

# LIQUID SEPARATED DAIRY MANURE AS A NUTRIENT SOURCE IN A SUGARBEET ROTATION

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## **Justification for Research:**

Using manure as a nutrient source can be more complicated than using commercial fertilizers since the nitrogen (N) and phosphorus (P) content can vary depending on species, storage and treatment methods, and application techniques. Farmers, particularly those that grow sugarbeets, are also concerned about when the nutrients are released in the growing season which changes depending on soil types and weather. Despite concerns, there are other benefits of manure beyond being a source of N and P, including improving soil health and providing micronutrients. Plus, the up and down price swings of the commercial fertilizer market make manure more attractive, especially if a farmer has a consistent supply which can offset fertilizer costs.

As large dairies are moving into western Minnesota, a consistent supply of manure is no longer a problem. However, these dairies are using a new technology to separate solids from liquids in the manure, and the impact on nutrient availability in this region's climate and soil types is unknown. Understanding this is particularly important for sugarbeet growers due to the effect that late season N availability in the soil has on the sugar content of their crop. Where in the rotation should this manure be applied to maximize the beneficial properties while minimizing risk of low sugar content due to excess nitrogen? Our goal is to answer this question so that farmers are able to make better decisions about using dairy liquid separated manure in their rotation to reduce fertilizer costs.

## **Summary of Literature Review:**

Little recent information is available on the effect of manure on sugarbeet root yield and quality. Halvorson and Hartman (1974) reported that sucrose concentration and recoverable sugar per acre were reduced with the addition of beef manure while root yield was increased. Schmitt et al. (1996) reported that swine manure mineralization occurs several years after application in a legume-corn rotation. Swine manure was found to be 80 to 90% available in the first year of application for corn production.

Since that time, the most activity for manure application in sugarbeet production systems has been conducted in the Southern Minnesota Beet Sugar Cooperative (SMBSC) growing area although it is expanding to other sugarbeet growing regions as well. Three major research projects have been conducted in the SMBSC growing area since 1999 and are summarized below.

Project 1. Lamb et al. 2002, Manure application on sugarbeet 1999-2001: The objectives of the first research project were to: 1) measure turkey and swine manure application effects on sugarbeet root yield and quality compared to fertilizer N applications; 2) determine the effect of manure mineralization differences on sugarbeet root yield and quality; and 3) develop management strategies for manure application in a sugarbeet rotation. The results from the three sites of this study indicated that the use of manure on a field with no prior manure application may not be as detrimental to sugarbeet quality as originally thought. However, the effect of manure application to sugarbeet root yield and quality on fields with a history of manure applications was not answered with this study. If manure was applied at reasonable rates equivalent to the N fertilizer recommendation, it did not negatively affect sugarbeet recoverable sucrose per acre on fields with no manure application history. Excessive application rates of manure will reduce quality.

Soil nitrate-N values during the growing season indicate that while the sugarbeet plant is actively growing, it will utilize most of the nitrate-N mineralized into the soil from manure. This utilization is greater than corn or soybean. A soil test for nitrate-N taken in the later stages of corn or soybean growth will reflect excess nitrate-N mineralized from manure. A nitrate-N soil test taken at later stages of the growing season will not reflect excess soil nitrate-N during sugarbeet production.

Results from 1999 indicated that sugarbeet top N concentration and N uptake at harvest reflect the N additions from both fertilizer and manure. This did not occur in the 2000 growing season. A long period of drought

conditions during August and September in which the sugarbeet plant was under moisture stress affected the plant uptake of soil nitrate-N.

Project 2. Lamb et al. 2013, Turkey litter use in a sugarbeet crop rotation 2007-2012: Turkey manure has a considerable amount of litter from bedding in it, thus slowing initial release of poultry manure-N. The implication of the manure-N release is critical, especially to sugarbeet growers. This research project was designed to: 1) determine when in a three-year rotation should turkey litter be applied and 2) determine nitrogen fertilizer equivalent of turkey litter applied two and three years in advance of sugarbeet production in the rotation.

With three sites worth of information, it was concluded that if a grower must apply turkey litter in the sugarbeet production system, it should be applied in the fall before sugarbeets. This conclusion is not what the current recommendation is. Caution about the use of any kind of manure in rotation should be used. In this study, the manure application rates were not excessive. Excessive applications could cause problems with quality. Applications made more than once during a three-year rotation should be avoided for the same reason. Too much of a good thing (turkey litter) can cause problems with management of the residual soil nitrates in the soil system.

Project 3: Lamb et al. 2016, Liquid swine manure in a sugarbeet production rotation 2010-2015: This research project was designed to: 1) determine when in a three-year rotation should swine manure be applied; 2) determine nitrogen fertilizer equivalent of swine manure applied one, two, and three years in advance of sugarbeet production; and 3) determine the effect of over-fertilization with N on the quality, root yield, and summer petiole nitrate-N. The results from this study can be summarized in the following two areas:

- I. The effect of timing of manure application in the soybean, corn, sugarbeet rotation.
  1. Manure application significantly affected 2 of the 3 sites.
  2. At the 2 sites, manure application increased root yield and extractable sucrose per acre. The closer to sugarbeet production the application is made, the greater the root yield and extractable sucrose per acre response.
  3. The application of swine manure in the fall before sugarbeet production significantly decreased sugarbeet sucrose concentration and extractable sucrose per ton. Depending on the quality payment system, this reduction can be economically significant.
- II. The effect of manure application timing in the rotation and the application of N fertilizer before sugarbeet production.
  1. No interaction occurred between N fertilizer application and manure management for any yield or quality variable measured at 2 of the 3 sites.
  2. N fertilizer rate increased root yield and extractable sucrose per acre at 2 of the 3 sites.
  3. Manure management affected root yield and extractable sucrose per acre at 1 site. The closer you apply manure to sugarbeet production, the greater the yield. There was no effect at 2 sites.
  4. N fertilizer application decreased extractable sucrose per ton at 2 of the 3 sites. This could affect the payment.

For both turkey and swine manure, application rates near the recommended amount of N for sugarbeet production resulted in an increase in root yield and extractable sucrose per acre. This application also reduced quality parameters such as sucrose concentration and extractable sucrose per ton. The application should be made the fall before sugarbeet production in the crop rotation. Unless the sugar payment is heavily quality-based, then increases in root yield and extractable sucrose per acre will make up for the decreases in quality. More information is needed regarding dairy manure applications, particularly liquid-separated dairy manure, as this is becoming more readily available in some sugarbeet production areas.

### **Objectives:**

The objective of this study is to evaluate the timing and rate of dairy liquid separated manure in a sugarbeet-soybean-corn rotation on crop yields and sugarbeet quality.

## Materials and Methods:

This is a 3-year field study at two locations - near Murdock, MN and Nashua, MN - in collaboration with the Southern Minnesota Beet Sugar Cooperative and Minn-Dak Farmers Cooperative. The goal was to see what part of a three-year rotation is best for dairy liquid-separated manure application. This study utilized a split plot experimental design with four replications. The main plots represent a crop rotation common to each sugarbeet growing region. Each treatment in the main plots started with a different crop in the rotation in Year 1 (see table 1). This allowed each crop to be planted in each year. Manure was only applied in the subplots during the first year of this study as this allowed for observation of where manure application had the greatest benefit within the crop rotation (before corn, sugarbeet, or soybean). After the first year, we continued to monitor the impact of that one application throughout the rest of the rotation. All crops were planted on 22-inch rows.

Table 1. Main plot treatments.

Treatment	Year 1	Year 2	Year 3
1	Corn	Sugarbeet	Soybean
2	Soybean	Corn	Sugarbeet
3	Sugarbeet	Soybean	Corn

Various manure application rates acted as treatments for the subplots (see table 2). The treatments were comprised of a high application rate (about 14,400 and 15,400 gallons per acre at the Murdock and Nashua sites, respectively), a low application rate (about 9,500 and 10,300 gallons per acre at the Murdock and Nashua sites, respectively), or no manure applied. The ‘high’ and ‘low’ rates were chosen based upon the rates typically offered by the large dairies specific to each region. Where manure was not applied in the first year, the crops were fertilized with commercial nutrients according to the state University guidelines. In years 2 and 3, state University fertility guidelines were utilized to apply commercial fertilizers to all plots, taking into account any residual fertility credits from the initial manure application.

Table 2. Subplot treatments.

Treatment	Year 1	Year 2	Year 3
a	Fertilizers	Fertilizers	Fertilizers
b	Manure low rate (fertilizers if needed to balance crop nutrient needs)	Fertilizers w/ second year manure N credit	Fertilizers w/ third year manure N credit
c	Manure high rate (fertilizers if needed to balance crop nutrient needs)	Fertilizers w/ second year manure N credit	Fertilizers w/third year manure N credit

Each experimental crop was taken to harvest and evaluated for yield, quality, and any other appropriate crop-specific quality parameters. Plot-specific 0-6 inch soil samples were collected prior to planting in each experimental year and subjected to routine soil analyses. Nitrate analysis on 0-2 foot and 0-4 foot soil samples was conducted on plots that were planted to sugarbeets at Nashua and Murdock, respectively. Soil samples (1-ft depth) were collected two times throughout each growing season to monitor potential changes in the levels of both nitrate and ammonium.

## Preliminary Results:

Year 1 following manure application - This experiment began in the fall of 2019 at a farm site near Murdock, MN and in fall 2020 at a farm site near Nashua, MN. Both sites followed a corn crop. Manure was surface applied and incorporated within 24 hours of application. Fertilizers were applied as appropriate in the spring prior to planting crops. Initial soil samples and manure samples were collected and analyzed (Table 3). At the Murdock site, corn (Enesvedt E-696RR), soybean (Stine Liberty Link GT27), and sugarbeet (SESVDH 863) were planted on April 30

to May 1, 2020 and maintained according to typical practices in the region. At the Nashua site, corn (Dekalb DKC49-44RIB), soybean (Dekalb AG10XF1), and sugarbeet (ACH 973) were planted on May 3, 2021.

Table 3. Soil and manure test results for Murdock site in fall 2019 and Nashua site in fall 2020.

Initial soil test results		Manure characteristics		Manure as-applied (lb/acre)†		
		Nutrient	(lb/1000 gal)	Nutrient	High rate	Low rate
<b>Murdock site – Fall 2019</b>						
pH	8.0	Total N	16-22	Total N	321	155
Nitrate – 0-24” (lb/ac)	40	Ammonium-N	12-13.5	First year N‡	177	85
Olsen P (ppm)	7	Total P <sub>2</sub> O <sub>5</sub>	6-13	Total P <sub>2</sub> O <sub>5</sub>	196	62
K (ppm)	190	Total K <sub>2</sub> O	20-21	Total K <sub>2</sub> O	300	187
<b>Nashua site – Fall 2020</b>						
pH	7.3	Total N	25	Total N	380	260
Nitrate – 0-24” (lb/ac)	16.5	Ammonium-N	13.1	First year N‡	209	143
Bray P (ppm)	53	Total P <sub>2</sub> O <sub>5</sub>	14	Total P <sub>2</sub> O <sub>5</sub>	219	145
K (ppm)	194	Total K <sub>2</sub> O	21	Total K <sub>2</sub> O	321	212

†Note that the high and low manure rates were balanced with spring-applied fertilizers to meet crop nutrient needs as appropriate. ‡First year availability was assumed to be 55% of total N.

Plant and soil samples were collected during the growing season to better understand nutrient cycling between the different nutrient source. We collected soil samples (0-1 ft) twice during the growing season for nitrate analysis. Early in the growing season at the Murdock site we noted some issues with the soybean in the manured plots; growth was stunted and the plants were yellow, indicative of iron chlorosis deficiency. We collected trifoliolate tissue samples to see if nitrate and/or chloride levels were elevated in the plants. This problem did not occur at Nashua. When corn reached maturity (around the R6 growth stage) we collected plant samples (stalk, cob, and grain) to evaluate nitrogen uptake. Post-harvest soil samples were also collected from each plot. These samples have not been fully analyzed yet and the results will be discussed in a later report.

At the Murdock site, sugarbeets were harvested on September 30, 2020. There were no significant differences between treatments on yield or extractable sucrose (per ton or per acre). The fertilized plots tended to result in lower overall yield but higher sucrose per ton than the manured plots. Sucrose purity was significantly affected by treatments, with fertilizer having a higher percent purity than the high dairy manure application rate, though the low manure application rate was not significantly different than the fertilizer or high manure rate (Table 4). Soybeans were harvested on October 2, 2020, with few plants in the manured plots (Figure 1). As expected, based on what we saw earlier in the growing season, soybean yield was significantly reduced by manure application in this field. Corn was harvested on November 4, 2020. Both treatments with manure tended to have higher yield than the fertilizer only plot (Figure 1), but differences were not significant.

Table 4. Yield, extractable sucrose (per ton and per acre), and sucrose percent purity at both sites the first year after manure application.

Nutrient Source	Yield (tons/acre)	Extractable Sucrose (lb/ton)	Extractable Sucrose (lb/acre)	Sucrose Purity (%)
<b>Murdock site – 2020 growing season</b>				
Fertilizer only	32.7a†	297a	9,710a	91.2a
Low dairy manure rate	35.8a	286a	10,266a	90.85ab
High dairy manure rate	35.6a	292a	10,380a	90.78b
<b>Nashua site – 2021 growing season</b>				
Fertilizer only	39.5a	282a	11,195a	91.2a
Low dairy manure rate	38.0a	283a	10,756a	91.8a
High dairy manure rate	41.4a	271a	11,282a	90.8a

†Similar letters within a row and research site indicate no significant differences between the values ( $p > 0.05$ ).

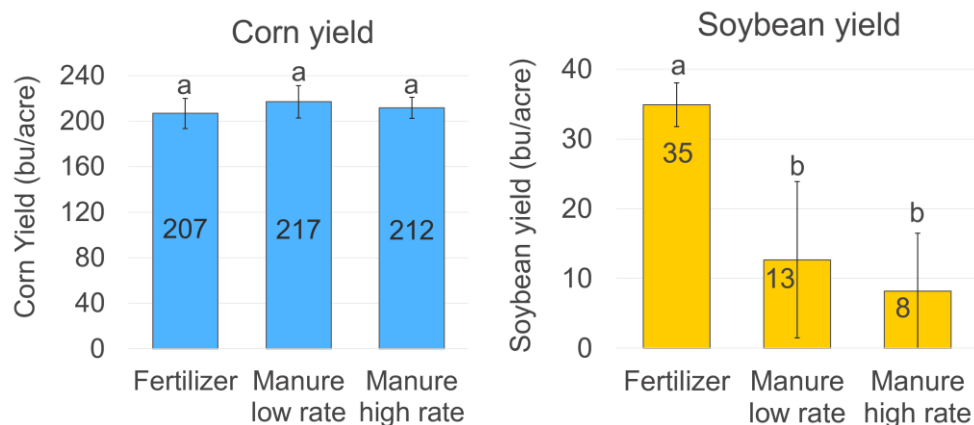


Figure 1. Corn (adjusted to 15.5% moisture) and soybean (adjusted to 13% moisture) yield at Murdock site in 2020. Manure was fall applied at 14,400 gallons per acre (high rate) or 9,500 gallons per acre (low rate) and fertilizer was spring applied. Different letters above a bar within a graph indicate a significant difference ( $p < 0.05$ ).

At the Nashua site, sugarbeets were harvested on September 26, 2021. As with the Murdock site, there were no significant differences between treatments on yield or extractable sucrose (per ton or per acre). One difference between sites is that sucrose purity was not affected by treatments at Nashua (Table 5). Soybeans were harvested on November 4, 2021 and manured plots tended to have higher yield than the fertilizer only plots, though differences were not significant (Figure 2). Corn was harvested on October 18, 2021. The low manure rate tended to have lower yield than the fertilizer only and high manure rate plots (Figure 2), but differences were not significant.

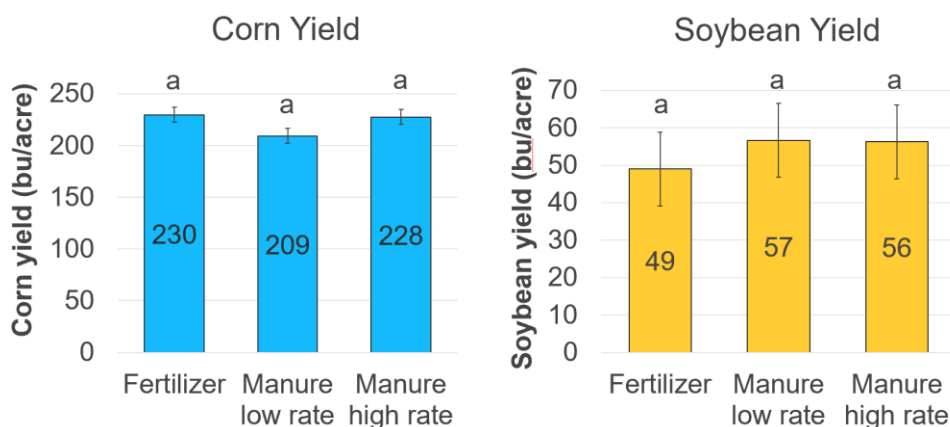


Figure 2. Corn (adjusted to 15.5% moisture) and soybean (adjusted to 13% moisture) yield at the Nashua site in 2021. Manure was fall applied at 15,400 gallons per acre (high rate) or 10,300 gallons per acre (low rate) and fertilizer was spring applied. Different letters above a bar within a graph indicate a significant difference ( $p < 0.05$ ).

Year 2 following manure application – We calculated the second-year nitrogen credit from the manure assuming 25% of the total nitrogen applied was available and then subtracted it from the fertilizer recommendations for each crop. There was a 39 and 80 lb/acre nitrogen credit for the low and high rate manure plots, respectively. Initial soil samples from the top six and 24 inches of soil (Table 5) indicated that there were differences in nutrient content across treatments. Soil nitrate levels in the top 24 inches of soil tended to be lowest in plots that were previously sugarbeet and were consistent across treatments. Soil nitrate increased with increasing manure application rate in the plots where soybean was the previous crop, while the opposite happened in the plots where corn was the previous

crop. Soil test phosphorus levels varied, though ranged from medium to high levels. Soil test potassium levels were all high or very high and tended to increase with increased manure application rate. Fertilizer rates were adjusted accordingly for each crop and nutrient treatment. At the Murdock site, corn (Enesvedt E-696RR), soybean (Stine Liberty Link GT27), and sugarbeet (Beta 9952) were planted on May 1, 2021 and maintained according to typical practices in the region. This year, Soygreen® was applied to the soybean plots to potentially reduce issues with iron-deficiency chlorosis. Similar soil and plant samples were collected in the second year as in the first year, though samples are still currently being analyzed.

Table 5. Soil test results for the Murdock site in fall 2020. All samples were taken in the top six inches of soil except the nitrate samples which were the top 24 inches of soil.

<b>Murdock site – Fall 2020</b>			
<b>Initial soil test results</b>	<b>Nitrate 0-24" (lb/ac)</b>	<b>Olsen P (ppm)</b>	<b>K (ppm)</b>
Previous crop sugarbeet (going into soybean)			
Fertilizer-only	37	10	157
Low-rate manure	33	9	178
High-rate manure	37	12	243
Previous crop soybean (going into corn)			
Fertilizer-only	29	10	155
Low-rate manure	143	12	201
High-rate manure	222	15	247
Previous crop corn (going into sugarbeet)			
Fertilizer-only	100	12	157
Low-rate manure	55	12	178
High-rate manure	38	10	229

At the Murdock site, sugarbeets were harvested on October 12, 2021. There were no significant differences between treatments on yield, extractable sucrose (per ton or per acre), or sucrose purity (Table 6). Soybeans were harvested on October 8, 2021 (Figure 3). Soybeans were not as affected by iron deficiency chlorosis this year, though random spots in the field were hit. The only exception was one low-rate manure plot (of four total) that was consistently looked poor across the growing season. The high-rate manure plots yielded similarly to the fertilizer only plots. Corn was harvested on October 25, 2021 by hand because the corn had lodged during a recent windstorm. Both treatments with manure tended to have higher yield than the fertilizer only plot (Figure 3), but the difference was only significant for the high-rate manure plots.

Table 6. Yield, extractable sucrose (per ton and per acre), and sucrose percent purity at the Murdock site the second year after manure application.

<b>Nutrient Source</b>	<b>Yield (tons/acre)</b>	<b>Extractable Sucrose (lb/ton)</b>	<b>Extractable Sucrose (lb/acre)</b>	<b>Sucrose Purity (%)</b>
<b>Murdock site – 2021 growing season</b>				
Fertilizer only	40.0a†	272a	10,846a	92.2a
Low dairy manure rate	40.0a	270a	10,844a	91.4a
High dairy manure rate	40.7a	271a	11,051a	91.7a

†Similar letters within a row indicate no significant differences between the values ( $p > 0.05$ ).

The trials at both research sites will continue into 2022. It will be the last year of the study for the Murdock site (third year after manure application) and the second year for the Nashua site. As before, manure nitrogen credits and soil tests will be used to adjust fertilizer rates as needed.

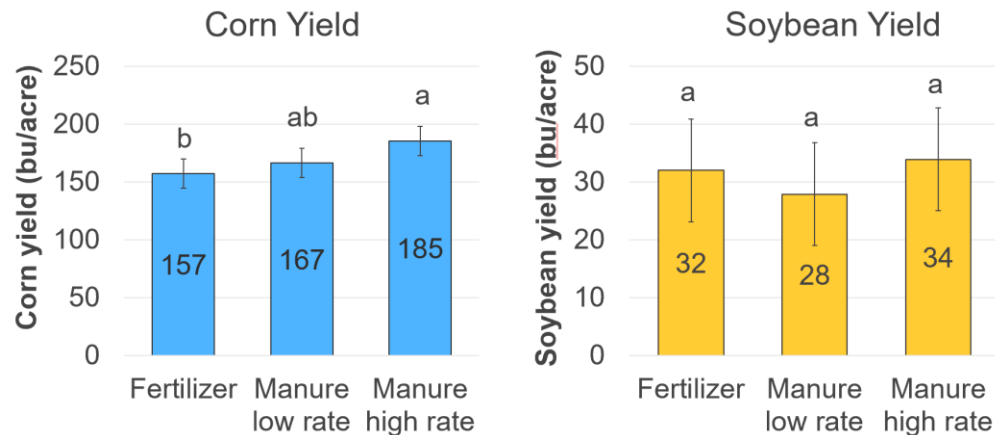


Figure 3. Corn (adjusted to 15.5% moisture) and soybean (adjusted to 13% moisture) yield at the Murdock site in 2021. Manure was fall applied two years ago at 15,400 gallons per acre (high rate) or 10,300 gallons per acre (low rate) and fertilizer was spring applied. In this second year, only fertilizer was applied but a nitrogen credit was taken for the manure. Soil tests for each treatment were used to adjust phosphorus and potassium application rates, as well. Different letters above a bar within a graph indicate a significant difference ( $p < 0.05$ ).

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