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
Murdock site – Fall 2019						
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_2O_5	6-13	Total P_2O_5	196	62
K (ppm)	190	Total K_2O	20-21	Total K_2O	300	187
Nashua site – Fall 2020						
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_2O_5	14	Total P_2O_5	219	145
K (ppm)	194	Total K_2O	21	Total K_2O	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 trifoliate 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.

Sugarbeets were harvested on September 30, 2020 at Murdock and on September 26, 2021 at Nashua. There were no significant differences between nutrient source treatments on yield or quality measurements when averaged over both sites (Table 4). There was a significant difference between sites for root yield (Nashua had higher root yield than Murdock) but not for quality measurements. Soybeans were harvested on October 2, 2020 at Murdock and November 4, 2021 in Nashua. There was a significant nutrient source treatment by site interaction. For the Murdock site, there were few plants that survived 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. At Nashua, however, manured plots tended to have higher yield than the fertilizer-only plots, though differences were not significant (Figure 1). Corn was harvested on November 4, 2020 at the Murdock site and October 18, 2021 at Nashua. Both treatments with manure tended to have higher yield than the fertilizer only plot (Figure 2), but differences were not significant. There were no differences between sites.

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

Main effect	Yield (tons/acre)	Extractable Sucrose (lb/ton)	Extractable Sucrose (lb/acre)	Sucrose Purity (%)
Nutrient Source				
Fertilizer only	36.1a†	290a	10,452a	91.2a
Low dairy manure rate	36.9a	285a	10,511a	91.3a
High dairy manure rate	38.5a	282a	10,831a	90.8a

Site				
Murdock	34.7b	292a	10,118a	90.9a
Nashua	39.7a	279a	11,078a	91.2a

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

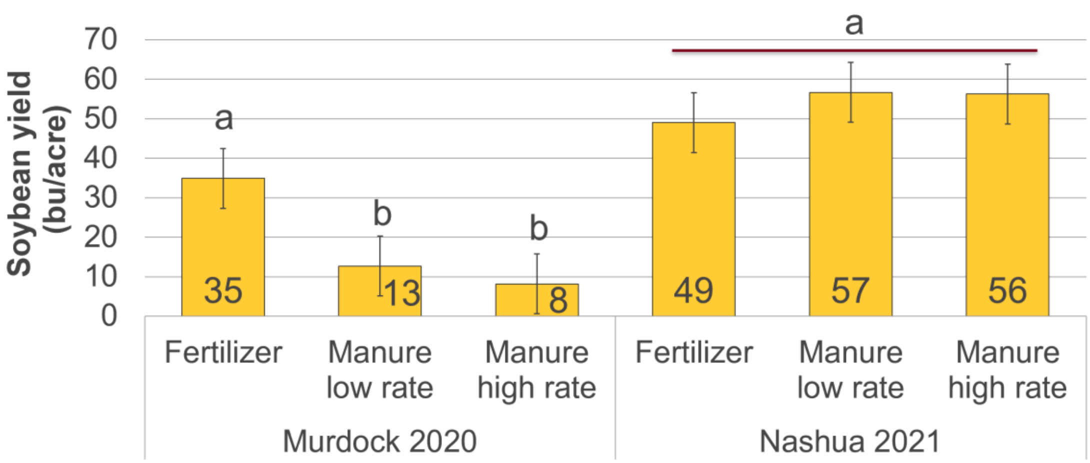

Figure 1. Soybean yield (adjusted to 13% moisture) at Murdock site in 2020 and Nashua site in 2021. There was a significant site by nutrient source interaction. Different letters above a bar indicates a significant difference (p <0 .05).

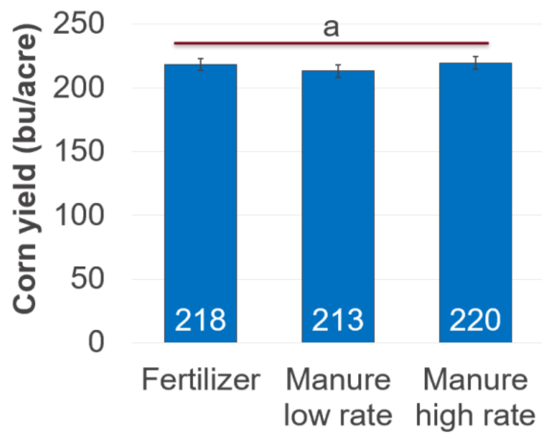

Figure 2. Corn yield (adjusted to 15.5% moisture) averaged over sites (Murdock in 2020 and Nashua in 2021). Different letters above a bar indicates a significant difference ($p < 0.05$).

Post-harvest soil samples from the top six and 24 inches of soil (Table 5) indicated that there were differences in residual nutrient content across treatments. Soil nitrate levels in the top 24 inches of soil tended to be lowest in plots that were previously in 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. This was interesting since these trends were consistent across sites and in two different years. Soil test phosphorus levels varied and ranged from medium to high levels. They tended to be higher at Nashua than at Murdock. 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.

Table 5. Soil test results for the Murdock site in fall 2020 and the Nashua site in fall 2021. All samples were taken in the top six inches of soil except the nitrate samples which were the top 24 inches of soil.

	Murdock site – Fall 2020			**Nashua site – Fall 2021**		
Initial soil test results	**Nitrate 0-24" (lb/ac)**	**Olsen P (ppm)**	**K (ppm)**	**Nitrate 0-24" (lb/ac)**	**Olsen P (ppm)**	**K (ppm)**
Previous crop sugarbeet (going into soybean)						
Fertilizer-only	37	10	157	15	16	216
Low-rate manure	33	9	178	14	26	233
High-rate manure	37	12	243	15	34	264
Previous crop soybean (going into corn)						
Fertilizer-only	29	10	155	31	17	206
Low-rate manure	143	12	201	44	29	240
High-rate manure	222	15	247	58	31	240
Previous crop corn (going into sugarbeet)						
Fertilizer-only	100	12	157	29	16	289
Low-rate manure	55	12	178	22	27	245
High-rate manure	38	10	229	19	29	280

Year 2 following manure application – The second growing season after manure was applied occurred in 2021 at the Murdock site and in 2022 at the Nashua site. 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. At Murdock, there was a 39 and 80 pounds of nitrogen per acre credit for the low and high rate manure plots, respectively. At Nashua, the nitrogen credit was 65 and 95 pounds of nitrogen per acre from the low and high manure rates, respectively. Fertilizer rates were adjusted accordingly for each crop and nutrient treatment based on these credits as well as the soil tests taken the previous fall. At the Murdock site, corn (Enesvedt E-696RR), soybean (Stine Liberty Link GT27), and sugarbeet (Beta 9952) were planted on May 1, 2021. This year, Soygreen® was applied to the soybean plots to potentially reduce issues with iron-deficiency chlorosis. At the Nashua site, corn (Dekalb DKC49-44RIB), soybean (Dekalb AG10XF1), and sugarbeet (ACH 973) were planted on May 25, 2022. All crops were maintained according to typical practices in the region. Similar soil and plant samples were collected in the second year as in the first year, though samples are still currently being analyzed.

Sugarbeets were harvested on October 12, 2021 at Murdock and October 3, 2022 at Nashua. Averaged over sites, root yield and extractable sucrose (lb/acre) was significantly highest in plots where the high rate of manure was applied in the rotation (Table 6). The low dairy manure rate and fertilizer only-plots yielded similarly. There were no differences across nutrient source treatments for extractable sucrose (lb/ton) and sucrose purity. There were also differences in sites with Murdock having higher root yield and sucrose purity while Nashua had higher extractable sucrose. Soybeans were harvested on October 8, 2021 at Murdock and September 29, 2022 at Nashua (Figure 3). Yield was not affected by nutrient source treatments nor did it differ by site. Corn was harvested on October 25, 2021 by hand at the Murdock site because the corn had lodged during a windstorm near harvest. At Nashua, corn was harvested October 7, 2022. There was a significant yield difference between sites, with Murdock yielding 197 bushels per acre while Nashua yielded 101 bushels per acre. We experienced drought in both years, so it is not surprising that yields were lower than anticipated. Interestingly, nutrient source treatments also affected corn yield even though this was the second year after application. The plots that had the high manure rate history yielded 25 bushels per acre than the fertilizer-only treatment (Figure 3). Yield in the low-rate manure plots was not significantly different than either of the other treatments, however.

Post-harvest soil samples from the top six and 24 inches of soil (Table 7) indicated that there were differences in residual nutrient content across treatments at the Murdock site in fall 2021. Similar to the previous rotation year, 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. Opposite of the previous rotation year, however, soil nitrate decreased with increasing manure application rate in the plots where soybean was the previous crop, while the reverse happened in the plots where corn was the previous crop. Soil test phosphorus levels varied. In fertilizer-only plots, soil test P levels were low, while plots with a manure history had medium to high soil test P levels. Soil test potassium levels were all high or very high and tended to increase with increased manure application rate.

Table 6. Yield, extractable sucrose (per ton and per acre), and sucrose percent purity averaged over both sites the second year after manure application. Manure was not applied this year, but fertilizers were applied as needed considering second-year manure nitrogen credits and soil tests.

Main effect	Yield (tons/acre)	Extractable Sucrose (lb/ton)	Extractable Sucrose (lb/acre)	Sucrose Purity (%)
Nutrient Source				
Fertilizer only	31.5b†	307a	9,378b	91.5a
Low dairy manure rate	31.1b	303a	9,148b	90.8a
High dairy manure rate	33.6a	302a	9,914a	91.6a
Site				
Murdock	40.3a	271b	10,914b	91.8a
Nashua	23.9b	337a	8,046a	90.8b

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

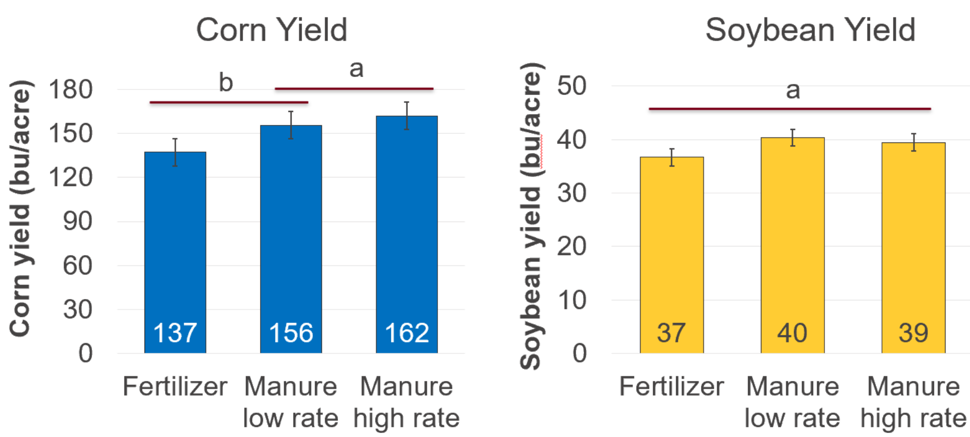

Figure 3. Corn (adjusted to 15.5% moisture) and soybean (adjusted to 13% moisture) yield averaged over sites (Murdock site in 2021 and Nashua site in 2022). In this second year, only fertilizer was applied but a nitrogen credit was taken for the manure. Soil tests for each treatment were used to adjust phosphorus and potassium application rates, as well. Different letters above a bar within a graph indicate a significant difference ($p < 0.05$).

Table 7. Soil test results for the Murdock site in fall 2021 and the Nashua site in fall 2022. All samples were taken in the top six inches of soil except the nitrate samples which were the top 24 inches of soil.

	Murdock site – Fall 2020			**Nashua site – Fall 2021**		
Initial soil test results	**Nitrate 0-24” (lb/ac)**	**Olsen P (ppm)**	**K (ppm)**	**Nitrate 0-24” (lb/ac)**	**Olsen P (ppm)**	**K (ppm)**
Previous crop sugarbeet (going into soybean)						
Fertilizer-only	14	7	172	14	9	247
Low-rate manure	12	8	186	13	15	229
High-rate manure	16	11	213	12	21	273
Previous crop soybean (going into corn)						
Fertilizer-only	76	8	209	18	14	176
Low-rate manure	85	10	241	27	16	185
High-rate manure	75	10	254	25	27	205

Previous crop corn (going into sugarbeet)						
Fertilizer-only	97	6	174	76	13	181
Low-rate manure	78	9	186	44	18	201
High-rate manure	86	12	222	43	16	202

Year 3 following manure application – The third growing season after manure was applied occurred in 2022 at the Murdock site and in 2023 at the Nashua site. Manure credits were not considered for the third growing season of the rotation. Fertilizer rates were based on N guidelines for each crop and the soil tests taken the previous fall. At the Murdock site, corn (Enesvedt E-696RR), soybean (Stine Liberty Link GT27), and sugarbeet (Beta 9952) were planted on May 26, 2022. Soygreen® was applied to the soybean plots to potentially reduce issues with iron-deficiency chlorosis. At the Nashua site, corn (Dekalb DKC49-44RIB), soybean (Dekalb AG10XF1), and sugarbeet (ACH 973) were planted on May 16, 2023. All crops were maintained according to typical practices in the region. Similar soil samples were collected in the third year as in the first and second year, though the 2023 samples from the Nashua site are still currently being analyzed.

Sugarbeets were harvested on October 5, 2022, soybeans on October 4, 2022, and corn on October 20, 2022 at Murdock. At Nashua, sugarbeets were harvested on October 3, 2023, soybeans on October 11, 2023, and corn on September 28, 2023. There were no differences across nutrient source treatments for sugarbeet root yield or quality measures, though there were differences across sites (Table 8). The Murdock site had higher yield and quality, though sucrose purity was not different between sites. Corn and soybean yields tended to be higher in the plots that had a manure history, though differences from the fertilizer-only plots were not significant (Figure 4). There were no differences between sites for corn yield (207 and 167 bu/ac for Murdock and Nashua, respectively) or soybean yield (47 and 34 bu/ac for Murdock and Nashua, respectively).

Post-harvest soil samples from the top six and 24 inches of soil (Table 9) indicated that there were differences in residual nutrient content across treatments at the Murdock site in fall 2022, though the differences were not as distinct as previous years. Soil nitrate levels in the top 24 inches of soil tended to be lowest in plots that were previously sugarbeet and were generally consistent across treatments. The exception being where the high rate of manure had been applied and corn was the previous crop, which had the highest residual nitrate levels. Soil test phosphorus levels ranged from 7 to 13 ppm (Olsen P test) which are mainly considered low to medium, with one set of fertilizer-only plots being rated high (in the plots where soybean was the previous crop). These levels were fairly consistent with the previous year. Soil test K levels remained high or very high, similar to the previous year. Soil test K levels tended to be lower in the manured plots where sugarbeet had just been harvested compared to the fertilizer only plot. Where corn and soybean had been harvested, soil test K levels tended to be higher in the manured plots and increased with increased manure application rate.

Table 8. Yield, extractable sucrose (per ton and per acre), and sucrose percent purity averaged over both sites the third year after manure application. Manure was not applied this year, but fertilizers were applied as needed considering nitrogen and soil test guidelines for each crop.

Main effect	Yield (tons/acre)	Extractable Sucrose (lb/ton)	Extractable Sucrose (lb/acre)	Sucrose Purity (%)
Nutrient Source				
Fertilizer only	40.3a†	277a	11,202a	90.0a
Low dairy manure rate	43.9a	274a	12,098a	89.8a
High dairy manure rate	43.3a	277a	12,021a	89.8a
Site				
Murdock	45.2a	284a	12,848a	89.9a
Nashua	39.8b	269b	10,700b	89.8a

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

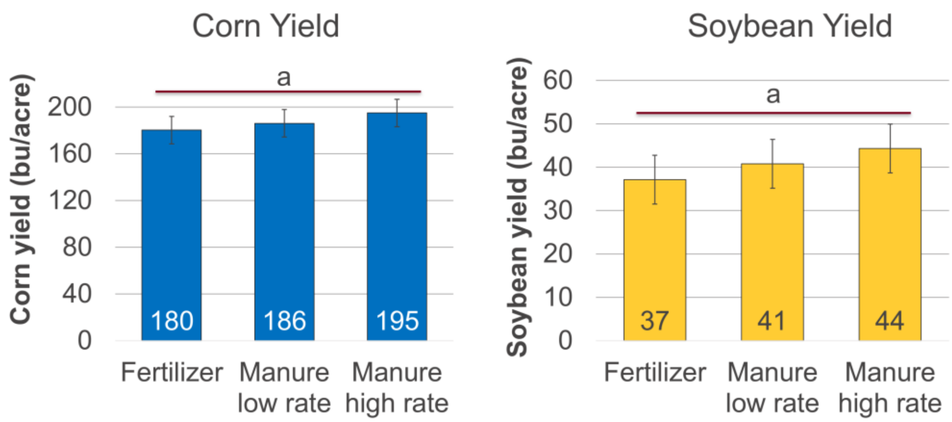

Figure 4. Corn (adjusted to 15.5% moisture) and soybean (adjusted to 13% moisture) yield at the Murdock site in 2022. In this third year, only fertilizer was applied based on N-needs of each crop. Soil tests for each treatment were used to adjust phosphorus and potassium application rates, as well. Different letters above a bar within a graph indicate a significant difference ($p < 0.05$).

Table 9. Soil test results for the Murdock site in fall 2022. All samples were taken in the top six inches of soil except the nitrate samples which were the top 24 inches of soil.

	Murdock site – Fall 2022		
Initial soil test results	**Nitrate 0-24" (lb/ac)**	**Olsen P (ppm)**	**K (ppm)**
Previous crop sugarbeet (going into soybean)			
Fertilizer-only	13	7	210
Low-rate manure	14	7	185
High-rate manure	13	9	184
Previous crop soybean (going into corn)			
Fertilizer-only	24	13	212
Low-rate manure	26	9	216
High-rate manure	27	7	238
Previous crop corn (going into sugarbeet)			
Fertilizer-only	55	7	177
Low-rate manure	55	8	191
High-rate manure	76	10	216

Overall, the liquid-separated dairy manure does not seem to have negatively affected sugarbeet yield, regardless of when it was applied in the rotation. In the second year after application, the high rate of manure application may have actually improved yield and quality. By the third year, however, there were no differences across treatments.

References:

- Halvorson, A.D., and G.P. Hartman. 1974. Longtime influence of organic and inorganic nitrogen sources and rates on sugarbeet yield and quality. In 1974 Sugarbeet Research and Extension Reports p. 77-79.
- Lamb, J.A., M.W. Bredehoeft, and C. Dunsmore. 2013. Turkey litter effects on sugar beet production. In 2012 Sugarbeet Res. And Ext. Rpts, https://www.sbreb.org/research/.
- Lamb, J.A., M.W. Bredehoeft, J. Rademacher, N. VanOs, C. Dunsmore, and M. Bloomquist. 2016. Swine manure application management in a sugar beet rotation. In 2015 Sugarbeet Res. And Ext. Rpts. https://www.sbreb.org/research/
- Lamb, J.A., M.A. Schmitt, M.W. Bredehoeft, S.R. Roehl. 2002. Management of turkey and swine manure derived nitrogen in a sugar beet cropping system. In 2001 Sugarbeet Res. and Ext. Rpts. 32:125-134.

- Schmitt, M.A., C.C. Sheaffer, and G.W. Randall. 1996. Preplant manure on alfalfa: Residual effects on corn yield and soil nitrate. J. Prod. Agric. 9:395-398.