# SWINE MANURE APPLICATION MANAGEMENT IN A SUGAR BEET ROTATION

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## Justification of Research

Livestock operations, mainly poultry and swine, are increasing in size and impact in the Southern Minnesota sugar beet growing area. Many sugar beet producers own or have interest in these operations; thus have manure available to use on their fields. Manure research data concludes that manure has a positive effect on crop production from its effects on soil nutrient availability and soil physical properties. A concern has been raised about the effect of late season nitrogen mineralized from the manure on sugar beet quality. Grower observations indicate better growth in fields that have had manure applied. With the large amount of manure available, the question has changed from whether to use manure but when in the sugar beet crop rotation should manure be applied to minimize quality concerns and realize benefits? Nitrogen from swine manure can be 80 % available in the year after application. The implication of the manure-N release is critical, especially to sugar beet growers. Therefore, recommendations need to be evaluated with sugar beets. This research project has been 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 sugar beet production, and determine the affect of over fertilization with N on the quality, root yield, and summer petiole nitrate-N.

## Summary of Literature Review

Little recent information is available on the effect of manure on sugar beet 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.

In a study conducted from 1999 to 2001, Lamb et. al 1999, 2000, and 2001 reported the effect of swine manure applied the prior fall on sugar beet production. The quality was reduced. Root yield was increased to the point that the increase compensated for the loss in quality. Results from applications made further ahead of sugar beet production were not reported because stand problems.

## Objectives

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 sugar beet production.
3. Determine the affect of over fertilization with N on the quality, and root yield.

## Materials and Methods

An experiment was conducted at three locations in the Southern Minnesota Beet Sugar Cooperative growing area over a period of seven years to meet the stated objectives. The locations were near Prinsburg, Raymond, and Montivideo, Minnesota. The experiment included four replications of the treatments listed in Table 1. Swine manure treatments were applied at a rate of 3500 gallons per acre 1, 2, and 3 years ahead in the three year rotation of soybean/corn/sugar beet. This rotation is the most common rotation is this growing area. Treatment 1 is the check treatment for the whole experiment while treatments 9, 17, and 25 are checks for the use of only manure. Treatments 2 through 7 are for N response to fertilizer in sugar beet following a soybean and corn crop fertilized according to University of Minnesota suggestions. Treatments 10 through 16 are for N response of sugar beet after manure application is made before the soybean crop, treatments 17 through 24 are for N response of sugar beet after manure application made before the corn crop, and treatments 25 through 32 are for N response of sugar beet after manure application made before sugar beet production. The N credit treatment was determined based on previous research for corn.

Table 1. Treatment List

| Treatment number | Year 1 (soybean) | Year 2 (corn) | Year 3 (sugar beet) |
|---|---|---|---|
| 1 | No manure | 0 N | 0 N |
| 2 | No manure | 120 N | 0 N |
| 3 | No manure | 120 N | 30 N |
| 4 | No manure | 120 N | 60 N |
| 5 | No manure | 120 N | 120 N |
| 6 | No manure | 120 N | 150 N |
| 7 | No manure | 120 N | 180 N |
| 8 | No manure | 0 N | 90 N |
| 9 | Manure | 0 N | 0 N |
| 10 | Manure | N credit | 0 N |
| 11 | Manure | N credit | 30 N |
| 12 | Manure | N credit | 60 N |
| 13 | Manure | N credit | 90 N |
| 14 | Manure | N credit | 120 N |
| 15 | Manure | N credit | 150 N |
| 16 | Manure | N credit | 180 N |
| 17 | 0 N | Manure | 0 N |
| 18 | 0 N | Manure | 30 N |
| 19 | 0 N | Manure | 60 N |
| 20 | 0 N | Manure | 90 N |
| 21 | 0 N | Manure | 120 N |
| 22 | 0 N | Manure | 150 N |
| 23 | 0 N | Manure | 180 N |
| 24 | 0 N | Manure | N credit |
| 25 | 0 N | 0 N | Manure |
| 26 | 0 N | 120 N | Manure |
| 27 | 0 N | 30 N | Manure |
| 28 | 0 N | 60 N | Manure |
| 29 | 0 N | 90 N | Manure |
| 30 | 0 N | 150 N | Manure |
| 31 | 0 N | 180 N | Manure |
| 32 | 0 N | 210 N | Manure |

The Raymond location was established in the fall of 2009. Soybean was grown in 2010, corn in 2011, and sugar beet in 2012. The Prinsburg location was established in the fall of 2010. Soybean, corn, and sugar beet were grown in 2011, 2012, and 2013, respectively. After the lose of a location established in the fall 2011, the final location was near Montivideo and established in the fall of 2012. Soybean, corn, and sugar beet were grown in 2013, 2014, and 2015.

Before the soybean production year, the manure treatments (YR 1) were applied. In the soybean production year, grain yield was determined with a small combine. The year 2 (Yr 2) manure and fertilizer treatments were applied in the late fall after soybean harvest. Corn grain was harvested either by hand or with a plot combine. The year 3 (Yr 3) manure treatments were applied late fall of year 2. Fertilizer treatments were applied in the spring before planting. Root yield and quality was determined in the fall. In each of the production years, optimum production practices for pest control and nutrient management besides nitrogen were used.

**Results and Discussion**

*Soybean:* Soybean was grown as the first crop in the rotation. The only treatment that was applied before soybean production was manure. The application of manure did not affect soybean grain yield at 2 of the 3 sites, Table 2. At the Montivideo site, the use of manure increase grain yields 6 bushels per acre. This is very similar to what has been reported in other studies conducted in Minnesota. Predicting when the response will occur is difficult. Application of manure before soybean production is not recommended if

the producer has corn acres to apply manure to first. The application has not cause a negative yield response in other research trials.

Table 2. The effect of manure application on soybean grain yield at Prinsburg, Raymond, and Montivideo.

| | Prinsburg | Raymond | Montivideo |
|---|---|---|---|
| Treatment | Soybean grain yield (bu/A) | | |
| Manure | 42 | 53 | 38 |
| No manure | 41 | 52 | 44 |
| | | | |
| Statistic (P>F) | 0.62 | 0.23 | 0.0007 |

*Corn:* Corn was grown in the second year of the rotation. Table 3 reports the effect of N fertilizer application on corn grain yields. The grain yield response was not statistically strong at any of the sites.

Table 3. The effect of nitrogen fertilizer application on corn grain yield.

| N rate | Prinsburg | Raymond | Montivideo |
|---|---|---|---|
| lb N/A | Corn grain yield (bu/A) | | |
| 0 | 215 | 191 | 182 |
| 30 | 227 | 184 | 184 |
| 60 | 237 | 192 | 190 |
| 90 | 237 | 193 | 214 |
| 120 | 232 | 189 | 209 |
| 150 | 235 | 200 | 194 |
| 180 | 235 | 178 | 210 |
| 210 | 246 | 198 | 202 |
| | | | |
| Statistic (P>F) | 0.13 | 0.16 | 0.09 |

Some comparisons between the different manure treatments and the 120 lb N/acre as fertilizer were made, Table 4. At Prinsburg, the application of manure before soybean had the poorest grain yields, while the application of manure just before the corn crop had the greatest grain yields. Application of manure before soybean production with the addition of fertilizer based on the nutrient credit from the manure before corn and the corn treated with 120 lb N/A as fertilizer had similar grain yields. These grain yields were between the corn grain yields for manure applied before soybean and the grain yields for corn with manure applied the fall before corn production. At Raymond and Montivideo, the manure applied before soybean production had smaller corn grain yield compared to the other N treatments. It appears that counting on the manure application before soybean production to supply enough N for corn production later in the rotation was not sufficient. Accounting for the N in the manure applied before the soybean production is important and if it is not enough for the needs of the corn plant then additional N fertilizer will be required.

Table 4. The effect of manure application and nutrient application on corn grain yield.

| | Prinsburg | Raymond | Montivideo |
|---|---|---|---|
| Comparison | Corn grain yield (bu/A) | | |
| *Yr 2 | 246 | 199 | 204 |
| **120 lb N/A | 232 | 196 | 210 |
| ***Yr 1 + NC | 230 | 214 | 207 |
| ****Yr 1 | 206 | 180 | 176 |
| | | | |
| Statistics | | | |
| Yr 2 vs 120 lb N/A | 0.01 | 0.30 | 0.74 |
| Yr 1 + NC vs Yr 2 | 0.004 | 0.85 | 0.60 |
| Yr 1 vs Yr 1 + NC | 0.04 | 0.002 | 0.003 |

*Yr 2 = manure applied the fall before corn production.
**120 lb N/A = 120 lb N/A applied and incorporated the fall before corn production.
***Yr 1 + NC = Manure applied the fall before previous soybean crop in the soybean, corn, sugar beet rotation plus N fertilizer applied before corn production based on the nutrient credit for the yr1 manure application.
****Yr 1 = Manure applied the fall before previous soybean crop in the soybean, corn, sugar beet rotation.

*Sugar beet:* *The effect of time of manure application before sugar beet production:* One of the questions that can be answered by this study is what is the effect of time of manure application before sugar beet production. At Prinsburg, the time of manure application significantly affected root yield, sucrose concentration, extractable sucrose per ton, and extractable sucrose per acre, Table 5. For root yield, the closer to sugar beet production was, the greater the root yield. Extractable sucrose per acre was increased with the application of manure in the rotation but time of application was not important. The quality parameters were decreased by manure being applied the fall before sugar beet production. Applying manure at other times earlier in the rotation did not affect sucrose concentration or extractable sucrose per ton.

Table 5. The means and statistical analysis for the effect of manure application on sugar beet yield and quality at the Prinsburg site.

| | Root yield | Sucrose | Extractable sucrose | |
|---|---|---|---|---|
| Manure treatment | ton/A | % | lb/ton | lb/A |
| *None | 29.9 | 17.0 | 297 | 8893 |
| **Yr 1 | 34.0 | 17.3 | 301 | 10242 |
| ***Yr 2 | 36.0 | 17.4 | 301 | 10850 |
| ****Yr 3 | 36.8 | 16.4 | 282 | 10366 |
| | | | | |
| Statistic (P>f) | 0.04 | 0.001 | 0.0002 | 0.05 |

* None = No manure or fertilizer applied in rotation.
**Yr 1 = Manure applied fall before soybean production in a soybean, corn, and sugar beet rotation. No fertilizer application.
***Yr 2 = Manure applied fall before corn production in a soybean, corn, and sugar beet rotation. No fertilizer application.
****Yr 3 = Manure applied fall before sugar beet production in a soybean, corn, and sugar beet rotation. No fertilizer application.

At the Raymond site, the results were similar to the Prinsburg site, Table 6. The closer in the rotation that you applied manure, the greater the root yield and extractable sucrose per acre were. The quality parameters, sucrose concentration and extractable sucrose per ton were reduced by the application of manure in the fall before sugar beet production.

Table 6. The means and statistical analysis for the effect of manure application on sugar beet yield and quality at the Raymond site.

| | Root yield | Sucrose | Extractable sucrose | |
|---|---|---|---|---|
| Manure treatment | ton/A | % | lb/ton | lb/A |
| *None | 22.0 | 16.9 | 281 | 5637 |
| **Yr 1 | 27.5 | 16.4 | 270 | 7390 |
| ***Yr 2 | 28.1 | 16.7 | 274 | 7727 |
| ****Yr 3 | 32.6 | 15.7 | 249 | 8182 |
| | | | | |
| Statistic (P>f) | 0.06 | 0.08 | 0.04 | 0.09 |

* None = No manure or fertilizer applied in rotation.
**Yr 1 = Manure applied fall before soybean production in a soybean, corn, and sugar beet rotation. No fertilizer application.
***Yr 2 = Manure applied fall before corn production in a soybean, corn, and sugar beet rotation. No fertilizer application.
****Yr 3 = Manure applied fall before sugar beet production in a soybean, corn, and sugar beet rotation. No fertilizer application.

The results for the Montivideo site are presented in Table 7. Unlike the Prinsburg and Raymond sites, manure application did not affect any of the pararmeters measured.

Table 7. The means and statistical analysis for the effect of manure application on sugar beet yield and quality at the Montivideo site.

| | Root yield | Sucrose | Extractable sucrose | |
|---|---|---|---|---|
| Manure treatment | ton/A | % | lb/ton | lb/A |
| *None | 25.1 | 16.3 | 277 | 7048 |
| **Yr 1 | 30.5 | 16.4 | 277 | 8601 |
| ***Yr 2 | 30.8 | 16.3 | 279 | 8592 |
| ****Yr 3 | 27.7 | 16.6 | 285 | 8002 |
| | | | | |
| Statistic (P>f) | 0.23 | 0.29 | 0.20 | 0.56 |

* None = No manure or fertilizer applied in rotation.
**Yr 1 = Manure applied fall before soybean production in a soybean, corn, and sugar beet rotation. No fertilizer application.
***Yr 2 = Manure applied fall before corn production in a soybean, corn, and sugar beet rotation. No fertilizer application.
****Yr 3 = Manure applied fall before sugar beet production in a soybean, corn, and sugar beet rotation. No fertilizer application.

At two of the three locations in this study, the closer the application of manure was before sugar beet production, the greater the root yield and extractable sucrose per acre. At those same two sites, the application of manure in the fall before sugar beet production resulted in reduced quality. One last observation for this data is that with out any N input for three year before sugar beet was grown, root yields were above 20 tons per acre at all locations. This means the N contribution from the organic matter in the soils is large.

*The effect of N fertilization and manure application:* Sugar beet was grown in the final year of the rotation. In this study, one objective was to determine of manure application timing affected N response on sugar beet yield and quality. To meet this objective, we are looking for a manure application by N rate interaction. If there is none then the result would be that manure application has no effect on the response from N fertilizer application before sugar beet production. The statistical analysis for the Prinsburg site is presented in Table 8. At Prinsburg, we did not have an interaction between manure and N fertilizer application for sugar beet root yield, sucrose, extractable sucrose per ton, and extractable sucrose per acre. Manure application and N fertilizer did not affect sucrose concentration or extractable sucrose per ton, Table 8 and 9. Manure application and N fertilizer application did significantly affect root yield and quality. Root yield increased with increasing N fertilizer application rate up to the 150 lb N/A, Table 9. This was also true for extractable sucrose per acre. The closer that you apply manure to the production of sugar beet the greater the root yield and extractable sucrose per acre.

Table 8. The statistical analysis of manure and N fertilizer application on sugar beet root yield and quality at the Prinsburg site.

| | Root yield | Sucrose | Extractable sucrose | |
|---|---|---|---|---|
| | | | lb/ton | lb/A |
| Source of variation | Probability of a greater F | | | |
| Manure | 0.03 | 0.66 | 0.57 | 0.04 |
| N rate | 0.0001 | 0.98 | 0.95 | 0.0001 |
| N rate X manure | 0.22 | 0.55 | 0.92 | 0.18 |

Table 9. The effect of manure and N fertilizer application on sugar beet root yield and quality at the Prinsburg site.

| N rate | Root yield | Sucrose | Extractable sucrose | |
|---|---|---|---|---|
| lb N/A | ton/A | % | lb/ton | lb/A |
| 0 | 32.9 | 17.1 | 296 | 9749 |
| 30 | 33.8 | 17.2 | 299 | 10136 |
| 60 | 35.3 | 17.1 | 297 | 10459 |
| 90 | 36.7 | 17.2 | 298 | 10907 |
| 120 | 37.1 | 17.0 | 295 | 10899 |
| 150 | 38.6 | 17.1 | 297 | 11478 |
| 180 | 38.1 | 17.1 | 297 | 11318 |
| | | | | |
| *None | 34.4 | 17.0 | 294 | 10088 |
| **Yr 1 + NC | 35.1 | 17.2 | 299 | 10489 |
| ***Yr 2 | 38.4 | 17.2 | 297 | 11424 |

*None = No manure applied in rotation, 120 lb N/A applied and incorporated the fall before corn production.
**Yr1 + NC = Manure applied the fall before previous soybean crop in the soybean, corn, sugar beet rotation plus N fertilizer applied before corn production based on the nutrient credit for the Yr 1 manure application.
***Yr 2 = manure applied the fall before corn production.

At the Raymond site, there was no interaction between manure and fertilizer N application for sugar beet root yield and quality, Table 10. Manure application did not affect any parameter measured while N fertilizer application affected root yield, extractable sucrose per ton, and extractable sucrose per acre, Table 10 and 11. Root yield was increased with fertilizer applications up to 120 lb N/acre. Extractable sucrose per ton was reduced as the N fertilizer rate increased. Extractable sucrose per acre increased with increasing N fertilizer application up to the 60 lb N/A application. The lack of response to manure was surprising. The yield and quality responses to N application were similar to what has occurred in the past.

Table 10. The statistical analysis of manure and N fertilizer application on sugar beet root yield and quality at the Raymond site.

| | Root yield | Sucrose | Extractable sucrose | |
|---|---|---|---|---|
| | | | lb/ton | lb/A |
| Source of variation | Probability of a greater F | | | |
| Manure | 0.88 | 0.68 | 0.72 | 0.66 |
| N rate | 0.01 | 0.14 | 0.02 | 0.04 |
| N rate X manure | 0.19 | 0.44 | 0.60 | 0.55 |

Table 11. The effect of manure and N fertilizer application on sugar beet root yield and quality at the Raymond site.

| N rate | Root yield | Sucrose | Extractable sucrose | |
|---|---|---|---|---|
| lb N/A | ton/A | % | lb/ton | lb/A |
| 0 | 28.7 | 16.5 | 272 | 7792 |
| 30 | 27.8 | 16.5 | 270 | 7537 |
| 60 | 31.3 | 16.6 | 272 | 8539 |
| 90 | 29.8 | 16.4 | 264 | 7836 |
| 120 | 31.8 | 16.1 | 259 | 8203 |
| 150 | 31.2 | 16.2 | 259 | 8104 |
| 180 | 28.7 | 16.3 | 263 | 7546 |
| | | | | |
| *None | 30.1 | 16.4 | 267 | 8050 |
| **Yr 1 + NC | 30.1 | 16.3 | 265 | 7960 |
| ***Yr 2 | 29.6 | 16.4 | 265 | 7833 |

*None = No manure applied in rotation, 120 lb N/A applied and incorporated the fall before corn production.
**Yr1 + NC = Manure applied the fall before previous soybean crop in the soybean, corn, sugar beet rotation plus N fertilizer applied before corn production based on the nutrient credit for the Yr 1 manure application.
***Yr 2 = manure applied the fall before corn production.

The Montivideo site did have a significant interaction between manure application and fertilizer N application for root yield and extractable sucrose per acre, Table 12. The interesting aspect of this interaction is the lack of root yield and extractable sucrose per acre response to manure and N fertilizer application individually. There was no interaction between manure and fertilizer N application for sucrose concentration and extractable sucrose per ton, but the application of N fertilizer alone, did have a significant effect, Table 12.

To understand the interaction, the means of the effect of N fertilizer at with each manure application management treatment needs to be examined, Table 13. The interaction occurred because of the differing root yield and extractable sucrose per acre responses as the 30 lb N/acre treatment. The trend of the response of root yield and extractable sucrose per acre were not the same at that N rate. When examining the data, there is no good explanation for this situation and it is concluded that random variability caused the differences. Because of this, neither manure or N fertilizer affected root yield and extractable sucrose per acre at this site.

Manure did not significantly affect sucrose concentration or extractable sucrose per ton, Table 12 and 14. As fertilizer N application rate increased, the sucrose concentration and extractable sucrose decreased, Table 14. This result occurs frequently in sugar beet.

Table 12. The statistical analysis of manure and N fertilizer application on sugar beet root yield and quality at the Montivideo site.

| | Root yield | Sucrose | Extractable sucrose | |
|---|---|---|---|---|
| | | | lb/ton | lb/A |
| Source of variation | Probability of a greater F | | | |
| Manure | 0.23 | 0.54 | 0.75 | 0.55 |
| N rate | 0.14 | 0.0008 | 0.0003 | 0.17 |
| N rate X manure | 0.02 | 0.91 | 0.92 | 0.03 |

Table 13. The means for the interaction between N fertilizer application and manure application for root yield and extractable sucrose per acre at the Montivideo site.

| | Manure | | | Manure | | |
|---|---|---|---|---|---|---|
| | *None | **Yr1 + NC | ***Yr 2 | *None | **Yr1 + NC | ***Yr 2 |
| N rate | Root yield | | | Extractable sucrose | | |
| lb/A | ton/A | | | lb/A | | |
| 0 | 22.8 | 30.9 | 30.8 | 6556 | 8549 | 8592 |
| 30 | 25.6 | 23.5 | 36.1 | 7235 | 6634 | 10032 |
| 60 | 32.2 | 33.8 | 33.3 | 8887 | 9439 | 9075 |
| 90 | | 28.9 | 31.7 | | 8293 | 8982 |
| 120 | 31.5 | 31.9 | 26.7 | 9160 | 9054 | 7253 |
| 150 | 33.4 | 27.7 | 30.8 | 9414 | 7246 | 7915 |
| 180 | 28.1 | 29.5 | 29.0 | 7636 | 7756 | 7613 |

*None = No manure applied in rotation, 120 lb N/A applied and incorporated the fall before corn production.
**Yr1 + NC = Manure applied the fall before previous soybean crop in the soybean, corn, sugar beet rotation plus N fertilizer applied before corn production based on the nutrient credit for the Yr 1 manure application.
***Yr 2 = manure applied the fall before corn production.

Table 14. The effect of manure and N fertilizer application on sugar beet root yield and quality at the Montivideo site.

| N rate | Root yield | Sucrose | Extractable sucrose | |
|---|---|---|---|---|
| lb N/A | ton/A | % | lb/ton | lb/A |
| 0 | 28.2 | 16.4 | 279 | 7899 |
| 30 | 28.4 | 16.4 | 280 | 7967 |
| 60 | 33.2 | 16.2 | 275 | 9155 |
| 90 | 30.3 | 16.5 | 280 | 8637 |
| 120 | 29.7 | 16.5 | 280 | 8355 |
| 150 | 30.3 | 15.8 | 266 | 8025 |
| 180 | 29.0 | 15.9 | 265 | 7669 |
| | | | | |
| *None | 28.3 | 16.4 | 280 | 7969 |
| **Yr 1 + NC | 29.6 | 16.3 | 275 | 8162 |
| ***Yr 2 | 31.0 | 16.1 | 271 | 8379 |

*None = No manure applied in rotation, 120 lb N/A applied and incorporated the fall before corn production.
**Yr1 + NC = Manure applied the fall before previous soybean crop in the soybean, corn, sugar beet rotation plus N fertilizer applied before corn production based on the nutrient credit for the Yr 1 manure application.
***Yr 2 = manure applied the fall before corn production.

**Summary**

The effect of timing of manure application in the soybean, corn, sugar beet rotation.

1. Manure 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 sugar beet production the application is the greater the root yield and extractable sucrose response.
3. The application of swine manure in the fall before sugar beet production, sugar beet sucrose concentration and extractable sucrose per ton is significantly decreased. Depending on the quality payment, this reduction can be economically significant.

The effect of time of manure application in the rotation and the application N fertilizer before sugar beet production.

1. No interaction occurred between N fertilizer application and manure management 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 at 1 site. The closer you apply manure to sugar beet 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.

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