from the plants in the zero N control. Plant N from the zero control is included because it represents the amount of mineral N the soil provided to the plant. Outputs include the amount of mineral N in the soil at harvest, and N in plant tissue, where crop removal indicates N content in the sugarbeet and crop residue represents N in the leaves (tops).

In the zero N control, there was an input of 247 kg N/ha (Table 5), which is typical of southwestern Ontario production. At harvest, there was no difference between N treatments in the amount of N in the beets, but there was more N in the leaves when fertilizer was applied compared to the zero N control (Table 5). Soil mineral N was not different at harvest for all treatments. When 112 kg N/ha extra fertilizer was applied (i.e. comparing 0 to 112 or 122 to 225 treatments), by harvest the soil mineral N and plant uptake was not significantly greater. Therefore, at the 225 kg N/ha treatment there was potential for significant N losses.

Nitrogen use efficiency is an indication of how much fertilizer is taken up by the crop relative to the zero control. Nitrogen use efficiency was not different when 112 and 225 kg N/ha was applied or between preplant and split N applications (Table 5). Thus, applying 112 kg N/ha more fertilizer (i.e. comparing 112 and 225 treatments) did not increase yields and did not increase crop N uptake. The N index compares the amount of N removed from the field (i.e. N content in the beets) with the amount of N applied. Based on OMAFRA's nutrient management (Nman) software, a -60 indicates that alternative N management practices (such as cover crops) should be considered. An N-index value of -209, which was the case when 225 kg N/ha was applied, would not be permitted under nutrient management planning. However, sugarbeet growers typically apply 100 lb N/ac (112 kg N/ha), which lowers the potential for N loss compared to higher rates.

Table 5. Estimated nitrogen budget in 2006 for sugarbeet[a].

Nitrogen Source	Nitrogen (kg N/ha)			
Input:				
Fertilizer N	0	112	225	56+56
Spring soil N	129	129	129	129
Plant N from 0N plots	118	118	118	118
total	247	359	472	359
Output at harvest:				
Crop removal (N content in beet)	21	23	21	22
Crop residue (N content in leaves)	97 a[*]	145 b	166 b	157 b
Soil mineral N	65	78	73	66
total	183 a	246 b	260 b	245 b
Calculations:				
Nitrogen use efficiency [b]	-	45	31	55
N index (crop removal - fertilizer)	21 a	-89 b	-204 c	-90 b

[a] Data were means (n=4).
[b] Nitrogen use efficiency (NUE) was calculated by the following equation NUE = ((Pnf-Pn0)/F)x100. Where Pnf = total plant N in fertilized plot, Pn0 = total plant N in non-fertilized plot, and F = fertilizer applied
[*] Different letters, within rows, indicates a statistically significant difference between treatments.

IN-SEASON SPAD READINGS: The Minolta SPAD® 502 meter estimates chlorophyll content using light transmission. The meter provides a number for each reading; the higher the reading, the higher the chlorophyll content, the greener the leaf. The SPAD has been used in many crops to correlate N fertilizer applications to chlorophyll content. The objective was to correlate leaf senescence in the fall to sugar content. This, however, did not work because leaves on the beet were either green or brown with very few yellow or senescing leaves.

An unexpected result of this research was the relationship between SPAD readings and sugarbeet yield and quality. There was a significant quadratic relationship between sugarbeet yield and SPAD reading taken on August 23rd only (Figure 4A). Moreover, 65% of the variability in yield is explained by the SPAD reading taken on August 23rd. SPAD readings taken later in the season did not relate to yield. Therefore, with further research the SPAD meter may be useful to predict yield. On November 1st, percent sugar, purity, and amino-nitrogen strongly correlated to SPAD readings (Figure 4A, 4B and 4C). Therefore, the SPAD meter may be a useful tool to determine which fields to harvest late in the season. Further, research over multiple years is needed to confirm the usefulness of the SPAD meter to predict sugar beet yield and quality. Thus, SPAD readings in August may be a reasonable predictor of yield and quality parameters in November. In 2007 and 2008, SPAD readings will be done earlier in the season to determine if the relationship is significant and the ideal time to take readings.

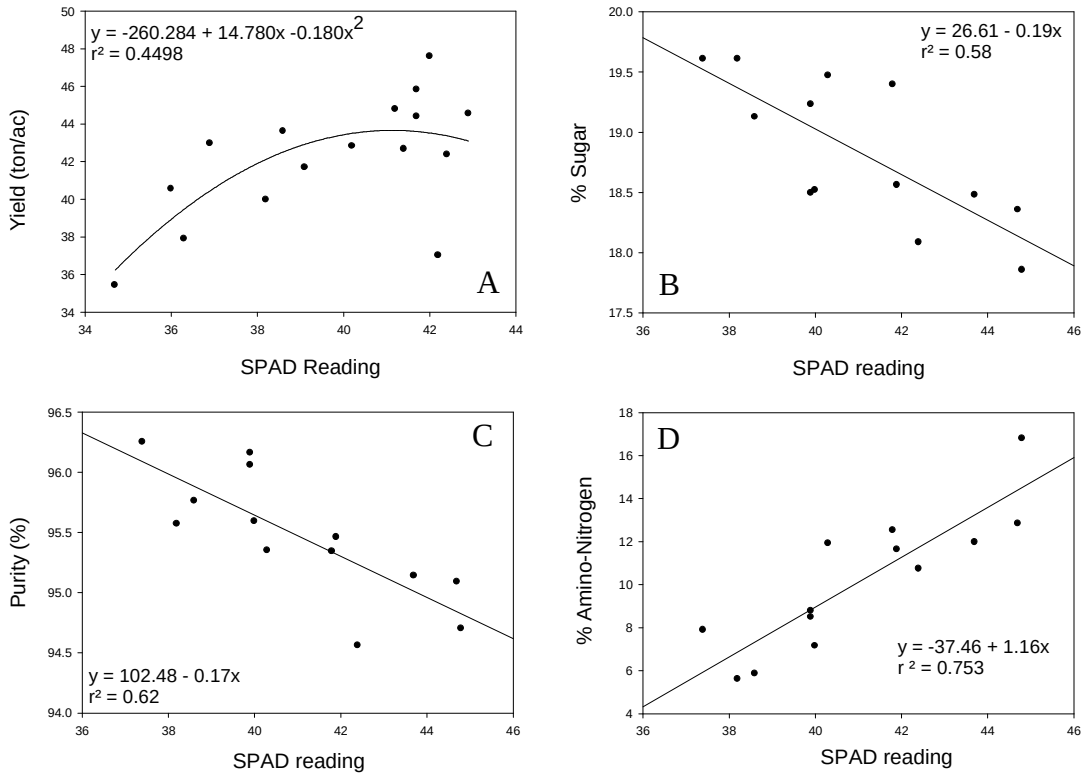

Figure 4. Correlation between SPAD chlorophyll readings taken on 23rd August 2007 and sugarbeet yield (A), as well as SPAD readings taken November 1st 2007 with sugarbeet quality parameters: sugar content (B), purity (C) and amino-nitrogen (D).

Potential Benefit of this Research:

During the 2004/2005 storage period, an estimated 44, 000 tons of sugarbeets with a farmgate value of $1.6 million were discarded in Ontario. Although weather and beet handing at harvest impact storage losses, there is little information on the impact of grower practices such as nutrient regime and/or crop variety on storage losses. There would be an obvious and immediate benefit to sugarbeet growers and Ontario agriculture if the causes of storage losses were better understood so best management practices could be developed to reduce them.

Michigan Sugar, the company which contracts and processes all Ontario grown sugarbeets, is a grower-owned cooperative. Storage losses directly affect the profitability of the company, which is shared by all growers. Direct beneficiaries of this research are the 109 Ontario sugarbeet growers and their employees. However a successful industry will also benefit associated sugarbeet industry employees, which include 6 full time equivalents at the piling station, 35 full time jobs in field operations and 24 full time equivalent seasonal jobs in the trucking industry. Moreover, with a farmgate value of $9.1 million, the Ontario sugarbeet industry has a positive influence on the local rural economy. Unfortunately, there was no opportunity to store beets from the N and variety trials in the large piles.

Reach and Communications:

Ontario sugarbeet producers are the primary target of this research, along with the processor – Michigan Sugar Company extension/research personnel, relevant OMAFRA staff, and industry consultants as well as Michigan members of the grower cooperative. It is estimated that that over 80%, 95% and 95% of the producers, OMAFRA staff, and processor personnel, respectively were reached by this project to date by the technology transfer activities described below. AAC/AAFC was acknowledged in all communications.

Presentations

Van Eerd, L.L.* and J.W. Zandstra. 2007. In-season estimation of sugarbeet yield and quality. Michigan/Ontario Sugarbeet Research Reporting Session. Chatham ON. *Presenter to 75 growers and industry reps. February 8th.*

Van Eerd, L.L. and J.W. Zandstra. 2007. Can the SPAD® meter be used in-season to assess sugar beet quality? First Annual Michigan/Ontario Sugarbeet Research Reporting Session. Frankenmuth, MI. *Presenter to 150 growers and industry reps. January 30th.*

Van Eerd, L.L. and J.W. Zandstra. 2007. Enhancing sugarbeet storage through N fertility and variety. Research Report to Ontario Sugarbeet Growers Association Research Committee. Chatham ON. *Presenter to 6 growers and industry reps. January 8th*

Field Days and Tours

Van Eerd, L.L. 2006. Impact of N fertility on sugarbeet storage. Sugarbeet Research Tour. Dover. ON. 9 Aug 2006. *Presenter to 20 Michigan Sugar industry, OMAFRA and growers*

Zandstra, J.W. 2006. Potential impact of variety on sugarbeet storage. Sugarbeet Research Tour. Dover. ON. 9 Aug 2006. *Presenter to 20 Michigan Sugar industry, OMAFRA and growers*

Van Eerd, L.L. 2006. Overview of N fertility research in vegetable crops. OMAFRA Research Tour. Dover. ON. 8 Aug 2006. *Tour organizer and presenter to 8 OMAFRA staff*

Popular Press Articles

Brown, L. 2007. Sugar beets that can't be beat: Researchers take new approach to improve quality. Research Magazine: Focus on Farming. University of Guelph. Spring 2007. XXII (1). pg. 13.

Technical Reports and Abstracts

Van Eerd, L.L. and Zandstra, J.W. 2007. Enhancing sugarbeet storage quality through nitrogen management and variety selection. Annual report to Ontario Sugarbeet Growers Association. January 2007. pp 2. *Report distributed to 75 growers and industry reps.*

Van Eerd, L.L. and Zandstra, J.W. 2007. Enhancing sugar beet storage quality through nitrogen management and variety selection. Michigan/Ontario Sugar Beet Research Reporting Session. January 2007. pp 1. *Abstract distributed electronically via CD to over 150 growers and industry reps.*

*Bold names indicates principle presenter/writer.

Preliminary Conclusions:
The most economic rate of N based on sugarbeet yield, quality, and fertilizer costs was 97.5 lb N/ac. Overall, sugarbeet quality decreases with increasing N fertilizer. There was no difference in yield and quality between split and preplant applications, if the same rate was applied. Soil and plant N analysis indicated no difference in nitrogen use efficiency when 100 or 200 lb N/ac was applied or when N fertilizer was applied at planting or at sidedress. The SPAD® meter appears to be a promising tool in the future to predict yield and quality, but requires more research over the entire season. It is anticipated that modifying N fertilizer applications and/or variety selection may enhance sugar beet profitability by maximizing sugar production per acre and minimizing storage losses. Further, because sugarbeet production is a grower cooperative, this facilitates an atmosphere of sharing production information that will benefit the entire industry.

This report summarizes one season of a 3-year project. However, due to the lack of storage in 2006-2007 and in order to have three seasons in the sugarbeet piles, it was proposed to expand this project to include another field season in 2009. In order to get meaningful results at least three storage trials should be conducted. Therefore, a revised budget and proposal was submitted to AAC for consideration in February 2007.

Next Steps: Activities and milestones for next period are as previously outlined, with two exceptions: 1) SPAD sampling will increase and 2) storage efficiencies.

SPAD READINGS: Due to the encouraging correlation between SPAD® readings and sugarbeet yield and quality, in-season readings will be expanded. If similar trends are observed in the next two years, the SPAD® meter may be used as a decision making tool for sugarbeet production. This may be increasingly important as the price for sugarbeets changes to reflect quality parameters such as % sugar.

STORAGE EFFICIENCIES: Arrangements have been made to modify how beets are stored in the large piles. All treatments will be stored in a large steel mesh container and placed on a platform. This will facilitate loading onto and retrieval from the piles thereby limiting inconveniences at the piling yard while maintaining representative storage conditions. Moreover, loading from the pile for shipment to Michigan will be done with a Euro Maus as opposed to the front end loader. This will make it easier to retrieve the steel containers because the pile is pealed off in layers from the outside in as opposed to from the front to the back. With personnel from the Dover Piling Yard, it was agreed that the steel containers will be placed in pile 2, near the end of the pile and each of three containers will be located in the middle of the pile. Thus, steps have been put into place to maximize efficiency of loading and retrieving samples from the large storage piles.

Acknowledgements
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Ontario Sugarbeet Growers' Association

OSGA

Promoting Profitable Sugarbeet Production In Ontario

Agricultural Adaptation Council

Canada

Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Michigan Sugar Company
A Grower-Owned Cooperative

AGRI-FOOD LABORATORIES

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