Management of Turkey and Swine Manure Derived Nitrogen in a Sugar Beet Cropping System

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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 where manure has been 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. The answer to this question may depend on the type of manure. Poultry manure has a considerable amount of litter in it compared to swine manure, thus slowing initial release of poultry manure-N.

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. Malzer and Graff (1995) reported that leached nitrate-N during second year after an application of turkey manure was greater than in the first year after application. This data suggests that poultry manure has a latter or more extended release of N when compared to liquid swine manure.

The implications of the manure-N release are critical, especially to sugar beet growers. Therefore, recommendations need to be evaluated with sugar beet. This research project has been designed to: 1) measure manure application effects on sugar beet root yield and quality compared to fertilizer N applications; 2) determine the effect of turkey and swine manure mineralization differences on sugar beet root yield and quality; and 3) develop management strategies for manure application in a sugar beet rotation.

Materials and Methods:

To address the objectives 1 and 2, a study was conducted in 1999, 2000, and 2001 to measure the effects of manure application directly before sugar beet production. The treatments include fertilizer nitrogen, turkey manure, and swine manure (Table 1). The manure applications occurred early November 1998 at the Renville 1 site, November 1999 at the Raymond site, and November 2000 at the Renville 2 site. The liquid swine manure was injected into the soil to a depth of six inches and with injector knifes spaced 30 inches apart. The turkey manure was broadcast applied and incorporated. The nitrogen analysis for each manure source and for each year of the study is reported in Table 2. Fertilizer nitrogen was applied in a series of rates to determine the equivalent of the N supplied by manure. Soil samples were taken to a depth of four feet for nitrate-N from the check plots Fall 1998, and April 1999 at the Renville 1 site, Fall 1999 and early May 2000 at the Raymond site, and in the fall 2000 at the Renville 2 site. The initial soil nitrate values for each site are reported in Table 3. Soil samples to one foot for nitrate-N were taken monthly to estimate the mineralization of N from manure during the growing season. Soil samples were taken to a depth of 4 foot in all plots at all sites after sugar beet harvest to measure residual nitrate-N.

Sugar beet top growth and N content, root yield, and root quality were measured at harvest. Quality samples were taken at harvest and analyzed by the Southern Minnesota Beet Sugar Cooperative Quality Laboratory.

Table 1. Treatments for manure study.

Treatment	Total N applied		
	1999	2000	2001
	---------- lb N A^{-1} ----------		
Check	0	0	0
Fertilizer 40	40	40	40
Fertilizer 80	80	80	80
Fertilizer 120	120	120	120
Fertilizer 160	160	160	160
Fertilizer 200	200	200	200
Swine manure 2500 gallon A^{-1}	228	104	196
Swine manure 5000 gallon A^{-1}	456	208	391
Turkey manure 2.5 ton A^{-1}	45	153	123
Turkey manure 5.0 ton A^{-1}	90	306	245

Table 2. Total nitrogen content of manure each year of study.

Manure type	Year of study		
	1999	2000	2001
Liquid swine (lb N per 1000 gallons)	91.2	41.6	78.2
Dry turkey litter (lb N per ton)	18	61.2	49.2

Table 3. Initial soil nitrate-N values for the study.

Location	Soil nitrate-N		
	0 – 2 ft.	2 – 4 ft.	0 – 4 ft.
	---------- lb A^{-1} ----------		
Renville 1 (1999)	27	18	45
Raymond (2000)	50	25	75
Renville 2 (2001)	55		

Results and Discussion:

Sugar beet root yield and quality:

Renville 1 site 1999 - The objective of this experiment was to determine the effect of manure application the fall before sugar beet production on sugar beet yield and quality. The soil nitrate-N content was 27 pounds per acre in the 0 to 2 foot depth and 18 pounds per acre in the 2 to 4 foot depth in the fall of 1998 at the Renville site. Root yield was not significantly affected by the nitrogen fertilizer applications (Table 4). Only the root yields of the 5 ton per acre turkey manure and 5000 gallons per acre swine manure applications were significantly greater than the root yield of the check. The loss to molasses for the 5 ton per acre turkey manure application was significantly greater than the check. No significant differences occurred for sucrose concentration, recoverable sucrose per ton, and recoverable sucrose per acre.

Raymond site 2000 - The soil nitrate-N for this site was 50 pounds per acre in the 0 to 2 foot depth and 25 pounds per acre in the 2 to 4 foot depth. The maximum root yield occurred with 120 pounds fertilizer N per acre, 5000 gallons of swine manure per acre, 2.5 tons turkey manure per acre, and 5 tons turkey manure per acre, Table 5. The sucrose concentration for the manure treatments and the 160 and 200 pounds of fertilizer N per acre treatments were decreased. Recoverable sucrose per acre was the greatest, approximately 10,000 pounds per acre, with the 120 pounds fertilizer N per acre, 5000 gallons of swine manure per acre, 2.5 tons turkey manure per acre, and 5 tons turkey manure per acre.

Table 4. Root yield, sucrose concentration, loss to molasses, recoverable sucrose per ton, and recoverable sucrose per acre at Renville 1 site in 1999.

Treatment	Root yield	Sucrose concentration	Loss to molasses	Recoverable sucrose	
	ton A^{-1}	------- % -------		lb ton^{-1}	lb A^{-1}
Check	23.9	18.3	0.93	348	8301
Fertilizer 40	24.9	18.2	1.01	345	8570
Fertilizer 80	25.3	18.1	0.94	342	8634
Fertilizer 120	25.7	17.5	0.86	332	8546
Fertilizer 160	26.1	17.4	0.94	329	8492
Fertilizer 200	24.2	17.6	1.03	331	8033
Swine manure 2500	25.3	17.5	1.00	329	8353
Swine manure 5000	28.0	17.5	0.94	330	9371
Turkey manure 2.5	26.2	17.8	0.93	337	8849
Turkey manure 5.0	27.3	17.3	1.10	323	8819
$LSD_{0.05}$	2.6	NS	0.10	NS	NS

Table 5. Root yield, sucrose concentration, loss to molasses, recoverable sucrose per ton, and recoverable sucrose per acre at Raymond site in 2000.

Treatment	Root yield	Sucrose concentration	Loss to molasses	Recoverable sucrose	
	ton A^{-1}	------- % -------		lb ton^{-1}	lb A^{-1}
Check	18.5	18.8	0.99	356	6593
Fertilizer 40	24.1	18.9	0.98	359	5632
Fertilizer 80	27.5	18.5	1.01	349	9644
Fertilizer 120	28.5	18.9	0.99	358	10206
Fertilizer 160	26.7	18.4	1.00	348	9300
Fertilizer 200	26.0	17.8	1.03	335	8701
Swine manure 2500	23.5	18.1	1.02	342	8026
Swine manure 5000	29.9	18.0	1.02	339	10135
Turkey manure 2.5	31.4	18.2	1.02	344	10819
Turkey manure 5.0	26.4	19.3	0.88	366	9643
$LSD_{0.05}$	3.4	1.3	0.06	28	1419

Renville 2 site 2001 – Maximum root yield occurred at 160 pounds fertilizer N per acre (Fertilizer 160) while the Swine 2500, Turkey 2.5, and Turkey 5.0 yielded as well or better than the Fertilizer 160 treatment, Table 6. The greatest sucrose concentration occurred for sugar beet grown with 0 pounds fertilizer N per acre (check) or 40 pounds fertilizer N per acre (Fertilizer 40). As the amount of fertilizer N increased the sucrose concentration decreased. The reduction was 2.4 % between the check and Fertilizer 40 treatments and the Fertilizer 200 treatment. The sucrose concentrations for the manure treatments decreased with increasing rates of application but did not reduce the sucrose concentration as much as the Fertilizer 200 treatment. The optimum recoverable sucrose per acre for the fertilizer treatments was the Fertilizer 40 treatment. The greatest recoverable sucrose per acre was the Swine manure 2500 treatment with the roots treated with Turkey manure at 2.5 tons per acre similar to the Fertilizer 40 treatment.

Table 6. Root yield, sucrose concentration, loss to molasses, recoverable sucrose per ton, and recoverable sucrose per acre at Renville 2 site in 2001.

Treatment	Root yield	Sucrose concentration	Loss to molasses	Recoverable sucrose	
	ton A^{-1}	------- % -------		lb ton^{-1}	lb A^{-1}
Check	17.3	17.5	1.04	329	5704
Fertilizer 40	18.6	17.5	1.04	330	6141
Fertilizer 80	18.9	17.0	1.08	319	6011
Fertilizer 120	18.9	15.9	1.17	295	5570
Fertilizer 160	19.5	15.7	1.18	291	5659
Fertilizer 200	17.4	15.1	1.23	279	4845
Swine manure 2500	19.9	17.0	1.08	319	6334
Swine manure 5000	19.0	16.3	1.14	303	5750
Turkey manure 2.5	19.6	16.9	1.09	315	6190
Turkey manure 5.0	20.1	15.7	1.19	290	5838
$LSD_{0.05}$	1.9	0.5	0.04	10	583

Soil nitrate in surface one foot during growing season:

Renville 1 1999 - Soil nitrate-N contents in the surface one foot at Renville in 1999 are reported in Table 7. During the June, and July soil sampling dates soil nitrate-N was greater in the soils treated with 160 pounds fertilizer N per acre, 200 pounds fertilizer N per acre, 5000 gallons of liquid swine manure per acre, and 5 tons of turkey manure per acre than the check, Figure 1. By August this difference was not measured. Sugar beet roots are very efficient at utilizing nitrate-N from the soil and leaves little nitrate-N in soil compared to corn.

Table 7. Soil nitrate-N content for the surface one foot measured during the 1999 growing season at Renville 1 site.

Treatment	Soil nitrate-N content in surface one foot				
	June	July	August	September	November
	---------- lb nitrate-N A^{-1} ----------				
Check	61	34	15	17	16
Fertilizer 40	76	40	16	16	22
Fertilizer 80	90	36	15	19	16
Fertilizer 120	101	40	14	18	18
Fertilizer 160	122	64	17	20	19
Fertilizer 200	126	63	28	19	25
Swine manure 2500	62	36	13	18	16
Swine manure 5000	132	54	18	21	18
Turkey manure 2.5	99	37	17	19	19
Turkey manure 5.0	160	74	22	20	19
$LSD_{0.05}$	38	23	NS	NS	NS

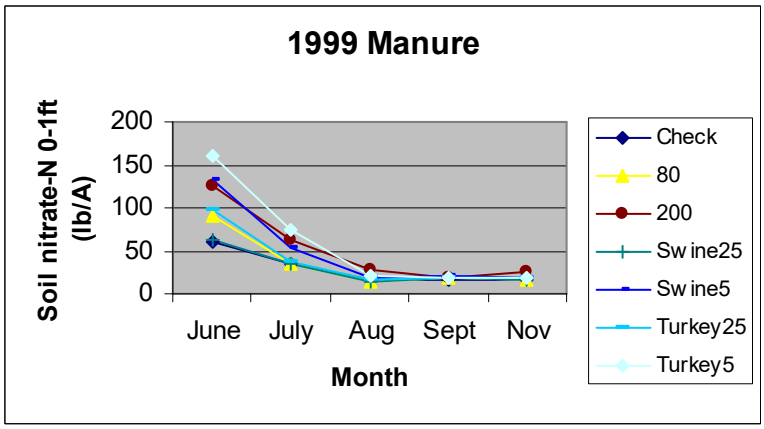

Figure 1. Soil nitrate-N contents in the surface foot of soil for check, optimum (Fertilizer 80), Fertilizer 200, and manure treatments from June 1999 to November 1999.

Raymond 2000 - In 2000, soil nitrate-N content in the surface foot was not affected by treatment, Table 8 and Figure 2. Soil nitrate was elevated in the early part of the growing season but as plant growth increased the amount of soil nitrate-N in the surface foot decreased. There was a marked increase in nitrate-N content from early September until November. This increase was caused by drought conditions in September which reduced the nitrate-N uptake by the sugar beet plant. No treatment differences in soil nitrate-N occurred in the later part of the growing season.

Table 8. Soil nitrate-N content for the surface one foot measured during the 2000 growing season at Raymond site.

Treatment	Soil nitrate-N content in surface one foot				
	June	July	August	September	November
	---------- lb nitrate-N A^{-1} ----------				
Check	57	10	18	10	20
Fertilizer 40	50	11	17	11	22
Fertilizer 80	63	10	20	11	34
Fertilizer 120	50	11	17	10	31
Fertilizer 160	72	17	17	12	30
Fertilizer 200	71	13	17	11	24
Swine manure 2500	70	12	17	12	30
Swine manure 5000	58	12	16	11	21
Turkey manure 2.5	57	13	16	11	23
Turkey manure 5.0	76	13	18	17	37
$LSD_{0.05}$	NS	4	NS	NS	NS

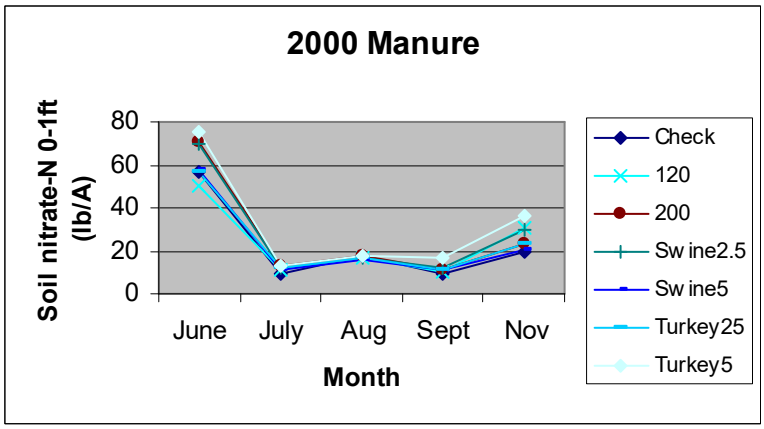

Figure 2. Soil nitrate-N contents in the surface foot of soil for check, optimum (Fertilizer 120), Fertilizer 200, and manure treatments from June 2000 to November 2000.

Renville 2 2001 - Soil nitrate-N content in the surface foot in 2001 was similar to soil nitrate-N values at the other two sites, Table 9 and Figure 3. Soil nitrate-N in the surface foot was elevated at the June sampling. In June, there were significant differences in soil nitrate values between the check, Fertilizer 40, and Fertilizer 80 treatments and the Fertilizer 160, Fertilizer 200, and Swine Manure at 5000 gallons. As the amount of fertilizer N applied increase about 80 pounds per acre, the soil nitrate-N in the surface foot increased in June. The July samples were still being analyzed at the time this report was being written. In August and September there were differences between treatments. At the late October sampling date, there was a small difference between the check and the Fertilizer 200 and the Swine manure 5000 treatments.

Table 9. Soil nitrate-N content for the surface one foot measured during the 2001 growing season at Renville 2 site.

Treatment	Soil nitrate-N content in surface one foot				
	June	July	August	September	November
	---------- lb nitrate-N A^{-1} ----------				
Check	43		29	12	13
Fertilizer 40	45		24	12	16
Fertilizer 80	50		30	13	14
Fertilizer 120	68		32	14	18
Fertilizer 160	85		33	13	15
Fertilizer 200	92		34	20	16
Swine manure 2500	60		33	14	16
Swine manure 5000	78		32	15	22
Turkey manure 2.5	40		24	13	13
Turkey manure 5.0	69		30	15	16
$LSD_{0.05}$	32		NS	NS	5

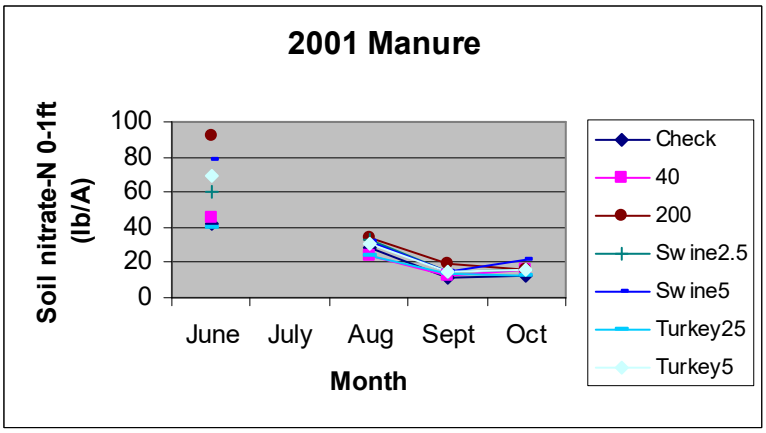

Figure 3. Soil nitrate-N contents in the surface foot of soil for check, optimum (Fertilizer 40), Fertilizer 200, and manure treatments from June 2001 to late October 2001.

Residual soil nitrate-N in surface four feet:

Residual soil nitrate-N for each treatment was determined on soil samples taken to a depth of four feet at the end of each growing season. The results from each site are presented in Tables 10, 11, and 12 and Figures 4, 5, and 6. The overall results show that at most soil depths at the three site there were no significant differences in soil nitrate-N content. When there were significant differences, these differences were very small in magnitude and had little practical implication.

Table 10. Residual soil nitrate-N content in surface four feet at Renville 1 site, fall 1999.

Treatment	Residual soil nitrate-N content						
	0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	0-2 ft.	0-3 ft.	0-4 ft.
	---------- lb nitrate-N A^{-1} ----------						
Check	16	7	5	5	23	28	33
Fertilizer 40	22	7	6	5	29	35	40
Fertilizer 80	16	7	6	6	23	29	35
Fertilizer 120	18	8	6	6	26	32	38
Fertilizer 160	19	8	6	5	26	32	38
Fertilizer 200	25	8	6	6	34	40	46
Swine manure 2500	16	7	6	5	23	29	34
Swine manure 5000	18	7	7	6	25	32	38
Turkey manure 2.5	19	8	6	5	27	33	38
Turkey manure 5.0	19	7	5	5	26	32	37
$LSD_{0.05}$	NS	NS	1	1	NS	NS	NS

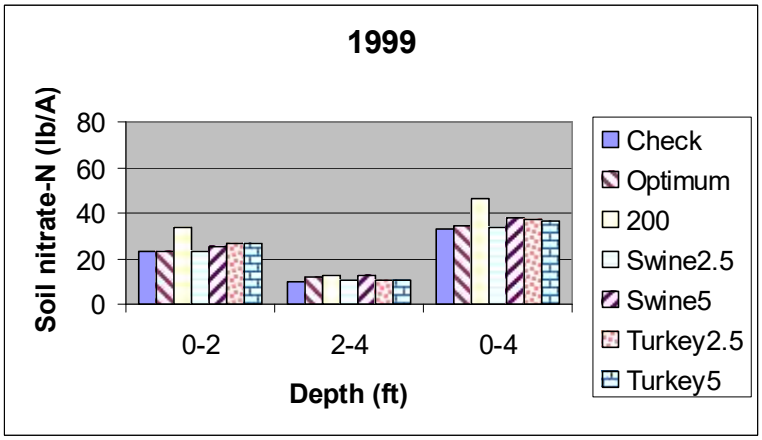

Figure 4. Fall residual soil nitrate for 0 to 2 feet, 2 to 4 feet, and 0 to 4 feet at Renville 1 in 1999.

Table 11. Residual soil nitrate-N content in surface four feet at Raymond site, fall 2000.

Treatment	Residual soil nitrate-N content						
	0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	0-2 ft.	0-3 ft.	0-4 ft.
	---------- lb nitrate-N A^{-1} ----------						
Check	20	10	6	6	29	36	42
Fertilizer 40	22	8	7	7	31	37	44
Fertilizer 80	34	10	8	8	44	52	60
Fertilizer 120	31	10	7	7	41	48	55
Fertilizer 160	30	9	6	6	39	45	51
Fertilizer 200	24	12	7	6	35	42	48
Swine manure 2500	30	13	7	8	43	50	58
Swine manure 5000	21	10	6	6	30	37	42
Turkey manure 2.5	23	10	9	7	33	42	48
Turkey manure 5.0	37	9	7	7	45	52	60
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS

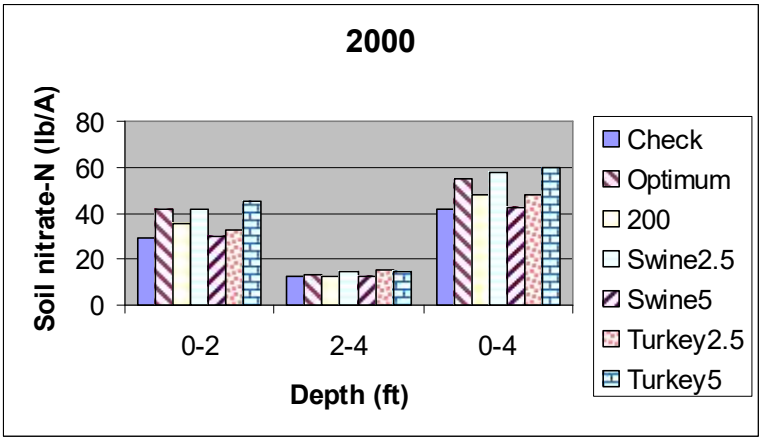

Figure 5. Fall residual soil nitrate for 0 to 2 feet, 2 to 4 feet, and 0 to 4 feet at Raymond in 2000.

Table 12. Residual soil nitrate-N content in surface four feet at Renville 2 site, fall 2001.

Treatment	Residual soil nitrate-N content						
	0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	0-2 ft.	0-3 ft.	0-4 ft.
	---------- lb nitrate-N A^{-1} ----------						
Check	13	6	6	5	19	24	29
Fertilizer 40	16	7	5	5	22	28	33
Fertilizer 80	14	6	5	5	20	26	31
Fertilizer 120	18	7	6	5	25	31	36
Fertilizer 160	15	7	6	5	22	27	32
Fertilizer 200	16	7	6	6	23	29	34
Swine manure 2500	16	6	6	5	22	28	33
Swine manure 5000	22	7	6	5	29	35	40
Turkey manure 2.5	13	7	6	6	20	25	31
Turkey manure 5.0	16	7	5	5	23	28	33
$LSD_{0.05}$	5	NS	NS	NS	NS	NS	NS

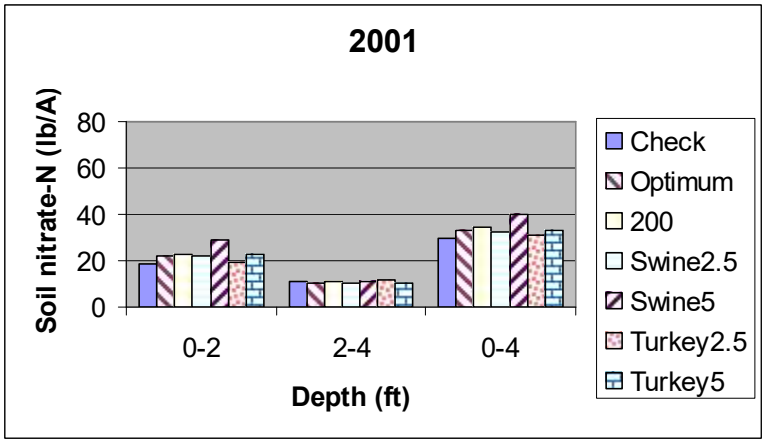

Figure 6. Fall residual soil nitrate for 0 to 2 feet, 2 to 4 feet, and 0 to 4 feet at Renville 2 in 2001.

Sugar beet top yield, N concentration, and N uptake:

Sugar beet top yield, N concentration, and N uptake values for Renville 1 and Raymond sites are presented in Table 13. The samples for 2001 are being analyzed at the time of the preparation of this report. Sugar beet top yield was not affected by treatments at Renville 1 or Raymond site. In 1999 at the Renville 1 site, there were significant differences in N concentration and N uptake in the sugar beet tops caused by the treatments. In general as the amount of N fertilizer increased the N concentration and N uptake increased. The application of manure also increased the N concentration and N uptake. The greater application amounts of manure (swine and turkey) increased N concentration and N uptake by the sugar beet tops. At the Raymond site, the top yields were less than at the Renville 1 site in 1999. The reduced top yield was attributed to drought conditions in August and September in 2000. These drought conditions probably contributed to the lack of significant differences in N concentration and N uptake in 2000.

Table 13. Sugar beet top yield, N concentration, and N uptake in 1999 and 2000.

	1999			2000		
Treatment	Top yield	N concentration	N uptake	Top yield	N concentration	N uptake
	lb A^{-1}	%	lb A^{-1}	lb A^{-1}	%	lb A^{-1}
Check	3963	1.93	77	991	2.06	21
Fertilizer 40	3861	1.94	75	1076	2.28	24
Fertilizer 80	3977	2.15	84	1092	2.27	26
Fertilizer 120	4856	2.41	117	1095	2.51	38
Fertilizer 160	4790	2.51	121	1276	2.53	33
Fertilizer 200	5608	2.72	160	1439	2.40	35
Swine manure 2500	4162	2.01	84	1385	2.61	36
Swine manure 5000	4520	2.46	111	1363	2.35	32
Turkey manure 2.5	4726	2.12	102	1101	2.38	26
Turkey manure 5.0	5485	2.58	143	1205	2.61	32
$LSD_{0.05}$	NS	0.42	43	NS	NS	NS

Overall conclusions:

The results from the three sites of this study indicate that the use of manure on field with no prior manure application may not be as detrimental to sugar beet quality as originally thought. The effect of manure application to sugar beet root yield and quality on field with a history of manure applications was not been answered with this study. If manure is applied at reasonable rates equivalent to the N fertilizer recommendation, it does not negatively affect sugar beet 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 sugar beet 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 will not reflect excess soil nitrate-N during sugar beet production.

Preliminary results from 1999 indicate that sugar beet top N concentration and N uptake at harvest do 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 sugar beet plant was under moisture stress affected the plant uptake of soil nitrate-N.

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