NARROW ROW SUGARBEET PRODUCTION

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INTRODUCTION

In recent years, an incursion of cultural practice changes has occurred within the sugarbeet (*Beta vulgaris L.*) industry. With ever-changing sugarbeet varieties and cultural practices, some producers and the industry have pondered whether sugarbeet production in narrow rows (row spacing of less than 22 inches) might demonstrate advantages utilizing existing cultural production practices. Currently in the Red River Valley of the North (Northwest Minnesota and Eastern North Dakota) over 97% of sugarbeet production is in 22-inch rows (Table 1). The 22-inch row spacings produce higher root yields of recoverable sucrose per acre while best satisfying the equipment row widths for other crops on these farms in the region.

Table 1 - American Crystal Sugar Company Database – Row Spacing

American Crystal Sugar Company Row Spacing

Grower Database

2002 - 2005 Crop Years

Row Width (inches)	Acres	% of Acreage
11	2,553	0.13%
16	852	0.04%
20	4,271	0.21%
21	1,479	0.07%
22	1,969,367	97.03%
23	29,783	1.47%
24	12,412	0.61%
25	3,554	0.18%
26	2,940	0.14%
27	56	0.00%
28	44	0.00%
30	2,145	0.11%
44	95	0.00%

European sugarbeet production shows higher recoverable sucrose production per hectare in terms of root yield and quality with 18-inch and 20-inch row spacing (Cattanach et al., 1995). Amalgamate this with the knowledge that smaller (diameter and weight) beets generally improve quality (lower impurities and increase sucrose) and that some of the sugarbeet processors in the world utilize a quality payment system based not only on root yield, but quality…the concept of narrow row sugarbeet production gains popularity.

The species *Beta vulgaris L.* includes Swiss chard, mangel (or fodder beet), table beets, and sugarbeet (Hilde, 1996). Sugarbeet and sugarcane (*Saccharum officinarum*) are the major sources of the sweetener, sucrose found in many of the foods we consume. Sugarbeet is a biennial. The first year of growth produces a white tap root, while after an over wintering period, sugarbeet produces a seed stalk and may be harvested for seed. For commercial sugarbeet production and sucrose extraction, at the end of the first year of the growing season, the petioles and leaves are removed and the roots are harvested and processed into refined sucrose (Hilde, 1996). Root yield is measured in tons per acre of harvested root.

The main challenge in sugarbeet production is to produce the highest quality root, while maintaining maximum root yield, minimizing harvest losses, and minimizing tare (leaf and soil) to enhance long-term storage. Nitrogen (N) is a major nutrient for increasing sugarbeet root yield, but excess nitrogen reduces sugarbeet root quality by reducing extractable sucrose and increasing root impurity. As a result of this conflicting nitrogen relationship, a major production challenge is to simultaneously produce a high yielding and high quality crop. Typical root yields in NW Minnesota and NE North Dakota are approximately 19 tons per acre. Sugarbeet root weight is approximately 75% water, 18 to 20% sucrose, with the remaining balance comprised of dry matter and impurities (McGinnis, 1982).

In the early 1980s, the American Crystal Sugar Company Board of Directors adopted a Quality Payment System (QPS) that rewarded growers who delivered a high quality product (more sucrose and less impurity per ton) and penalized them for low RST (Recoverable Sucrose per Ton). Prior to the Quality Payment System, growers were paid on net tons (root yield less canopy and tare, with no compensation for high sucrose content). Growers had no incentive to improve crop root quality. The reasoning for the Quality Payment System was to entice management practices to produce higher percent sucrose content per ton and lower impurities in sugarbeet to improve sucrose extraction efficiency through nitrogen and plant population management. With higher sucrose content in the sugarbeet root, growers could conceivably transport fewer tons of sugarbeet and receive an increased payment per acre. An example of this (Table 2) demonstrates this payment system by comparing two different crop scenarios: one with an increased root yield and decreased sucrose content (Field example A), and the other with a decreased root yield and an increased sucrose content (Field example B). The overall gross beet payment (total field) for this 80 acre field comparison is within $80 total; however, the grower having field example B benefited by harvesting and hauling four tons less per acre (or 320 tons less for the total field). The factories also benefited by processing fewer tons of sugarbeet while extracting increased amounts of sucrose or quality from the roots.

Table 2 – Sugarbeet Gross Payment Comparison Examples:

2006 Sugarbeet Gross Sugarbeet Payment Calculator

	Field A	***Field B***
	Higher Yield Lower % Sucrose	**Lower Yield Higher % Sucrose**
Acres	**80**	**80**
Tons per Acre	**26.0**	**22.0**
Sucrose delivered %	**17.50**	**19.20**
Sugar loss to molasses %	**1.15**	**1.15**
Gross beet payment per ton	**$47.32 ***	**$55.97 ***
Gross beet payment (total field)	**$98,435 ***	**$98,515 ***

* Using 2006 Beet Payment Variables

These quality measurements involve percent sucrose content in the root and percent sucrose loss to molasses (LTM). LTM is sucrose that cannot be extracted during the initial sucrose extraction process and this lost sucrose goes into low value molasses. The impurity (LTM) is calculated using the Carruthers formula (Equation 1), developed by Dr. A. Carruthers of the British Sugar Company in the 1960s (Hilde, 1996):

Equation 1 – The Modified Carruthers Formula for calculating Sucrose Loss to Molasses

$$\text{\% Sucrose Loss To Molasses} = \frac{(\text{ppm Na} \times 3.5) + (\text{ppm K} \times 2.5) + (\text{ppm Amino-N} \times 9.5)}{11{,}000} \times 1.5$$

With a multiplying factor of 9.5, the Amino-N factor in the Carruthers Formula indicates the importance of nitrogen in the LTM calculation. This emphasizes the need for careful nitrogen management practices in sugarbeet root production. Recoverable sucrose per acre (RSA) is an industry measurement that takes into account the sucrose content, LTM content, and root yield (Equation 2). The RSA is an accurate way of reporting the total production of sucrose per unit of area and includes the deductions of sucrose that can't be recovered (LTM), so the calculation is the net amount of sucrose produced, in this case, per acre.

Equation 2 – Recoverable Sucrose per Acre (RSA) Formula for calculating the net sucrose produced per acre of land

$$\text{RSA} = ((\text{\% sucrose content} - \text{\% LTM}) \times 20) \times \text{root yield tons per acre}$$

Example, using actual 2006 crop data from American Crystal Sugar Company:

$$\text{RSA} = ((18.20\ \% - 1.26\ \%) \times 20) \times 25.40 = 8{,}606 \text{ lbs. sucrose per acre}$$

The objective of this research was to determine a plant population or row configuration to maximize Recoverable Sucrose per Acre (RSA) in commercial narrow row sugarbeet production. In these experiments, sugarbeet was produced in 22-inch and 11-inch row spacings utilizing traditional cultural practices associated with commercial production in the 22-inch row spacing, with the exception of plant population.

LITERATURE REVIEW

Four general production/cultural aspects of narrow row sugarbeet production were reviewed in the literature. These four areas are:

1) Quality - An overlying reason for planting sugarbeet in narrow rows is to increase the sugar (sucrose) content in the sugarbeet using the same or reduced amounts of nitrogen by narrowing row spacing and inevitably through increased plant populations. Higher plant populations increase the ratio of sugarbeet plants to the available nitrogen and corresponding nitrogen uptake per beet is reduced. Currently, sugarbeet varieties are available to growers that tend to produce higher root yield; however, they often have lower quality including lower sucrose content and higher impurities or loss to molasses (LTM). LTM is sucrose that is combined so tightly with impurities in the root that separation is not easily accomplished. High plant populations allow more sugarbeet roots to take up soil nitrogen, so more root mass intercepts available nitrogen. Total nitrogen taken up is proportional to increasing root yield, and inversely proportional to increasing LTM (decreasing sucrose yield).

2) Weed control – Another reason for exploring narrow row production occurs from the changing sugarbeet leaf canopy architecture engineered through breeding techniques. Sugarbeet varieties are hybrids that produce progeny's of diploid (2N), triploid (3N), or anisiploid (combination of 2N and 3N) offspring depending on the breeding technique used. Each of these hybrid progeny demonstrates varying physical features in their growth habits, mainly leaf arrangement and structure. The triploid varieties tend to have a planophile or broad canopy growth habit that canopy over and close the rows quickly. The diploid varieties have more of an upright or erectophile growth habit that causes slower canopy closure allowing for increased intra-row air movement and reduced leaf disease presence. However, these open rows allow increased sunlight penetration through the canopy to the soil surface, and therefore allow weeds to germinate over a longer period and compete more with the sugarbeet crop. Recent adoption of diploids, with their higher root yield potential and improved root disease tolerance, has been the sugarbeet variety ploidy of choice.

3) Root yield - A third factor behind the narrowing row width movement originates from observations of Genetically Engineered (GE) herbicide-resistant sugarbeet varieties that tend to produce higher root yield potential. The theory is to use higher plant populations and narrower rows to achieve higher root yields while maintaining high quality, along with, increased crop competition with weeds to virtually eliminate weed competition. This category combines the three aspects studied. A semi-algebraic equation of this aspect would be plant population, plus narrow rows, plus glyphosate; equals greatly reduced or nearly eliminated weed competition.

4) Cultivation – Row cultivation was the fourth factor identified. With transgenic sugarbeet on the horizon, perhaps cultivation for weed control in sugarbeet could be eliminated. Through the combined use of RoundUp Ready® sugarbeet and high plant populations/row spacing, arrangements could be studied to find the highest sucrose production per acre using two means of weed management: 1) use of herbicide resistant sugarbeet, such as RoundUp Ready® sugarbeet. 2) use of higher plant populations per acre to improve the competitive advantage of sugarbeet over weeds.

A review of sugarbeet row spacing literature compared 22-inch row spacing with the same effects narrow row planted sugarbeet had on overall sucrose production. These studies investigated narrow row sugarbeet production and 22-inch row spacing with the same or similar plant populations per acre. Also, research was conducted using similar within-row spacings and comparing 22-inch row spacing with narrow rows, primarily comparing 18-inch and 11-inch row spacing to 22-inch row spacing. One study reviewed compared 22-inch rows spacing with 30-inch row spacing. Early narrow-row sugarbeet production research was performed by Skuderna around 1940 (Cattanach and Schroeder, 1979). This research demonstrated that root yield and overall sucrose per acre decreased when row spacings were increased from 22 to 30 inches. In the Red River Valley of the North, crop rotations include other row crops, such as edible beans, soybeans, potatoes, corn, and sunflowers. These row crops utilize wider row widths, so early sugarbeet production utilized the wider 30-inch row spacing for equipment compatibility with rotational crops. In 1976, questions arose whether new varieties, herbicide use, and/or cultural practices could increase RSA via narrowing the row spacing. Recently interest has increased in growing sugarbeet in narrower row spacing arrangements to enhance existing production practices. The question of wider than 22-inch row spaced sugarbeet production was investigated by Cattanach and Schroeder (1979), where they studied the effects of 22-inch row spacing compared to 30-inch row spacing on sugarbeet production. In these studies, they noted 31 previous studies in the United States where results showed an average advantage of 589 pounds of sucrose per acre in 22-inch rows when compared to wider spacing. Greater stand loss occurred on 30-inch row spacing compared to 22-inch spacing. Improved quality was found in sugarbeet from higher plant populations per acre. Recoverable sucrose per acre was significantly higher in 22-inch row spacings when compared to 30-inch row spacing. Row spacing had no effect on sugarbeet root diameter; however, higher plant populations tended to decrease sugarbeet root diameters.

In a two-year North Dakota State University research study Cattanach et al. (1995) and Cattanach et al. (1996) found that recoverable sucrose per acre increased as plant populations increased. In 1995, using populations of 17,820, 23,760, 29,700, 35,640 and 41,580 plants per acre in 18-inch and 22-inch row-widths, RSA increased with each increase in plant population; a slight decrease in RSA was observed with the 18-inch treatment at a plant population of 41,580. In that 1995 study, treatment differences were significant. In 1996, the study was repeated with the same plant population and row treatments (18 and 22 inch). No significant differences in either quality or overall root yield were identified between 18- and 22-inch row spacings; however, the highest plant population in the study (41,580 plants per acre) produced the highest RSA in the 18-inch row treatment. Combining the two years of the study, the treatment differences were not significant and that no benefits were achieved by producing sugarbeet in 18-inch row spacing.

Oregon State University, at the Malheur Experiment Station, studied the effect of narrow row sugarbeet production (11-inch row spacing) with transgenic sugarbeet and no cultivation. Ransom et al. (1998) found root yields from sugarbeet grown in 11-inch rows with 16-inch in-row spacing produced higher RSA than sugarbeet grown in 22-inch rows with 6- or 8-inch in-row spacing. Sucrose was higher in sugarbeet from the 11-inch row spacing compared to the 22-inch row spacing except where sugarbeet were grown in 22-inch row spacing with 6-inch in-row spacing. Overall, estimated recoverable sucrose per acre was highest in the 11-inch row spacing with 12-inch or 16-inch in-row spacing compared to the 22-inch row spacing. One unmeasured advantage (data not presented) was expedited row closure in the 11-inch row spacing resulting in increased competition from sugarbeet with weeds. A RoundUp Ready® sugarbeet variety was treated with glyphosate to eliminate weed competition in this study. The mean 11-inch row spacing production was 11,546 lbs Recoverable Sucrose per Acre (RSA) compared to the mean 22-inch row spaced production of 9,410 lbs RSA for a difference of 2,136 lbs (RSA).

Glyphosate resistant sugarbeet varieties were introduced into research trials with great expectations for commercial use. How these varieties would perform was a question pondered by many in the industry, so an experiment (Wilson et al., 2001) was designed to determine an appropriate plant population utilizing 11-inch and 22-inch row spacings. In each of the experiments, the plots were planted and thinned to equal plant populations. Four final plant populations were tested ranging from 23,760 plants per acre to 71,280 plants per acre. The experiment concluded that at each of the four plant populations, the 11-inch row spacing had similar or better percent sucrose, greater tonnage (root yield), and as a result, greater recoverable sucrose per acre in comparison to the 22-inch row spaced sugarbeet. Sucrose production per acre reached a plateau between populations of 35,640 to 47,520 plants per acre regardless of the row spacing utilized in the study.

Nebraska sugarbeet growers typically utilize 30-inch row spacing in their sugarbeet production. In a detailed experiment (University of Nebraska, 2003), a group of Nebraska growers made plans to produce sugarbeet in a narrow 18-inch row spacing. The motivation for this production change was to: 1) increase root yield, 2) improve weed control (especially late season) by early canopy closure and a denser crop canopy, 3) reduce or eliminate row cultivation, and 4) achieve higher plant populations, which was difficult to obtain in the 30-inch row spacing system. Expectations for the 18-inch row spacing were to gain three tons root yield per acre or the equivalent in Recoverable Sucrose per Acre. The growers in the study harvested four fields totaling 230 acres. With good early season weed control, sugarbeet crop observations indicated that the 18-inch row spacing with higher plant populations had quicker canopy closure allowing better competition with the weeds. The 18-inch versus 30-inch production data was collected not replicated, so the root yields were not analyzed statistically. However, they concluded that sugarbeet produced in the 18-inch row width could produce a higher yield and a higher income than sugarbeet produced in traditional 30-inch rows.

A sugarbeet research trial (University of Nebraska, 2003) used eight replicates to compare 18- and 30-inch row spacings in field length strips. Data from machine harvested sugarbeet indicated a significantly greater yield from the 18-inch row spacing as compared to the 30-inch spacing. Sugarbeet yield increased by 1.9 tons per acre, 1.1% sucrose content, and 1,400 lbs Recoverable Sucrose per Acre from the 18-inch rows.

A Canadian experiment (Rogers Sugar Ltd., and Alberta Sugar, 2003) compared 11-inch and 22-inch row spacing and found no significant differences in Extractable Sucrose per Acre (ESA). Canopy differences (increased dry weight of the tops and color) varied within the 11-inch row spaced beets, and yet no ESA differences were found in spite of canopy variability that was caused by different plant populations and differing nitrogen rates. In the trials, increasing total nitrogen availability significantly increased ESA in the 11-inch row spaced beets. This result may have occurred from a nitrogen deficiency in the plots or that portion of the field.

Camp and Foote (2003) compared 11-inch row spaced production with 22-inch row spaced production with 8, 12, 16, and 20 inch in-row plant spacing. They found no significant difference in tons per acre, sucrose percent or Estimated Recoverable Sucrose (ERS) per acre within the row spacing. Sucrose percent tended to be higher with the 12-inch in-row spacings using the 11-inch row width. When compared with a nearby 22-inch plot, the 11-inch rows produced approximately a one percent increase in sucrose content. However, root yields were similar from 11-inch and 22-inch row spacings. Row closure in the 11-inch row spacing was a week to ten days sooner than the 22-inch row spacing. Row closure was noticeably faster with the narrower in-row spacing in the study and this may allow better weed control/management.

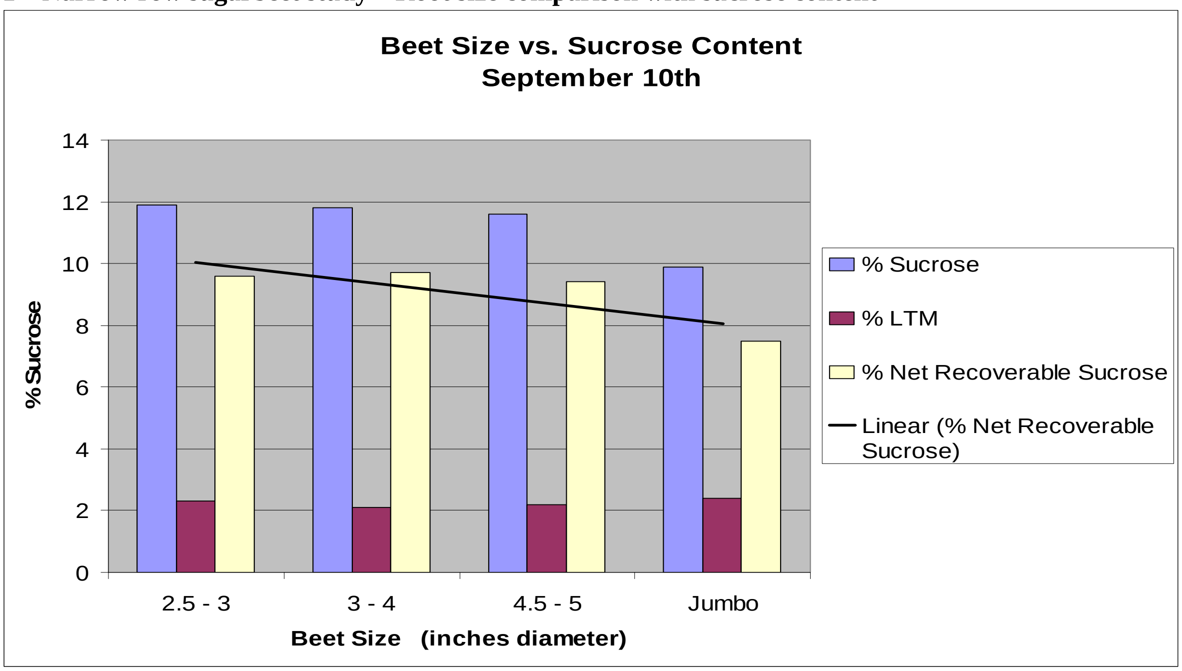
Khan et al. (2004) compared sugarbeet production in an 11-inch row spacing with 8, 10, 12, and 14 inches between plants within the row to 22-inch row spacing, with 8-inch in-row spacing. The 11-inch row width with 8-inch in-row spacing produced the lowest mean root weight. Respiration rates of the roots from the differing row configurations and also from the differing in-row spacings were measured. Respiration rates increased in the smaller roots (11-inch row spacing and 8-inch spacing) and respiration rates were decreased in larger roots from the 22-inch row spacing with 8-inch in-row spacing. Overall, the data indicated that RSA was greatest in sugarbeet produced in 11-inch rows, and spaced 12 to 14 inches apart compared to the 22-inch row width spaced 8 inches apart. An important item to note, however, that as a result of the higher population of beets, root size and root weights were significantly smaller in the 11-inch row spacing. This characteristic may negatively affect root harvest (higher root yield loss) and root storage (increased storage respiration losses).

In 2005, 11-inch and 22-inch row widths were compared (Khan and Nelson, 2005). The lowest average root weights were found in the 11-inch row width with 8-inch in-row spacing. Reducing the row spacing from 22- inches to 11-inches, decreased the average root weight per beet. However, sugarbeet from the 11-inch row produced sugarbeet also trended lower in LTM. A trend of increasing RSA occurred as spacing within-row increased in the 11-inch row width. Although not significantly different than 22-inch row width treatment, the within row spacing of 12- and 14-inch spacings in the 11-inch row width yielded the highest RSA in the study. This increase in RSA was perceived to have occurred from less inter and intra-row competition for essential water, sunlight, and plant food. The authors concluded that producing sugarbeet in 11-inch row spacings provided no economic advantage. The traditional 22-inch row spacing sugarbeet production generated RSA as high as from sugarbeet in 11-inch rows when higher stand counts of up to 175 beets per 100 feet of row were established.

PROJECT OVERVIEW

The primary motive for this study was initiated based upon observation of the sugarbeet roots found in the bar chart in Graph 1 where net sucrose content (sucrose % minus Loss to Molasses %) is presumably inversely proportional to sugarbeet root size (diameter and/or weight). Graph one demonstrates how root size generally affects sugarbeet root quality.

Graph 1 – Narrow row sugarbeet study – Root size comparison with sucrose content



This project was initiated in 2002 as a commercial on-farm experiment of the owner/shareholder involving 657 acres of sugarbeet production. A research study for the project was not requested until crop year 2003, so the references made to the 2002 crop year were not studied nor recorded and so comparisons of 11-inch rows and 22-inch row sugarbeet production were not made in this first year. In 2002, the entire test farm produced sugarbeet in 11-inch row width with 6 inch in-row spacing (a planting population of about 83,000 seeds per acre or approximately 62,500 plants per acre using a 75% expected final stand estimate) on all acres planted. Sugarbeet production with traditional 22-inch row widths with 6 inch (or less) in-row seed spacing can achieve a population of about 48,000 sugarbeet seeds planted per acre. Using a 75% expected final stand estimate, this results in approximately 36,000 sugarbeet plants per acre.

In 2002, the 6-inch within row spacing yielded less RSA (Recoverable Sucrose per Acre) than anticipated when comparing to sugarbeet produced in 22-inch rows. The producer requested assistance to identify an in-row spacing and row configuration that would maximize RSA utilizing the 11-inch narrow row spacing in his commercial sugarbeet production. Working with the producer, several in-row spacings were identified for testing, to aid in establishing the ideal in-row spacing and overall plant population. This report involves results of the study from production years 2003, 2004, and 2005.

YEAR ONE PROJECT – 2003

2003 - Materials and Methods:

A John Deere planter was converted from a 12 row 22-inch planter to a 21 row 11-inch row spacing planter. The forward planter was set to plant 12 rows spaced 22 inches apart and the trailing attached planter was set to fill in nine rows between the front rows to create a 21-row planter that was 22 feet wide, the same width as the forward attached sugarbeet planter bar. Looking down the planter rows, the planting units were staggered to achieve planting in an 11-inch row width with one pass of the planter, leaving a 22-inch row spacing for the two wheel tracks.

Two commercial fields were planted with this arrangement and sampled for this study: Northland section 35 of Polk County, Minnesota (Field 35) and Sullivan section 4 of Polk County, Minnesota (Field 4). Soil association at both locations were Bearden – Colvin Complex (Fine- silty, mixed, superactive, frigid Aeric Calciaquolls (NRCS, 1996) with the dominant soil order, Mollisol, and dominant suborder, Aquoll (Brady and Weil, 2002). Pertinent field information utilized to establish and maintain the production fields in this study is described in Table 3.

Table 3 – 2003 Narrow Row Sugarbeet Study - Field Information

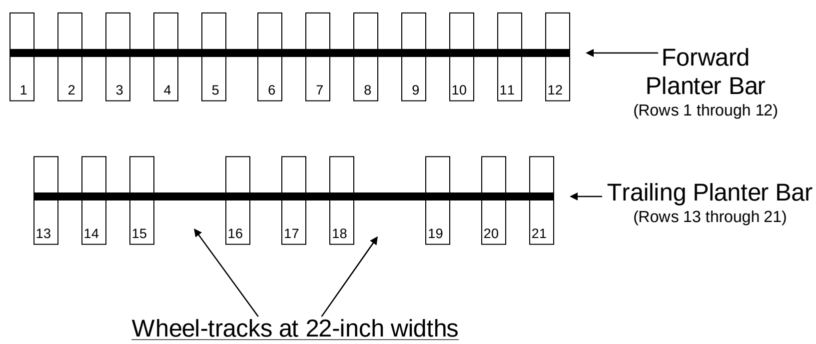
2003 Narrow Row Sugarbeet Study Field Information	Field 35	Field 4
Variety	Beta 6447	Crystal 725
Seed size	Pro 200	Regular Pellet
Planting date	May 16, 2003	May 27, 2003
Soil test lbs. actual N (0 -2')	153	20
Soil test lbs. actual N (0 - 4')	32	16
Soil test P (Olsen) ppm	9	15
Soil test K ppm	220	355
Soil test pH	8.0	8.1
Fertilizer applied (lbs/acre)	4+58+0	94+37+0
Starter Fertilizer (10-34-0) gal/acre	3	3
Total N (available + applied)	189	130
Previous crop	Potato	Wheat
Years between sugarbeet	3	6
Insecticide	2.1 oz/acre Mustang Max®	2.1 oz/acre Mustang Max®
POST herbicide (MicroRates)	3 X - Broadcast	2 X - Broadcast
Lay-by herbicide	None	None
Row cultivation	None	None
Rotary hoe	5 X	4 X
Fungicide (rate/acre & date)	Eminent ® - 13 oz July 18	Eminent ® - 13 oz July 28
Fungicide (rate/acre & date)	Topsin ® / Super Tin ® 1/2 lb & 3.75 oz Aug. 8	Super Tin ® - 5 oz Aug. 18
Fungicide (rate/acre & date)	Super Tin ® - 5 oz Aug. 27	None
Harvest date	October 16, 2003	October 16, 2003

To further determine the best locations for the research plots in the fields and to help identify consistent areas of the fields, two previous years of Near Infrared (NIR) satellite imagery allowed identification of the most uniform areas of the fields used in the study, based on sugarbeet leaf canopy reflectance. Topography and nitrogen content are important influences on sugarbeet root yield and sucrose content. Satellite imagery aids in identifying field variability for these traits. The satellite images used have an applied logarithm NDVI (Normalized Difference Vegetation Index) which estimate the density of leaf canopy along with the color of the canopy. These variations occur in the field from varying nitrogen amounts which are influenced by soil topography. Since this study was not a small plot experiment, satellite images were a very helpful option to utilize in the studies to minimize variability of data. Late August satellite imagery was used in the 2003 study.

Sugarbeet samples were harvested for all four weeks by hand. For both locations, the experiment was arranged in a complete-block design with five treatments and four replicates. One planter pass was used for each treatment within the field to keep a close proximity within the area to study for soil uniformity purposes. The four replicates were sampled within the center seven rows of the 21 row sugarbeet planter pass and one row away from the wheel tracks (rows six, seven, and seventeen – Diagram 1) to separate the treatments with a uniform buffer from the other treatments and to reduce the impact of soil compaction found in the wheel track rows. The treatment replicate samples were harvested in-line across the treatments using a random replicate order. To further explain the row spacing configurations studied, Diagram 1 indicates the sugarbeet planter row configuration. Table 4 indicates how each planter row was arranged at planting. The following five treatments, or in-row spacing, configurations were studied in each of the fields:

11-inch 12 x 6 **11-inch 12 x 9** **11-inch 9 x 9**
11-inch 6 x 6 **22-inch @ 6-inches in-row**

Diagram 1 – Narrow Row Sugarbeet Production Sugarbeet Planter Configuration



- Forward planter bar rows spaced 22-inches apart
- Trailing planter bar rows fit in-between each forward row for 11-inch row width. The rows between 15 & 16 and 18 & 19 were removed to allow 22-inch row widths wheel tracks

Table 4 - Narrow Row Sugarbeet Production Study (Row Configurations)

Narrow Row Sugarbeet Production Study - Row Configuration

Final Row-width (inches)	Treatment	Rows	In-row Spacing (inches)	Rows	In-row Spacing (inches)
11	12 x 6	1 to 12	6 (thinned to 12 inches)	13 - 21	6
11	6 x 6	1 to 12	6	13 - 21	6
11	12 x 9	1 to 12	6 (thinned to 12 inches)	13 - 21	9
11	9 x 9	1 to 12	9	13 - 21	9
22	22-inch	1 to 12	6	13 - 21	Trailing planter not used

A company-traditional 22-inch row spacing utilizing 6 inch in-row plant spacing was used as a bench-mark comparison in each of the fields. The 6 x 6 treatment was utilized in Field 4 to gauge the performance of the project had the producer continued to employ the 6 x 6 spacing as used in the first year (2002) of his 11-inch row spacing sugarbeet production. To further describe the in-row spacing alternations used in the study, for example, a 12 x 6 planting configuration was achieved by planting all rows with 11-inch row spacing and 6 inch in-row spacing. At about the six-leaf sugarbeet stage, mechanical sugarbeet thinners were used to thin the alternating rows by theoretically removing every other sugarbeet seedling to achieve the 12 x 6 inch spacing pattern. To achieve a 9 x 9 pattern, the in-row spacing was set at 9 inches apart in each row with no thinning. A 6 x 6 pattern was achieved by setting the planter at 6 inch in-row spacing for each row with no thinning. A 12 x 9 pattern was accomplished by planting the beets with an in-row spacing of 6 inches alternating with an in-row spacing of 9 inches by row. The 6-inch spaced rows were then thinned back to 12 inch spacings (essentially eliminating every other sugarbeet seedling) using the mechanical thinners to achieve the 12 x 9 pattern.

The sugarbeet planter used in the study, planted rows in three groups of seven rows (identified best in Diagram 1) with 22 inches left as wheel tracks between rows 15 & 16 and rows 18 & 19 to reduce the affect of tractor compaction or row movement from the weight of the tractor and equipment, while all other rows were spaced 11 inches apart. The hand samples were pulled with one row separating the sample area from the 22-inch wide rows to minimize the influence of wheel track rows might have in the study.

Root and canopy (leaves and petioles) samples were pulled by hand on August 19, September 3, and September 16, 2003. In stockpile harvest, October 16, 2003, hand samples were taken prior to harvesting. Every sugarbeet root in one row for a 10-foot distance (10 foot row sample or 18.3 sq feet) was pulled from the 22-inch row spacing. For the 11-inch row spacing, two 10-foot rows (20 foot row samples or 18.3 sq feet) were pulled and sampled to equalize the area of the 22-inch spaced rows. The beet tops or canopy (petioles and leaves) were removed from each sample and weighed using a hand scale at the test plot. The samples were processed at the American Crystal Sugar Company Quality Lab in East Grand Forks, MN. At the Quality Lab, the roots were washed, weighed, counted, and tested for sucrose content (percent sucrose), and percent Sucrose Loss to Molasses or LTM (sodium, potassium, and amino N). For Tables 5, 6, 7, and 8, data were analyzed using analysis of variance (ANOVA) using Microsoft Excel 2002 (10.6834.6830) SP3 and for Fisher's LSD and CV (Coefficient of Variation) calculations (Clewer and Scarisbrick, 2001). In the realm of sugarbeet yield and RSA studies, CV's of 5 to 15% are considered acceptable.

The leaf and petiole separation process (defoliation) chosen by the producer, involved a stalk shredder that was used to remove the majority of the sugarbeet leaf canopy. This allows about four inches of petiole material to remain attached to the sugarbeet roots. The producer removed the remaining petiole material using a defoliator, leaving a defoliated sugarbeet root. As the final leaf canopy removal process, the producer in the study implemented a unique way of "scalping" which is a term used for a knife that travels over each row above the crown or the very top portion of the sugarbeet root where most of the impurities accumulate as was discussed earlier in this paper (Carruthers Formula, Equation 1). This method used by the producer was unique as the scalpers were mounted on the front of the tractor as compared to mounting them on the trailing end of the sugarbeet defoliator. The mounting on the front of the tractor was created out of necessity as adding scalpers to the trailing end of the defoliator would have added too much weight for the twenty-one scalpers needed for the 21 rows of the defoliator. Mounting them on the front of the tractor required only seven rows, thus reducing the overall weight from the scalpers, and allowed the beet roots to be scalped just in front of the harvester.

The sugarbeet harvester used in the study was a commercial sugarbeet harvester modified by the producer to accommodate the harvesting of the narrow rows. The modifications made to this harvester were patented by the producer as a result of this project: U.S. Patent # US 6,988,559B2 (Date of patent January 24, 2006). Typically six sets of lifter wheels spaced 22 inches are placed side-by-side across the machine. In the harvester utilized in this project, the lifter wheels were spaced 11 inches apart in two rows across the machine (four rows in front and three rows in the back) to create a seven row sugarbeet harvester.

2003 Results and Discussion:

The 2003 project discussion begins with discussion of the 2002 sugarbeet crop for this producer. The 2002 11-inch row spaced planting configuration was in commercial production prior to establishing the row spacing treatment field studies in 2003. In 2002, the project farm averaged 15.5 tons per acre of sugarbeet roots, 17.04 % sucrose, and 1.27 % Loss to Molasses, 4,889 lbs RSA across 657 acres of commercial production. With narrow row sugarbeet production, having too few plants per acre would be one of several root yield reducing threats in this type of production system, so approximately 83,000 seeds per acre were planted and a 75% estimated final stand, would result in 62,500 plants per acre for a final stand count. Some seed does not emerge due to factors such as seedling diseases, soil crusting, or other emergence problems. The project farm utilized 6 inch in-row spacing in 11-inch spaced rows with no thinning of the final plant population. Observations from the 2002 sugarbeet production for this producer indicated that planting 83,000 seeds per acre in 11-inch rows most likely increased sugarbeet competition for available nutrients, moisture, and light interception resulting in smaller sugarbeet root diameter and excessive yield loss at harvest due to high final plant population. A visual observation to note from the 2002 crop was that weed control appeared to be excellent with the high final plant population found by planting sugarbeet in 11-inch rows with 6 inch in-row spacings.

In 2003, the project farm yielded an average of 20.6 tons per acre of sugarbeet roots, 18.6 % sucrose, and 1.21 % LTM for a total of 7,165 lbs RSA across 608 acres. This was a 147 % increase in RSA in comparison to the 2002 crop. Sugarbeet yield was much improved in 2003 than in 2002 possibly because the plants were thinned to a lower population in 2003 and not thinned in 2002. This presumably allowed the seedlings more room for growth, nutrient uptake (mainly nitrogen), soil water uptake, and light interception for root growth accumulation. Weather conditions, planting dates, pest management, and stand establishment (to name a few) undoubtedly played a major role in the improvement shown in 2003, however from visual observations of just sugarbeet root size alone, differences in root size could be distinguished between the two years of narrow row sugarbeet production. Harvest losses due to the reduced sugarbeet root size allowed more beets to drop through the sugarbeet harvester in 2002. In 2003, weed management was more difficult in that the final plant populations were decreased, allowing weeds to develop more rapidly, and no lay-by herbicide was utilized to reduce the weed development once weed growth was established. The producer relied more heavily on POST (Post-emergence) herbicide applications and rotary hoeing for weed management.

An interesting portion of this study was to theorize which sugarbeet production method (22-inch rows or 11-inch row spacing) would produce the highest amount of total fresh weight or total plant material (sugarbeet root, petioles, and leaves). In Table 5, the total fresh weight for Field 35 is displayed. These data were collected during the first three sample dates and were sampled by hand.

Significant differences were identified in the second week (Sept. 3, 2003) of hand sampling in Field 35 (Table 5). The 9 x 9 and 22-inch treatments yielded the least total fresh weight in comparison to the 12 x 9 and the 12 x 6 treatments. For the previous sampling week (Aug. 19, 2003) and the week following (Sept. 16, 2003) however, the total fresh weight production differences were not significant. The 9 x 9 treatment produced the least total fresh weigh in all three sampling dates. The CV% for these observations ranged from 13.8 to 14.8%.

Table 5 - 2003 Narrow Row Sugarbeet Study, Field 35 Total Fresh weight

2003 Narrow Row Study Field 35 Total Fresh Weight (tons/acre) Roots & Canopy

Hand Samples	Aug 19, 2003	Sept 3, 2003	Sept 16, 2003
11-inch & 9 x 9 inch in-row	36.8	35.4	34.5
11-inch & 12 x 9 inch in-row	38.6	47.6	47.2
11-inch & 12 x 6 inch in-row	47.0	46.6	42.4
22-inch & 6 inch in-row	37.7	41.5	38.4
LSD (0.05)	NS	9.1	NS
CV %	14.0	13.8	14.8

NS = No Significant Treatment Differences

For Field 4, significant differences were observed (Table 6) in the last sample date (Sept. 16, 2003). The 12 x 6 treatment yielded a significantly different (heavier) total fresh weight in comparison to the other three treatments. No significant differences in total fresh weight from this field study were observed during the previous two hand samples dates (Sept. 3 and Aug. 19, 2003). In Field 4 however, a similar trend to Field 35 was observed where the 22-inch treatment tended to produce the least total fresh matter for the first two sample dates, and nearly the third sampling week. The 12 x 6 treatment tended to yield the heaviest total fresh weight, throughout the three sampling dates. For the 12 x 6 treatment, the total fresh weight tended to increase as the season progressed into the later portion of the growing season (up to September 16th). The CV % for these observations ranged from 9.5 to 12.2%

Table 6 - 2003 Narrow Row Sugarbeet Study, Field 4 Total Fresh weight

2003 Narrow Row Study Field 4 Total Fresh Weight (tons/acre) Roots & Canopy

Hand Samples	Aug 19, 2003	Sept 3, 2003	Sept 16, 2003
11-inch & 6 x 6 inch in-row	43.5	45.0	40.7
11-inch & 9 x 9 inch in-row	42.6	50.1	44.4
11-inch & 12 x 6 inch in-row	46.1	49.8	52.7
22-inch & 6 inch in-row	42.4	41.0	43.2
LSD (0.05) CV %	NS 12.0	NS 12.2	6.6 9.5

NS = No Significant Treatment Differences

From the Field 35 harvest samples (Table 7), significant differences among the treatments were observed with weight per beet, % LTM, and RSA. The 22-inch and the 12 x 9 treatments produced the heaviest sugarbeet roots with an average weight of 1.9 and 1.8 lbs per beet, respectively. The smallest sugarbeet roots were produced with the 12 x 6 and 9 x 9 treatments at nearly one-half of a pound less per average beet. The 22-inch treatment produced a significantly larger LTM at 1.5 % when compared to all other treatments in the study. All three 11-inch treatments averaged similar percent LTM, and contained significantly fewer impurities. No significant differences were identified from the measurements of root yield or sucrose content; however the least percent sucrose was produced in the 22-inch treatment by nearly one percent. Root yields ranged from a low of 26.5 tons per acre in the 22-inch treatment to 33.9 tons per acre with the 12 x 9 treatment. The CV% for this field study ranged from 2.7 to 14.0 %.

Significant differences occurred with the treatments in the Field 35 field study (Table 7), from the measurement of Recoverable Sucrose per Acre (RSA). The RSA data set summarizes the overall sucrose produced per acre by treatment and by field, as RSA takes into account root yield, percent sucrose, and percent LTM (Equation 2). In this field, the 12 x 9 and 9 x 9 treatments produced significantly higher RSA with 12,214 and 10,533 lbs RSA, respectively. The 12 x 9 treatment produced over 3,100 lbs RSA more than the 22-inch treatment in the study.

Table 7 – 2003 Narrow Row Sugarbeet Study – Field 35 – Harvest Data

2003 Narrow Row Study Field 35 Harvest Data (Oct 16, 2003)

Harvest Samples	% Sucrose	% LTM	Weight / Beet (lbs)	Root Yield (tons/acre)	RSA (lbs.)
11-inch & 9 x 9 inch in-row	19.7	1.30	1.2	28.7	10,533
11-inch & 12 x 9 inch in-row	19.4	1.35	1.8	33.9	12,214
11-inch & 12 x 6 inch in-row	19.4	1.25	1.3	27.2	9,874
22-inch & 6 inch in-row	18.6	1.50	1.9	26.5	9,063
LSD (0.05) CV %	NS 2.7	0.14 6.8	0.33 14.0	NS 13.9	2,044 12.7

LTM refers to loss to molasses
NS = No Significant Treatment Differences

Significant differences in percent sucrose, weight per beet, and percent LTM were identified in the Field 4 study (Table 8). The largest percent sucrose was identified in all three of the 11-inch treatments with largest percent sucrose, at 19.3 %, in the 12 x 6 treatment. The least percent sucrose treatment in the study was with the 22-inch treatment with 17.5% sucrose, 1.8% less than the 12 x 6 treatment. At 1.4 lbs per beet, the largest average weight per beet in Field 4 was from the 22-inch and the 9 x 9 treatments. The 6 x 6 and 12 x 6 treatments in Field 4 produced significantly smaller roots at 0.8 lbs per beet. With sugarbeet roots of only 0.8 lbs per beet, harvest ability of the physical root size is challenged as the smaller roots tend to fall through the harvester resulting in more harvest loss. Significantly lower % LTM was produced in the 6 x 6 and 12 x 6 treatments when compared to the other treatments in the study. Root yields were not significantly different in the Field 4 study (Table 8). Only 3.2 tons per acre separated the least yielding treatment (22-inch treatment at 20.0 tons per acre) from the largest yielding treatment (the 9 x 9 treatment at 23.2 tons per acre). The CV% for this field study ranged from 2.8 to 16.0.

The results from the Field 4 study for RSA (Table 8) identified no significant difference among the treatments. The least producing RSA treatment in the study, at 6,360 lbs RSA, was the 22-inch treatment. The largest RSA treatment was the 9 x 9 treatment at 7,830 lbs, so 1,470 lbs RSA separated the two extremes for this portion of the study.

Table 8 – 2003 Narrow Row Sugarbeet Study – Field 4 – Harvest Data

2003 Narrow Row Study Field 4
Harvest Data (Oct 16, 2003)

Harvest Samples	% Sucrose	% LTM	Weight / Beet (lbs)	Root Yield (tons/acre)	RSA (lbs.)
11-inch & 6 x 6 inch in-row	19.1	1.18	0.8	21.6	7,754
11-inch & 9 x 9 inch in-row	18.3	1.45	1.4	23.2	7,830
11-inch & 12 x 6 inch in-row	19.3	1.23	0.8	21.0	7,571
22-inch & 6 inch in-row	17.5	1.60	1.4	20.0	6,360
LSD (0.05) CV %	0.8 2.8	0.2 8.8	0.3 16.0	NS 11.8	NS 12.5

LTM refers to loss to molasses
NS = No Significant Treatment Differences

Observations of the 11-inch row spacing production as compared to the traditional 22-inch row-spacing follow:

- Each of the 11-inch row spacing treatments reached canopy closure approximately two weeks earlier than the 22-inch row treatment with no noticeable increase in Cercospora (*Cercospora beticola*) leaf spot presence comparing any of the 11-inch treatments to the 22-inch treatment.
- The 6 x 6 treatment tended to have longer leaf petioles and smaller leaves.
- Taproots were longer with the 6 x 6 treatments resulting in increased harvest losses (estimated at over two tons per acre) from the breakage of the long, thin roots.
- The higher stand counts in the 6 x 6 treatment produced significantly smaller roots in terms of weight per beet. Root weight in the 6 x 6 treatment was about half of the root weight in the 22-inch rows.
- Weed control was notably improved with the 11-inch row spacing in 2002. In 2002, with the higher plant populations, combined with a soil applied layby herbicide (Outlook®), and only one post-emergent (POST) herbicide application, weed control was excellent in all 11-inch fields. In 2003, weed control was more challenging as three and four POST applications were made with no layby Outlook® while utilizing a rotary hoe four to five times over the fields.

- Stand counts on each side of the tractor wheel tracks were less than in other rows, most likely as a result of compaction or row movement (the movement of the root due to the weight of the tractor on the tires physically pushing out or moving the soil and sugarbeet root from its original planting position.
- The 9 x 9 treatment appeared to produce the most sucrose (RSA) and the 12 x 9 treatment produced the largest root yield per acre among the treatments in the two field studies

YEAR TWO PROJECT – 2004

2004 - Materials and Methods

In 2004, the number of locations was doubled from two to four. Three commercial fields were arranged and sampled as in the 2003 study:

- Sullivan Township, section 4 of Polk County, Minnesota (Field 4).
- Keystone Township, section 17 (the east portion and west portion of the field) of Polk County, Minnesota (Field 17 East & Field 17 West)
- Tabor Township, section 31 of Polk County, Minnesota (Field 4)

Soil association in the study were:

- Sullivan 4 (Field 4) Bearden – Colvin Complex (Fine- silty, mixed, superactive, frigid Aeric Calciaquolls (NRCS, 1996) with the dominant soil order, Mollisol, and dominant suborder, Aquoll (Brady and Weil, 2002).
- Keystone 17 (Field 17) Colvin – Perella Complex (Fine- silty, mixed, superactive, frigid Typic Calciaquolls) (NRCS, 1996) with the dominant soil order, Mollisol, and dominant suborder, Aquoll (Brady and Weil, 2002).
- Tabor 31 (Field 31) Bearden – Colvin Complex (Fine- silty, mixed, superactive, frigid Aeric Calciaquolls (NRCS, 1996) with the dominant soil order, Mollisol, and dominant suborder, Aquoll (Brady and Weil, 2002).

One hand sample date was taken on August 17th in each of the four locations, per treatment, and per replicate. For the harvest samples, net weights from truckloads were used root yield determination. Three sub-samples per truck were taken for quality analysis. The plots were arranged in a complete-block design with six treatments and four replicates.

Satellite imagery was used to identify consistently uniform areas in the fields for the study sites. These images were taken in late August, 2004. The images utilized, demonstrated a fairly uniform sugarbeet canopy reflectance for commercial sugarbeet fields. Other pertinent field information for the 2004 study is presented in Table 9.

Table 9 – 2004 Narrow Row Sugarbeet Study Field Information

2004 Narrow Row Sugarbeet Study Field Information	Field 17 - East	Field 17 - West	Field 4	Field 31
Variety	Beta 3820	Crystal 822	Beta 6447	Beta 3820
Seed size	Pro 200	Reg. Pellet	Pro 200	Pro 200
Planting date	April 30, 2004	April 30, 2004	May 4, 2004	May 1, 2004
Soil test lbs. actual N (0 -2')	28	28	18	20
Soil test lbs actual N (0 - 4')	8	8	4	8
Soil test P (Olsen) ppm	12	12	8	11
Soil test K ppm	274	274	212	239
Fertilizer applied	94+48+0	94+48+0	108+62+0	102-51+0
Soil test pH	8.1	8.1	8.1	8.2
Starter fertilizer (10-34-0) gal/acre	3	3	3	3
Total N (available + applied)	130	130	130	130
Previous crop	Wheat	Wheat	Barley	Wheat
Years between sugarbeet	5	5	2	2
Insecticide	2.1 oz/acre Mustang Max®	2.1 oz/acre Mustang Max®	2.1 oz/acre Mustang Max®	2.1 oz/acre Mustang Max®
POST herbicide (Micro Rates)	3 X - Broadcast	3 X - Broadcast	3 X - Broadcast	3 X - Broadcast

Lay-by herbicide	None	None	None	None
Row cultivation	None	None	None	None
Rotary hoe	2 X	2 X	2 X	2 X
Fungicide (rate/acre & date)	Eminent ® 13 oz July 14	Eminent ® 13 oz July 14	Eminent ® 13 oz July 15	Gem ® 3.5 oz July 15
Fungicide (rate/acre & date)	Headline ® 9 oz July 28	Headline ® 9 oz July 28	Topsin ® /Super Tin® 1/2 lb & 3.75 oz Aug. 11	Eminent ® 13 oz July 29
Fungicide (rate/acre & date)	Super Tin ® 5 oz Aug. 30	Super Tin ® 5 oz Aug. 30	Eminent ® 13 oz Sep. 3	Headline ® 9 oz Aug. 31
Harvest date	October 11, 2004	October 11, 2004	October 21, 2004	October 14, 2004

From the 2003 narrow row project, the 12 x 9 and the 9 x 9 treatments performed well in the field studies. The treatment, modified 12 x 9, was added to the 2004 study. The two rows on each side of the tractor wheel tracks had four rows total per planter pass, rows four and five and rows eight and nine (Diagram 1) were seeded to 6 inch in-row spacing to increase the in-row final stand count (hence the name modified 12 x 9) as a result of reduced stand counts observed along the wheel tracks from the 2003 narrow row sugarbeet study. One other treatment, 12 x 12, was added to this years study. For the 12 x 12 treatment, sugarbeet was planted as 6 x 6 and later thinned at the 6-leaf stage to 12 x 12. The 6 x 6 treatment was included in the 2004 study as a baseline to compare where the project farm started in 2002. The 22-inch row spacing treatments were used as a traditional and widely-used treatment (Table 1) to compare the 11-inch treatments with. For Table 10, the data were analyzed using analysis of variance (ANOVA) using Microsoft Excel 2002 (10.6834.6830) SP3 and for Fisher's LSD and CV calculations (Clewer and Scarisbrick, 2001).

2004 – Results and Discussion

For the four locations, data was summarized to show the treatment yield trends found in Table 10. A notable trend to point out is with the 22-inch treatment where the 11-inch row spacing in each of the treatments generally produced higher sugarbeet root yields than the standard 22-inch row spacing. Not surprisingly, the 11-inch row spacing 6 x 6 treatments, yielded the least at 20.0 tons per acre.

The sucrose content of the roots exhibited only minor differences across treatments and was not significantly different (Table 10). Looking at the data generated for each of the treatments a bit closer, the differences are small when only about 0.3% sucrose content separates the lowest content treatment to the highest content treatment. The somewhat surprising treatment result was the least % sucrose content found in the 9 x 9 treatment.

From Table 10, no significantly different percent LTM was identified with the treatments in this quality metric. One observation was that all of the 11-inch treatments had lower percent LTM than the 22-inch treatment. Of the 11-inch treatments, the 12 x 9 modified had the lowest percent LTM.

The parameters of root yield, sucrose content, and loss to molasses were used to calculate Recoverable Sucrose per Acre (RSA) (Table 10). No significant RSA treatment differences were identified in this portion of the study. The 9 x 9 treatment stands out above the remaining treatments with 7,740 lbs RSA. The 22-inch row treatment lagged behind the 9 x 9 treatment by 360 lbs RSA. The 6 x 6 treatment yielded the least with about 700 lbs RSA less than the top treatment for RSA.

For the portion of the study relating to weight per beet (Table 10) the 6 x 6 treatment produced significantly smaller sugarbeet roots. This was to be expected, as the plant populations with sugarbeet planted in 11-inch rows with 6 inch in-row spacing resulted in a large number of roots per acre (nearly 75,000 per acre). These increased numbers of roots compete for nutrients, light, and water and are left with reduced overall root mass as was discovered on this farm in 2002 when sugarbeet was raised in the 6 x 6 arrangement. From Table 10, all treatments are significantly different than the 6 x 6 treatment. Also, another item to note with this portion of the study, the weight per beet analysis had a CV % of 20.3.

Table 10 - 2004 Narrow Row Sugarbeet Study, Harvest Data

2004 Narrow Row Average of 4 Locations
Harvest Data (Oct 11, 14, 21, 2004)

Harvest Samples	% Sucrose	% LTM	Weight / Beet (lbs)	Root Yield (tons/acre)	RSA (lbs.)
11-inch & 6 x 6 inch in-row	18.7	0.93	0.8	20.0	7,061
11-inch & 9 x 9 inch in-row	18.6	0.94	1.2	22.0	7,740
11-inch & 12 x 9 inch in-row	18.8	0.95	1.3	21.0	7,477
11-inch & 12 x 12 inch in-row	18.7	0.94	1.1	20.5	7,282
11-inch & 12 x 9 inch in-row (Modified)	18.9	0.91	1.1	20.5	7,340
22-inch & 6 inch in-row	18.9	0.95	1.3	20.6	7,380
LSD (0.05)	NS	NS	0.2	NS	NS
CV %	2.7	8.9	20.3	8.7	7.1

NS = No Significant Treatment Differences

YEAR THREE PROJECT – 2005

2005 - Materials and Methods

The 2005 project was confined to one field location where a study of nitrogen use could be observed and documented. One commercial field was set up and sampled for this study:
Northland Township, section 5 of Polk County, Minnesota (Field 5). Soil association was a Bearden – Colvin Complex (Fine- silty, mixed, superactive, frigid Aeric Calciaquolls (NRCS, 1996) with the dominant soil order, Mollisol, and dominant suborder, Aquoll (Brady and Weil, 2002).

Three nitrogen rates were used in the study with the 11-inch row spacing planted at 6 x 9 and thinned to a 12 x 9 row configuration. The 22-inch row spacing treatment, had 120 lbs total available (actual) nitrogen per acre. Total available nitrogen goals studied were 80, 100, and 120 lbs total available (actual) nitrogen per acre. For the treatments:

- The 22-inch 120 lb actual nitrogen per acre spacing study was observed on two separate areas of the field studied, with three replicates each.
- The 11-inch 80 lb actual nitrogen per acre spacing study was observed on two separate areas of the field, with three replicates each.
- The 11-inch 100 lb actual nitrogen per acre spacing study was observed on two separate areas of the field, with three replicates each.
- The 11-inch 120 lb actual nitrogen per acre spacing study was observed on four separate areas of the field, with three replicates each.

Hand samples were pulled from each study area of the field prior to mechanical harvesting of the sugarbeet roots. For the harvest samples, net weights from full truckloads were used root yield determination. Three sub-samples per truck were taken for quality analysis. The experiment was arranged in a complete-block design with four treatments and three replicates. The samples were tested for quality at the American Crystal Sugar Company Quality Lab in East Grand Forks, MN on October 17th, 2005. Pertinent information for the field study is included in Table 6. For Table 12, data were analyzed using analysis of variance (ANOVA) using Microsoft Excel 2002 (10.6834.6830) SP3 and for Fisher's LSD and CV calculations (Clewer and Scarisbrick, 2001).

Table 11 - 2005 Narrow Row Sugarbeet (Nitrogen Rate Study) Field Information

2005 Narrow Row Sugarbeet Nitrogen Rate Study Field Information	Field 5
Variety	Beta 4797
Seed size	Pro 200
Planting date	May 6, 2005
Soil test lbs. actual N (0-2')	Zone
Soil test lbs. actual N (0-4')	Zone
Soil test P (Olsen) ppm	Zone
Soil test K ppm	Zone
Soil test pH	8.1
Target nitrogen	130
Starter fertilizer (10-34-0) gal/acre	3
Total N (available + applied)	134
Previous crop	Wheat
Years between beets	2
Insecticide	2.1 oz/acre Mustang Max®
POST herbicide (MicroRates)	3 X - Broadcast
Lay-by herbicide	None
Row cultivation	None
Rotary hoe	2 X
Fungicide (rate/acre & date)	Headline ® 10 oz July 26
Fungicide (rate/acre & date)	Mancozeb ® 2 lb Aug. 17
Fungicide (rate/acre & date)	Eminent ® 13 oz Sep. 2
Harvest date	October 19, 2005

2005 Results and Discussion

The main goal of the 2005 study project was to maximize Recoverable Sucrose per Acre using the least amount of nitrogen within the parameters established for the traditional 22-inch row spaced sugarbeet production. The CV's in this study, particularly with root yield, RSA, and weight per beet (Table 12) were higher than the previous two years of the study. The field was subjected to water damage in mid season (about the third week of July), so the effects of water damage to the crop in the study are fairly evident as indicated in satellite images of the field studied, where the yellow zones in the field show lower reflectance (increased water damage) and the darkening green areas indicate higher reflectance (lower water damage). The water generally accumulated in the SW corner and west side of the field which caused damage to the field and contributed to a high percent CV for this field study.

Root yield per acre (Table 12), produced no significant treatment differences among the varying nitrogen rates in relation to root yield, however, 120 lbs of actual nitrogen per acre in the eleven-inch row configuration produced the highest root yield of 24.4 tons per acre. The lowest root yield of 22.1 tons per acre was with 120 lbs of actual nitrogen per acre in the 22-inch row spacing. All 11-inch row treatments yielded more root weight than the 22-inch row spacing regardless of nitrogen content. A CV % of 29 for root yield (Table 12) was higher than desired and definitely out of the range that is deemed acceptable for sugarbeet studies. Additional research is needed to explain this result, but perhaps nitrogen content below the sampled zone was not accounted for in the soil sampling process, soil type mapping, and satellite imagery. The water damage may have affected root uptake, denitrification, and leaching which may have also delayed nitrogen uptake.

The treatments produced no significant percent sucrose differences as shown on Table 12. The sucrose content from the results of the study indicate that utilizing the decreased 80 lbs actual nitrogen per acre seemed to negatively affect sucrose content, which is contrary to what is known of sugarbeet response to nitrogen. Increased levels of available nitrogen generally produce decreased root sucrose content than areas treated with less nitrogen. The highest observed sucrose content was 18.5% from the area treated with 100 lbs of actual nitrogen per acre in the 11-inch row spacing. This is a slight improvement over the 22-inch row spacing treatment with 120 lbs actual nitrogen per acre which had 18.3 % sucrose. The 11-inch row spacing had a higher stand count which enabled more sugarbeet plants to take up the available nitrogen versus fewer sugarbeet plants to take up available nitrogen in the 22-inch row spacing. The results are surprising in that the lowest nitrogen rate available produced the least sucrose content.

The treatment differences were not significantly different for percent LTM (Table 12); however, the nitrogen impact on sugarbeet root quality was as expected for percent LTM. LTM is directly proportional to decreasing nitrogen availability and increased plant population (22-inch row treatment versus 11-inch row spacing both at 120 lbs actual nitrogen per acre). The result from the 80 lbs actual nitrogen per acre rate treatment (Table 12) was unexpected. Plots with the least nitrogen should have had a lower percent LTM than other treatments. However, the reaction does follow the same trend or affect on quality as observed in sucrose content (Table 12), so percent LTM may have been affected by deep nitrogen not measured by the soil test. Sugarbeet tap-roots can develop effectively to six or even seven feet deep in the soil profile, so the sugarbeet roots may have utilized available nitrogen below the four foot sampling depth.

The treatment differences were not significant for the RSA portion of the study (Table 12). The analysis indicates, however, that 120 lbs of nitrogen available in the 22-inch row treatment produced the lowest RSA of any of the treatments at 7,686 lbs RSA (Table 12). The 11-inch row spacing with 120 lbs per acre actual nitrogen produced the highest sucrose per acre with 8,510 lbs. This is an increase of 824 lbs of sucrose per acre over the 22-inch row treatment and may demonstrate that the higher population utilized the available nitrogen more efficiently using the same rate of available nitrogen per acre in comparison to the 22-inch treatment. The higher populations also utilize solar radiation more efficiently, especially in the long days of June.

Weight per beet (lbs) was measured to determine the influence of narrow row spacing and nitrogen content on sugarbeet root size (Table 12). The results indicated that no significant differences were identified for weight per beet. The 22-inch row width treatment was expected to produce a larger root in comparison to those sugarbeet roots produced in 11-inch rows with an increased plant population, and did at 1.34 lbs per beet. With a CV % of 33.1, a substantial challenge would be to draw an accurate conclusion from the data. The water damage most likely played a negative role on this portion and the outcome of this portion of the study.

Table 12 – 2005 Narrow Row Sugarbeet (Nitrogen Rate Study) Harvest Data

2005 Narrow Row Nitrogen Study Average of 2 Locations Harvest Data (Oct 19, 2005)

Harvest Samples	% Sucrose	% LTM	Weight / Beet (lbs)	Root Yield (tons/acre)	RSA (lbs.)
11-inch & 12 x 9 inch in-row @ 80 Lbs N	18.1	1.1	1.18	23.6	8,059
11-inch & 12 x 9 inch in-row @ 100 Lbs N	18.5	1.06	1.12	22.9	8,031
11-inch & 12 x 9 inch in-row @ 120 Lbs N	18.5	1.08	1.26	24.4	8,510
22-inch & 6 inch in-row @ 120 Lbs N	18.3	1.12	1.34	22.1	7,686
LSD (0.05)	NS	NS	NS	NS	NS
CV %	3.7	6.7	33.1	29.0	30.7

NS = No Significant Treatment Differences

3-Year Overall Project Discussion

The results from the three-year narrow row sugarbeet project along with the prior year (2002) observations indicated that the adjustments made to the spacing and population configuration in this farm study aided in moving sucrose production upward. These adjustments included planting more seed on each side of the two wheel tracks throughout the sugarbeet fields in the study and by thinning alternating rows with the sugarbeet thinner to allow the sugarbeet more room to develop larger roots, reducing harvest losses. Over the period of four years (2002-2005) with approximately 650 acres per year, the Recoverable Sucrose per Acre (RSA) on this farm increased from an average of 4,889 lbs RSA in 2002 to an ending average of 6,063 lbs RSA in 2005 for a 124% increase and to a peak of 7,159 lbs RSA in 2003. The in-row spacing configurations proved successful in comparing production results from 2002 to 2003 and from 2003 to 2004. The 2005 research suffered from water damage to the fields in the study. The water damage occurred on all the cooperating growers' fields in 2005 reducing gains from improved production practices over the course of the study.

The 2003 study identified significant differences in total fresh weight production (leaves, petioles, and roots) between the varying 11-inch row spacing treatments in comparison to the 22-inch row spacing, in early to mid September. Earlier in the growing season, the third week of August produced no significant differences between the treatments or between fields in the study.

In comparing the percent sucrose content, percent LTM, RSA (lbs per acre), and weight per beet (lbs), significant differences were found throughout the course of the three-year study when comparing narrow row production with the 22-inch row spacings. These results were not consistent among fields in the study, however, within the fields studied. The only metric over the three-year study that was not significantly different in any of the studies comparing the 11-inch rows widths with the 22-inch row width treatments, was root yield (tons per acre). The root yields from the 11-inch treatments (with the exception of the 6 x 6 treatment) were favorable to observe in that production of sugarbeet in narrow rows (sub 22-inch row spacing) did not result in substantial decreases in production when compared to the 22-inch row spacings typically used in the Red River Valley of Minnesota and North Dakota. The 11-inch treatment that did appear to have a higher root yield potential, was the 12 x 9 treatment. The downside to the results of the studies, are that the quality parameters (% sucrose and % LTM) were not consistently different (improved) for the narrow row project as was the objective of the project. Increased plant populations (most notably in the 11-inch row spacings) tended to produce smaller root size or root weight per beet. In those same two years, of the study, the RSA was not significantly different, so one could conclude that root weight is not directly coupled to root yield as much as perceived in the past.

In each of the years of the study, the 11-inch narrow row sugarbeet treatments appeared to have no visual increase of Cercospora leaf spot infection, nor any earlier visual infection compared to the 22-inch treatment in each of the studies. These observations include the 2002 sugarbeet crop produced in the 11-inch (6 x 6) treatment across the entire farm where the estimated final plant population per acre was extremely high (an estimated 75,000 plus plants per acre).

Weed control was excellent with the higher populations in 2002 (the year prior to the study). Row closure was earlier (as much as two weeks) with the 11-inch row spacing in nearly all treatments. This observation reflected those found in the Idaho eleven-inch row study (Camp and Foote, 2003). One broadcast POST herbicide application was applied that year along with one layby broadcast application of Outlook® herbicide. Canopy cover eliminated the opportunity for weeds to progress as light interception or PAR (Photosynthetically Active Radiation) reaching weeds below the crop canopy was greatly reduced which allowed the sugarbeet to become a dominant monoculture. Weed competition with this high level of sugarbeet canopy and herbicide use was greatly reduced.

From the data presented in the results and discussion portion of the 2005 project, the results suggest no need for altering the nitrogen available for narrow row sugarbeet production. The recommended 120 lbs per acre of actual nitrogen seemed to suffice; however, water damage also played a role in reducing the accuracy and reliability of the results of the nitrogen rate study.

With the high stand counts achieved in the 6 x 6 treatment in the 11-inch row spacings in 2002, water ponding in the fields reduced the stands in 22-inch spaced rows more than those stand reductions found in the 6 x 6. Visual observations (data were not collected) indicated that the 6 x 6 treatment suffered as much percent stand loss of the total plants as the 22-inch rows; however, a more than optimum plant population was available to work with throughout the remaining growing season, so the end result was an unmeasured (no data collected) increase in root yield and RSA. High stand counts, to a point, serve as an "insurance policy" to minimize the impact of stand loss. Overall, stand establishment was more easily obtained using the 11-inch row spacing in combination with plant-to-thin stand establishment methods (planting thicker in rows and then using the beet thinner to achieve the desired treatment) in comparison to the traditional 22-inch row widths planted to stand with 6 inch in-row spacing.

As a further metric, Table 13 shows an economic comparison of the two 11-inch treatments in each of the fields tested in 2003. The highest RSA producing 11-inch row treatment in each field, 12 x 9 for Field 35 and 9 x 9 for Field 4, are listed along with the 22-inch row spacing with 6-inch in-row spacing treatment in each field. The 11-inch treatments were then averaged together and compared to the average of the 22-inch row treatments. The economic advantage in these two fields studied was with the 11-inch row treatment for a $360 (gross) per acre. The 2003 harvest data was utilized in the economic calculations as the 2003 harvest samples were hand-pulled, so harvest (root) losses were nearly zero. These economic calculations in Table 13 represent the best-case scenario of the 11-inch study because of very limited or no harvest loss (roots). In the 2004 and 2005 studies (Tables 10 and 12), the harvest samples were hand-sampled for quality and mechanically harvested for yield. The yield data in the 2004 and 2005 studies were more commercially correct in that the sugarbeet harvester gleaned small root harvest losses for a more realistic root yield.

Table 13 – Narrow Row Sugarbeet Study – Economic Comparison

Economic Comparison: 2003 Narrow Row Project Trials

Field	Treatment	Rec. Sugar / Acre (lbs.)	Gross $$ / Acre
35	11 - inch 12 x 9	12,214	$1,711 **
4	11 – inch 9 x 9	7,830	$1,043 **
	Average	**10,022**	**$1,377 ** **
35	22 – inch with 6-inch in-row	9,063	$1,222 **
4	22 – inch with 6-inch in-row	6,360	$812 **
	Average	**7,712**	**$1,017 ** **
	11- inch Row Advantage	**2,310**	**$360 ** **

** ACS 2003 Crop Year Payment

In Table 14, additional inputs of narrow row sugarbeet production are considered. Comparing the highest RSA producing 11-inch row treatment in each field, 12 x 9 for Field 35 and 9 x 9 for Field 4, input costs that would be incurred as additional to 22-inch row sugarbeet production, are listed. Seed costs were an additional average of $15 per acre. The in-row spacing for the 12 x 9 and 9 x 9 11-inch treatments were spread out when compared to an 11-inch 6 x 6 treatment where the seed costs would simply double for about a $50 per acre seed cost increase. Herbicide costs would be essentially doubled as band-spraying of the herbicides was not an option, so each herbicide application was applied broadcast. With an increase of treated rows per acre in the 11-inch rows, an increase in insecticide costs was realized as was an additional amount of starter fertilizer. Since 11-row cultivators were not an option to use, rotary hoeing was substituted for row-cultivation for the 11-inch row sugarbeet production. The producer rotary hoed more often with the 11-inch rows for weed control, so the amount of dollars that would have been spent for row cultivation as compared to rotary hoeing was essentially nullified. The sugarbeet harvester design utilized in the project being 7 (11-inch) rows wide was an actual width of about a 4-row (22-inch) sugarbeet harvester. Harvesting just over 600 acres of sugarbeets with essentially a 4-row (22-inch) harvester was not very efficient. For the 2005 production year, the producer assembled a second sugarbeet harvester to improve harvesting efficiency, which increased his farm per acre harvest cost. Utilizing a great deal of ingenuity and thought, the producer kept his machinery costs to a minimum and was able to accomplish the harvest process with little additional machinery investment. The producer found that commercial 11-inch European sugarbeet planters are available. However, 11-inch row sugarbeet harvesters are very rare if not, non-existent, so purchasing new harvesting equipment would not be an option. This then leads to an equipment redesign cost that would need to be considered for 11-inch row sugarbeet production. Overall, the net economic effect is that the 11-inch rows did not substantially produce more RSA (tons and sucrose) per acre to effectively offset the additional economic inputs of the narrow row production practice.

Table 14 – Narrow Row Sugarbeet Study – Extra Input Costs to consider

Narrow Row Extra Input Costs to Consider

Seed Cost/A (12 x 9 and 9 x 9 avg.)	**$15**
Herbicide Cost/A	**$45**
Insecticide Cost/A	**$6**
Starter Fertilizer	**$5**
Cultivation & Rotary Hoe (off-setting)	**$ --**
Harvesting Cost/A	**$100 +**
Equipment Cost/A:	
- Additional Harvester	**$??**
- Additional Planter	**$??**
- Equipment Redesign Costs	**$??**

At this point, the main challenge of raising sugarbeet in narrow rows (sub 22-inch row spacing) remains with the harvesting of the sugarbeet roots. This project and the ingenuity of the shareholder demonstrated that sugarbeet can indeed be produced in narrow rows and can be done successfully. The harvesting portion of the production cycle becomes the bottleneck in the efficiency of harvesting the sugarbeet roots with the harvester design as used in this study.

Recommended areas to explore for enhancing production of narrow row sugarbeet production might be:

1. To incorporate recent high yielding sugarbeet varieties, preferably in the diploid genetics. Those varieties were not utilized in the study and they could conceivably increase overall sucrose production with significant improvements.
2. For sugarbeet harvesting, continued work in refining the efficiency of harvest will also need to be revisited as to keep in pace with the fast-paced harvest and for the financial efficiency of running equipment that essentially slows the harvest process.
3. To explore the production of sugarbeet utilizing the now industry approved genetically engineered sugarbeet, particularly the RoundUp Ready®, for the potential elimination (or reduction) of row crop cultivation which can also reduce the spread and incidence of sugarbeet root diseases.
4. From observations made from weed control in 2002 with this project particularly with the extremely high plant populations, narrow row sugarbeet production could provide a role in resistance management in the herbicide arena. Concerns of overuse of glyphosate herbicides echo throughout the agricultural community. Seed costs and technology fees associated with the genetically engineered sugarbeet could be offset with high yielding conventional diploid sugarbeet varieties planted at higher populations. These population targets could be set high (probably not quite as high as the 75,000 plants per acre range as was achieved in the 6 x 6 treatment), but to levels where weed competition was reduced. Root to Leaf Ratios ranged from about 2:1 just three years ago (or at about the start of this project) compared to the 5:1 root to leaf ratio that are available with the current high-yielding diploid Rhizomania resistant varieties. Recently grown sugarbeet varieties produce less canopy (leaves and petioles), so the competitive edge for weeds may increase with this reduced (5:1 root to leaf ratio) canopy architecture.
5. Since the CV's were higher than desired in the 2005 narrow row sugarbeet nitrogen study as a result of water damage to the study area, and because nitrogen plays such a large role in sucrose production, it would be prudent to perform a more accurate study of the nitrogen requirements that maximize sucrose production produced in these narrow rows.

A version of the Narrow Row Sugarbeet project report with photos, is available upon request

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