Table 3. Soil NO_3-N levels as affected by N application at HRC. Samples were collected June 6, 1989. Mean ± Standard deviation.

Depth (ft.)	N-Rate (lb/A) 25	62.5	100
	ppm NO_3-N		
0-1	10.5±2.7	13.5±1.20	25.1±1.5
1-2	6.0±1.9	6.1±0.04	10.9±3.7
2-3	3.5±0.4	4.8±0.40	6.3±2.9

Table 4. Soil NO_3-N levels as affected by N application at Hastings. Samples were collected June 7, 1989. Mean ± Standard deviation.

	Cultivar					
	Foch			Millot		
	N-Rate (lb/A)					
Depth (ft.)	30	60	90	30	60	90
	ppm NO_3-N					
0-1	7.8±1.0	11.1±6.1	13.7±2.5	7.3±2.7	13.1±3.4	17.8±8.6
1-2	7.7±2.8	8.2±2.3	11.3±1.8	7.3±3.9	9.7±3.1	12.6±5.5
2-3	2.5±0.6	4.2±1.8	3.8±1.5	2.8±2.0	4.0±2.0	3.2±1.3

Table 5. Comparison of nitrate-N concentrations in grape petioles and petiole sap for two cultivars and 3 N rates at seven sampling dates (HRC, Excelsior 1989).

		Quick Test NO_3-N					Water Extractable NO_3-N						
		Sampling Date											
Cultivar	N Rate (lb/A)	June 6	June 22	July 6	July 20	Aug 31	June 6	June 22	July 6	July 20	Aug 3	Aug 17	Aug 31
		ug/ml NO_3-N					ug/g NO_3-N						
Seyval	25	691	412	452	261	194	1716	1767	1720	766	210	185	312
	62.5	700	603	733	386	345	2279	2448	2710	1112	727	279	306
	100	548	581	601	339	227	1795	2308	2282	1181	620	249	522
Vignoles	25	351	233	253	113	127	1061	875	1018	593	175	85	102
	62.5	279	260	300	149	158	968	1147	1383	497	261	386	356
	100	436	295	388	140	165	1520	1334	1294	363	254	219	236
Analysis of Variance													
Cultivar													
Seyval		647	532	595	329	255	1930	2174	2237	1020	519	238	380
Vignoles		355	263	314	134	150	1183	1119	1232	484	230	230	231
Significance		NS	*	**	**	NS	NS	**	**	*	**	NS	NS
N Rate													
25		521	322	353	187	160	1389	1321	1369	680	192	135	207
62.5		490	431	517	267	251	1624	1798	2047	805	494	332	331
100		492	438	495	240	196	1657	1821	1788	772	437	234	379
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
Linear		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
Quad.		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
Interaction													
CXN		NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS

NS = nonsignificant; * = significant at 5%; ** = significant at 1%.

Table 6. Comparison of NO_3-N concentrations in grape petioles and petiole sap for two cultivars and 3 N rates at seven sampling dates (Hastings, 1989).

		Quick Test NO_3-N						Water Extractable NO_3-N						
		Sampling Date												
Cultivar	N Rate (lb/A)	June 7	June 23	July 6	July 20	Aug 17	Aug 31	June 7	June 23	July 6	July 20	Aug 3	Aug 17	Aug 31
		ug/ml NO_3-N						ug/g NO_3 N						
Millot	30	1394	818	814	703	278	321	3222	3885	2625	1468	966	481	364
	60	1099	804	915	717	416	429	3420	3530	2532	1747	1111	673	480
	90	1152	782	1063	622	525	321	3921	3712	2703	1349	1222	515	348
Significance		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Linear		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Quad.		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Foch	30	785	654	649	490	339	257	2714	2407	1447	580	569	250	338
	60	1022	680	607	369	246	195	1768	1565	1261	545	577	260	203
	90	878	727	718	529	270	580	2163	1962	1219	565	709	290	352
Significance		NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
Linear		NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
Quad		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = nonsignificant; * = significant at 5%; ** = significant at 1%.

Table 7. Yields, brix, pH, and titratable acidity as affected by N rate. (HRC, 1989).

Cultivar	N rate (lb/A)	Yield (lb/vine)	Brix	pH	Titratable Acidity
Seyval	25	16.05	16.8	3.34	0.99
	62.5	7.50	14.7	3.18	1.33
	100	10.34	15.6	3.39	1.21
Vignoles	25	1.69	18.6	3.28	1.50
	62.5	0.49	20.1	3.17	1.08
	100	2.09	18.0	3.15	1.51
Analysis of Variance					
Cultivar					
	Seyval	11.29	15.7	3.30	1.17
	Vignoles	1.52	18.5	3.21	1.44
Significance		**	**	NS	*
N-Rate					
25		9.02	17.7	3.31	1.24
62.5		6.11	16.1	3.18	1.27
100		6.22	17.0	3.25	1.39
Significance		NS	NS	NS	NS
Linear		NS	NS	NS	NS
Quad.		NS	NS	NS	NS
Interaction					
CXN		NS	NS	NS	NS

NS = nonsignificant; * = significant at 5%; ** = significant at 1%.

Table 8. Yield, brix, pH, and titratable acidity as affected by N rate. (Hastings, 1989).

	Cultivar							
	Millot				Foch			
N Rate (lb/A)	Yield (lb/vine)	Brix	pH	Titratable Acidity	Yield (lb/vine)	Brix	pH	Titratable Acidity
30	5.97	18.5	3.46	0.78	12.10	20.0	3.27	0.92
60	5.25	17.9	3.46	0.72	13.56	19.2	3.28	0.87
90	6.72	19.4	3.42	0.83	14.02	20.1	3.39	0.89
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Linear	NS	NS	NS	NS	NS	NS	NS	NS
Quad.	NS	NS	NS	*	NS	NS	NS	NS

NS = nonsignificant; * = significant at 5%; ** = significant at 1%.

EVALUATION OF THE LAND APPLICATION OF HIGH RATES OF BY-PRODUCT LIME

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ABSTRACT: Disposal of by-product-lime from water softening plants has become a major problem. One possible solution is to apply this material on agricultural land. In this study, high rates of by - product lime were applied to sandy soils. Heavy applications had no negative impact on yield of sweet corn, soybeans, and field corn. As would be expected, there were some changes in soil properties.

Introduction:

The importance of lime for optimum crop production on sandy soils has been recognized for some time. Traditionally, agricultural limestone has been used to raise the pH level of acid soils. Other sources of liming materials exist in Minnesota.

By-product lime is produced as a result of the water softening treatment process used by several municipalities. Previously, this material was disposed of in area landfills. Recent legislation has eliminated this method of disposal. Land application is one attractive alternative to disposal in a landfill. Although the benefits of the use of low rates of liming material are well known, there is very little information which pertains to the measurement of the effects of application of high rates of this by-product liming material.

Objectives:

The overall purpose of this project is to evaluate the effect of high rates of by-product lime applied to acid, sandy soils. Within this overall purpose there are specific objectives which are:

- To measure the effect of high rates of by-product lime use on crop yield.
- To monitor plant nutrient content as affected by the application of high rates of by-product lime.
- To determine the effect of the high rates of by-product lime on properties of the sandy soils.

Experimental Procedure:

This study was initiated in 1989. Seven experimental sites were selected. Three sites were established at the Sand Plains Research Farm at Becker, two were located in Isanti County, and two were established in Chisago County. One site at the Sand Plains Research Farm was seeded to alfalfa. The remaining two were planted to soybeans and sweet corn and will be part of a soybean/sweet corn rotation.

Corn was planted at both sites in Isanti County. Both corn and soybeans were planted in Chisago County. Both sites in Chisago County will be in a corn/soybean rotation. All sites selected were irrigated. Soils at the experimental sites are representative of the acid, sandy soils in East-Central Minnesota.

Soil samples were collected from each experimental site before any treatments were applied. Results of the analysis of these samples are summarized in Table 1.

Samples of the stock-piled by-product lime that was to be used for this project were analyzed for Effective Calcium Carbonate Equivalent in early April. This analysis showed that an application of 2 ton of by-product lime per acre would be equivalent to a rate of 1 ton per acre of regular ag lime. On a dry weight basis, this material was approximately 28% Ca and .5% Mg.

A practical minimum application of ag lime is 2 ton per acre. The by-product lime was applied at rates of 4, 16, 32, and 64 ton per acre at each experimental site. Two controls were also used. One was the complete control where no lime is used. The application of 2 ton of ag-lime per acre serves as the second control. An additional treatment consisted of the application of 50 lb. magnesium (Mg) per acre (supplied as epsom salts) in addition to the 32 ton of by-product lime per acre. This treatment was included to determine if added Mg would be beneficial when high rates of by-product lime were applied. Each treatment was replicated 4 times at each experimental site. All liming materials were incorporated with conventional tillage equipment prior to planting.

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Table 1. Relevant soil properties (0-6 inches) for the selected experimental sites before treatment application.

Location	Crop	pH	P	K	Mg	Zn	O.M.
			- - - - - - - - - - ppm			- - - - - - - -	%
Becker	Alfalfa	5.4	20	48	55	.5	2.3
Becker	Sweet Corn	5.3	21	53	56	.5	1.8
Becker	Soybeans	5.4	21	73	69	.4	2.6
Isanti Co.	Corn (North)	5.4	80	128	33	1.5	1.4
Isanti Co.	Corn (South)	5.5	73	158	52	2.2	.7
Chisago Co.	Corn	5.5	100+	98	58	.8	1.5
Chisago Co.	Soybeans	5.3	100+	117	46	.9	1.7

Management practices conducive to high yields were used at all sites. Plant tissue samples were collected during the growing season to monitor nutrient uptake. For field corn, the leaf opposite and below the ear was taken for the sample. A similar leaf sample was collected when sweet corn was the test crop. Nutrient content of the sweet corn ear was also measured. For soybeans, the most recently matured trifoliate at early bloom was used for the sample. Water samples were collected from irrigation wells in mid summer and the results are in Table 2.

The sweet corn, soybean and field corn crops were harvested when they were mature. Following harvest, soil samples (0-6 inches) were taken from all plots. These soil samples were analyzed for pH, phosphorus (P), exchangeable calcium (Ca), exchangeable potassium (K), exchangeable magnesium (Mg), micronutrients, and heavy metals by standard analytical procedures. In addition to samples taken from 0-6 inches, soil samples were collected from 6-12, 12-24, 24-36, 36-48, and 48-60 inches from the control treatment and the 64 ton/acre BPL treatment at all locations. These samples were analyzed in the same way as samples taken from 0-6 inches.

Table 2. Nutrient content of irrigation water at the experimental sites.

Nutrient	Chisago Co.	Isanti Co.	Becker
	- - - - - - - - - -	ppm	- - - - - - - - - -
nitrogen (N)	3.9	.5	8.0
phosphorous (P)	.04	.04	.04
potassium (K)	.9	1.5	.9
sulfur (S)	8.8	4.5	11.9
calcium (Ca)	38.2	46.2	64.2
magnesium (Mg)	16.0	9.7	18.0
zinc (Zn)	.02	.03	.03
iron (Fe)	.03	.03	.03
manganese (Mn)	.19	.14	.01
copper (Cu)	.03	.03	.03
boron (B)	.03	.03	.04

Standard regression procedures and appropriate "t" tests were used to analyze the data collected.

Results and Discussion:

Yield

The alfalfa was seeded at the Becker location in late May and no yields were measured during the 1989 growing season.

The soybean yields measured at the Becker and Chisago County sites are listed in Table 3. Yields were much higher at the Becker site. This is attributed, in part, to earlier planting and less damage from grasshoppers.

Considering the rates of by-product lime at Becker, there was a linear increase in yield. The yield from the use of 2 ton of ag lime was equivalent to the application of 4 ton of by-product lime. The addition of 50 lb Mg per acre to the 32 ton of by-product lime did not increase yield.

Lime use had no significant effect on soybean yield at the Chisago County site. There was considerable variability in the data and this may have masked treatment effects.

Table 3. The effect of high rates of by-product lime on soybean yield.

Treatment	Location: Becker	Location: Chisago Co.
ton/acre	- - - - - - bu./acre	- - - - - - -
Control	53.4	30.5
2 AL[1/]	54.1	33.7
4 BPL	54.1	33.3
16 BPL	54.0	33.0
32 BPL	55.7	30.3
64 BPL	55.6	32.7
32 BPL + 50 lb. Mg	53.0	33.1

[1/] AL = ag lime; BPL = by- product lime

The effect of the treatment used on the yield of both sweet corn and field corn is summarized in Table 4. There was a substantial difference in yield levels at the Isanti County sites. The majority of this is attributed to soil characteristics. The soil texture at the north site was a sandy loam with an organic matter content of 1.4%. The water holding capacity of this soil was higher than the soil at the south site which was classified as a loamy sand having an organic matter content of .7%. There is a rather high probability that corn grown at the south site was stressed more during the growing season than the corn grown at the north site.

The application of high rates of by-product lime as well as 2 ton of ag lime per acre had no significant effect on grain yield at all locations in 1989. The yield of the sweet corn at the Becker location was not significantly affected by the application of either ag lime or by-product lime.

Table 4. The effect of high rates of by-product lime on the yield of both sweet corn and field corn.

Treatment	Location: Becker[2/]	Location: Isanti Co. (North)	Location: Isanti Co. (South)	Location: Chisago Co.
ton/acre	ton/acre	- - - - - - - - - - - - - - - bu./acre	- - - - - - - - - - - - - - -	
Control	8.6	203.7	133.4	130.7
2 AG[1/]	9.4	203.4	148.3	124.7
4 BPL	7.6	190.3	162.9	131.6
16 BPL	7.9	195.4	149.4	136.2
32 BPL	8.5	196.1	130.6	133.5
64 BPL	8.8	191.6	141.8	138.8
32 BPL + 50 lb. Mg	8.2	192.2	160.7	137.2

* Sweet corn was grown at the Becker site; field corn at all other sites.
[1/] Al = ag lime; BPL = by-product lime
[2/] Yield of green, unhusked ears

Nutrient Content

The application of high rates of the by-product lime had a consistent effect on the concentration of potassium (K), and magnesium (Mg) in the soybean leaf tissue (Table 5). The K concentration increased slightly as the rate of lime was increased. By contrast, there was a general decrease in the concentration of Mg as lime rates increased. The concentration of Ca was quite variable.

At Becker, the concentration of copper (Cu) decreased with rate of applied lime. This was not observed at the Chisago County site. Lime application increased the P concentration in the soybean tissue at Chisago County but had no effect on the uptake of this nutrient at Becker. The uptake of iron (Fe), manganese (Mn), zinc (Zn), and boron (B) was not affected by lime application at both experimental sites.

Comparing the application of 2 ton of ag lime per acre, there was no significant difference in nutrient concentration at both locations. The use of an additional 50 lb. of Mg per acre did not increase the concentration of Mg in the soybean leaf tissue at both sites.

Table 5. Influence of lime application on the nutrient concentration of leaf tissue of soybeans at early bloom.

Treatment	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	Nutrient								
tons/A	%				ppm				
Becker:									
Control	0.259	2.98	0.771	0.409	92.1	92.4	19.0	10.4	4.5
2 AG*	0.276	3.27	0.741	0.476	95.6	83.4	19.1	10.2	4.4
4 BPL**	0.271	2.99	0.804	0.442	91.9	87.1	19.9	10.5	4.5
16 BPL	0.274	3.28	0.686	0.347	88.4	107.0	21.7	9.9	4.3
32 BPL	0.262	3.21	0.735	0.394	92.3	84.1	18.8	9.6	4.3
64 BPL	0.265	2.95	0.747	0.512	93.9	79.0	17.5	10.2	4.4
32 BPL + 50 lbs. Mg	0.276	3.23	0.751	0.367	91.6	92.8	21.7	10.1	4.6
Chisago:									
Control	0.742	2.48	0.865	0.587	91.6	97.0	53.0	10.0	28.3
2 AG	0.810	2.58	0.891	0.589	86.9	80.1	54.4	9.5	29.2
4 BPL	0.759	2.46	0.902	0.581	89.3	86.5	51.8	10.1	27.6
16 BPL	0.786	2.55	0.930	0.571	88.1	69.8	50.8	9.9	27.7
32 BPL	0.789	2.56	0.881	0.591	90.4	65.9	50.2	10.4	27.4
64 BPL	0.801	2.49	0.841	0.625	87.1	70.2	50.5	10.4	28.8
32 BPL + 50 lbs. Mg	0.751	2.48	0.882	0.613	90.8	76.3	50.2	10.6	27.7

* = ag lime; ** = BPL by-product lime.

The concentration of Mg in the ear leaf of the field corn tissue increased with rate of applied lime at all locations. Nutrient concentrations from the Isanti County locations are summarized in Table 6, while concentrations for corn grown in Chisago are listed in Table 7.

The effects of the application of high rates of by-product lime on the concentration of other essential nutrients were not consistent at all locations.

The application of 2 ton of ag lime and 4 ton of by-product lime per acre had an equal effect on the concentration of all nutrients in the ear leaf tissue of corn at all locations. The addition of 50 lb. of Mg per acre to the 32 ton of by-product lime per acre did not increase the concentration of Mg in the ear leaf tissue.

For sweet corn, the Mg concentration in the ear leaf increased with rate of application of the by-product lime. The concentration of manganese (Mn) decreased as the rate of by-product lime increased. Otherwise, the application of high rates of lime had no significant effect on the concentration of nutrients in the ear leaf tissue.

The nutrient concentration in the sweet corn ear was measured at harvest and the results are summarized in Table 7. Except for a decrease in the Mn concentration, the application of high rates of by-product lime had no significant effect on the nutrient concentration in the edible sweet corn.

Table 6. Influence of lime application on the nutrient concentration of the ear leaf tissue of corn at silking in Isanti County.

Treatment	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
tons/A	%				ppm				
North Site:									
Control	0.324	2.76	0.430	0.200	229.3	102.2	46.0	9.3	4.4
2 AG *	0.319	2.77	0.440	0.203	207.7	103.7	46.2	9.1	4.4
4 BPL**	0.324	2.64	0.451	0.196	218.3	109.8	51.6	8.5	4.5
16 BPL	0.308	2.75	0.422	0.208	203.3	102.6	44.4	8.8	4.4
32 BPL	0.319	2.65	0.457	0.226	225.2	108.6	45.8	9.6	4.5
64 BPL	0.312	2.65	0.424	0.242	224.1	100.7	42.3	9.1	4.2
32 BPL + 50 lbs. Mg	0.307	2.63	0.438	0.242	215.0	113.1	46.4	8.6	4.6
South Site:									
Control	0.339	2.62	0.342	0.123	156.8	137.0	55.6	6.8	4.3
2 AG	0.315	2.63	0.364	0.141	154.4	130.3	50.1	6.9	4.1
4 BPL	0.315	2.66	0.367	0.141	147.1	119.7	52.3	7.3	4.0
16 BPL	0.313	2.62	0.369	0.179	150.0	128.8	49.7	7.2	4.2
32 BPL	0.299	2.60	0.388	0.220	141.8	119.8	42.7	6.9	4.4
64 BPL	0.313	2.69	0.379	0.233	147.9	148.8	47.1	7.3	4.5
32 BPL + 50 lbs. Mg	0.289	2.60	0.361	0.221	140.9	112.0	48.7	7.2	4.1

* = ag lime; ** = BPL by-product lime.

Table 7. Influence of lime application on the nutrient concentration of the ear leaf of corn at the Chisago County site, sweet corn at the Becker site, and the the sweet corn ear at the Becker site.

Treatment	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
tons/A	%				ppm				
Chisago Co:									
Control	0.273	2.16	0.429	0.265	89.7	66.5	26.6	9.3	4.4
2 AG *	0.276	2.19	0.429	0.268	90.1	55.0	24.3	8.6	4.4
4 BPL**	0.286	2.16	0.444	0.300	90.0	51.3	25.2	9.1	4.9
16 BPL	0.286	2.09	0.449	0.312	92.4	48.0	24.8	9.5	4.2
32 BPL	0.300	2.10	0.450	0.371	94.0	42.3	25.3	9.7	4.5
64 BPL	0.293	2.04	0.443	0.419	92.8	61.7	24.8	10.2	4.8
32 BPL + 50 lbs. Mg	0.286	2.02	0.427	0.378	87.0	51.1	23.8	9.4	4.5
Becker: (earleaf)									
Control	0.26	3.19	0.68	0.30	90	114	22	9.9	4.3
2 AG	0.27	3.21	0.74	0.36	90	94	22	10.2	4.6
4 BPL	0.27	3.06	0.78	0.36	92	98	21	10.6	4.5
16 BPL	0.27	3.10	0.78	0.44	94	83	18	10.0	4.5
32 BPL	0.27	3.15	0.77	0.46	94	78	18	9.9	4.4
64 BPL	0.29	3.35	0.70	0.49	95	85	20	10.1	4.3
32 BPL + 50 lbs. Mg	0.26	2.83	0.78	0.54	91	74	17	10.3	4.4
Becker: = (ear)									
Control	0.47	1.47	.026	0.18	36	19.6	45	6.2	6.0
2 AG	0.41	1.27	.024	0.16	35	17.1	38	6.0	5.4
4 BPL	0.46	1.41	.026	0.19	39	18.5	41	5.9	6.2
16 BPL	0.42	1.28	.025	0.17	34	16.5	38	5.7	5.5
32 BPL	0.44	1.33	.025	0.18	37	15.9	39	5.5	5.4
64 BPL	0.47	1.44	.024	0.19	32	16.6	42	5.9	5.8
32 BPL + 50 lb. Mg	0.44	1.37	.023	0.19	34	16.2	39	6.1	5.6

* = ag lime; ** BPL = by-product lime

Nutrient Content In Soil

From the measurement of yields of sweet corn, field corn, and soybeans, it was obvious that the use of very high rates of by-product lime had no negative effect on crop production. Soil samples from 0-6 inches were taken from all plots after harvest in order to determine the effect of the by-product lime on the nutrient content of soils as well as the concentration of heavy metals that might be added when the lime is applied to the land.

The results from the plots that were planted to soybeans in 1989 are summarized in Table 8. As would be expected, the soil pH increased with the rate of lime that was applied. The increase was greater at the Chisago County site. Liming had no significant effect on the K values at both sites.

The substantial increase in both exchangeable Ca and exchangeable Mg would be expected. This increase was substantial at both sites.

Considering the micronutrients, lime application reduced the level of Mn only at Becker. The decrease was curvilinear. At the Chisago County site, the application of the by-product lime reduced the amount of Fe, Mn, and Cu extracted by the DTPA procedure. At the present time, there is no apparent explanation for the differences in effect on micronutrients noted.

Table 8. Effect of lime application on soil pH and the concentration of essential nutrients in soil (0-6 inches) where soybeans were grown in 1989.

Treatment	pH	K	Ca	Mg	Fe	Mn	Zn	Cu
	Nutrient							
tons/A	ppm							
Becker:								
Control	5.3	66	636	84	75.6	27.2	1.1	.7
2 AG *	5.7	66	688	118	63.4	14.6	.8	.5
4 BPL**	5.5	74	858	106	74.3	21.9	1.0	.7
16 BPL	6.0	78	846	104	46.0	8.9	.5	.5
32 BPL	6.2	74	1248	150	53.9	9.1	.7	.6
64 BPL	6.3	82	2144	212	60.0	12.4	.8	.7
32 BPL + 50 lbs. Mg	6.2	70	1196	131	59.6	12.8	.8	.6
Chisago Co:								
Control	6.0	109	624	78	56.3	3.1	.8	.3
2 AG	6.1	121	528	125	53.3	2.3	.9	.3
4 BPL	6.4	82	726	90	47.3	1.9	.8	.3
16 BPL	6.8	105	1118	133	42.4	1.6	.7	.3
32 BPL	7.2	121	1730	190	40.1	1.7	.7	.4
64 BPL	7.6	113	3498	330	35.6	2.1	.7	.5
32 BPL + 50 lbs. Mg	7.2	98	1838	205	39.1	1.5	.7	.3

* = ag lime; ** = BPL by-product lime.

Results of the analysis of soil samples collected from the experimental sites in Isanti County are summarized in Table 9. Again, there was an increase in soil pH which is consistent with expectations. The increase was greater at the South site. The soil at this site has a lower organic matter content and, therefore, would be less resistant to changes in pH produced by liming.

In general, the effect of lime applications on soil properties was consistent at both sites. The exchangeable K content did not change. There was, however, a substantial increase in both exchangeable Ca and Mg with lime application. This observation is consistent with expectations.

The effect of liming on the amounts of micronutrients extracted by the DTPA procedure was consistent. At both sites, there was a decrease in the amount of both Fe and Mn extracted. This decrease was linear with rate of by-product lime applied.

Table 9. Effect of lime application on soil pH and the concentration of essential nutrients in soil (0-6) inches at the experimental sites in Isanti County.

Treatment	pH	K	Ca	Mg	Fe	Mn	Zn	Cu
	Nutrient							
tons/A	ppm							
North Site:								
Control	5.8	160	430	76	78.1	7.5	2.2	.5
2 AG *	6.5	179	686	146	57.1	4.8	2.0	.4
4 BPL**	6.4	129	660	94	56.3	3.4	1.5	.4
16 BPL	6.9	137	1166	138	57.2	3.3	1.7	.4
32 BPL	7.1	148	1700	188	53.8	3.8	1.5	.5
64 BPL	7.3	125	2736	269	49.3	3.5	1.9	.6
32 BPL + 50 lbs. Mg	7.0	113	1024	152	53.9	3.3	1.9	.4
South Site:								
Control	5.8	117	212	35	47.7	3.9	3.0	.3
2 AG	6.0	117	248	60	41.5	2.6	1.7	.3
4 BPL	6.3	105	416	54	38.0	2.6	1.6	.3
16 BPL	7.0	109	770	85	34.8	2.3	1.2	.3
32 BPL	7.4	90	1592	143	30.8	2.2	2.7	.4
64 BPL	7.6	98	2236	200	32.4	2.4	1.1	.5
32 BPL + 50 lbs. Mg	7.5	101	2246	191	28.6	2.4	1.5	.4

* = ag lime; ** = BPL by-product lime.

Table 10. Effect of lime application on soil pH and the concentration of essential nutrients in soil (0-6) inches) at Chisago County where corn was grown and at Becker where sweet corn was grown.

Treatment	pH	K	Ca	Mg	Fe	Mn	Zn	Cu
	Nutrient							
tons/A	ppm							
Chisago Co:								
Control	5.5	66	320	54	59.1	3.8	.9	.2
2 AG *	6.0	66	552	102	52.6	2.7	.8	.2
4 BPL**	6.1	86	502	73	48.2	2.2	.8	.3
16 BPL	6.6	74	870	112	42.6	1.8	.9	.3
32 BPL	7.2	82	2264	211	39.9	2.2	.7	.4
64 BPL	7.3	82	2586	240	41.7	2.4	.7	.4
32 BPL + 50 lbs. Mg	6.9	62	1048	144	41.3	1.9	.7	.3
Becker:								
Control	5.0	133	616	88	74.9	25.1	1.0	.7
2 AG	5.1	109	610	90	65.1	21.3	.9	.7
4 BPL	5.2	90	608	82	61.0	20.7	.8	.6
16 BPL	5.4	98	646	88	49.8	12.0	.6	.6
32 BPL	5.6	113	834	98	54.2	12.9	.8	.6
64 BPL	5.8	156	1334	152	61.3	14.8	.8	.8
32 BPL + 50 lbs. Mg	5.7	90	812	108	44.5	9.9	.6	.5

* = ag lime; ** = BPL by-product lime

The soil samples were also analyzed for lead (Pb), nickel (Ni), cadmium (Cd), and chromium (Cr). These heavy metals could be added to soils when the high rates of by-product lime are applied. At Becker, the amount of these metals extracted by the DTPA procedure did not change with lime application (Table 11). The concentration of these heavy metals decreased as rate of lime increased at the Chisago County site. It is important to note that concentrations did not increase with any rate of lime applied.

Considering the heavy metals, the amount of lead extracted decreased as rate of lime was increased at the North site (Table 12). At the South site, the amount of nickel extracted decreased as the rate of lime was increased. Otherwise, the rate of lime applied had no significant effect on the amount of 4 heavy metals extracted from the soil. Again, there was no increase in heavy metal concentrations when high rates of by-product lime were applied.

Table 11. Effect of lime application on heavy metal content of soil at sites where soybeans were grown.

Site	Heavy Metal	Treatment (ton/acre) 0	2 AG*	4 BPL	16 BPL	32 BPL	64 BPL	32 BPL+Mg
		ppm						
Becker	Lead	1.18	.91	1.11	.79	.70	1.00	.84
"	Nickel	1.61	1.11	1.36	.85	.97	1.07	1.06
"	Cadmium	.13	.09	.13	.07	.13	.15	.10
"	Chromium	.04	.05	.04	.02	.03	.03	.03
Chisago Co.	Lead	.49	.55	.48	.41	.30	.30	.34
"	Nickel	.31	.38	.25	.23	.17	.13	.15
"	Cadmium	.08	.05	.05	.05	.06	.04	.05
"	Chromium	.02	.02	.02	.02	.02	.02	.05

AG = ag lime; BPL = by-product lime

Table 12. Effect of lime application on heavy metal content of soil at the sites where corn was grown in 1989.

Site	Heavy Metal	Treatment (ton/acre) 0	2 AG*	4 BPL	16 BPL	32 BPL	64 BPL	32 BPL+Mg
		ppm						
~~Becker~~ I Sandi N	Lead	.70	.36	.50	.48	.47	.31	.36
"	Nickel	.48	.45	.28	.31	.28	.21	.23
"	Cadmium	.05	.07	.04	.05	.05	.04	.03
" I Sandi S	Chromium	.03	.03	.02	.02	.02	.03	.02
~~Chisago Co.~~	Lead	.32	.35	.31	.34	.36	.34	.27
"	Nickel	.27	.19	.22	.15	.11	.09	.10
"	Cadmium	.03	.03	.02	.03	.03	.03	.03
"	Chromium	.02	.02	.02	.02	.02	.02	.02
Chisago Co.	Lead	.70	.55	.52	.40	.35	.36	.40
"	Nickel	.23	.22	.20	.17	.11	.14	.16
"	Cadmium	.05	.05	.06	.03	.03	.04	.05
"	Chromium	.02	.02	.02	.02	.02	.02	.03
Becker	Lead	1.29	1.13	1.11	.93	.97	1.01	.79
"	Nickel	1.40	1.29	1.06	.91	.96	1.02	.81
"	Cadmium	<.04	<.03	<.03	<.02	<.04	<.03	<.02
"	Chromium	<.05	<.03	<.02	<.02	<.02	<.03	<.03

* AG = ag lime; BPL = by-product lime

Soil samples were also collected to a depth of 5 feet in order to monitor any changes in soil properties below the 0-6 inch depth. To do this, the properties from the control treatment are compared to properties from plots where the rate of 64 ton per acre of by-product lime was used. This comparison was made at each site. Results are summarized in Tables 13-18.

Composite samples were prepared for each treatment and were analyzed. Therefore, there is no statistical interpretation of data presented in Tables 13-18. Except for the 6-12 inch depth, there were no major differences in the concentration of both plant nutrients and heavy metals. The increase in pH, exchangeable Ca, and exchangeable Mg at the 6-12 inch depth is probably due to the incorporation of the limestone with the tillage implements that were used for crop production.

Table 13. Effect of the application of a high rate of by-product lime on soil properties at the Chisago County site where soybeans were grown in 1989.

Crop Grown	Lime Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
				Soil Property										
	tons/A	inches		ppm										
Soybeans	0	6-12	4.9	101	296	42	58	3.1	0.6	0.3	0.59	0.18	0.03	0.05
"	0	12-24	5.7	59	402	53	33	0.6	0.1	0.2	0.43	0.19	<0.02	0.05
"	0	24-36	5.9	51	522	84	26	0.9	0.1	0.3	0.34	0.11	<0.02	0.05
"	0	36-48	6.7	35	354	66	19	1.3	0.1	0.3	0.22	0.09	<0.02	0.03
"	0	48-60	7.6	12	538	108	19	5.5	0.1	0.3	0.22	0.09	<0.02	0.03
Soybeans	64	6-12	7.4	70	1456	161	29	0.8	0.3	0.3	0.53	0.09	0.02	0.05
"	64	12-24	5.6	59	400	61	39	0.9	0.1	0.2	0.39	0.15	<0.02	0.02
"	64	24-36	6.3	62	364	53	27	0.3	0.1	0.2	0.34	0.11	<0.02	0.02
"	64	36-48	6.0	39	280	26	23	1.0	0.1	0.2	0.22	0.09	<0.02	0.02
"	64	48-60	6.9	51	276	25	-	-	-	-	-	-	-	-

Table 14. Effect of the application of a high rate of by-product lime on soil properties at the Chisago County site where corn was grown in 1989.

Crop Grown	Lime Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
				Soil Property										
	tons/A	inches		ppm										
Corn	0	6-12	5.1	74	324	52	53	2.4	0.6	0.3	0.56	0.12	<0.02	<0.02
"	0	12-24	5.9	55	382	77	32	0.4	0.1	0.2	0.34	0.09	<0.02	<0.02
"	0	24-36	6.1	47	256	34	20	0.3	0.1	0.2	0.22	0.09	<0.02	<0.02
"	0	36-48	6.3	43	502	89	23	1.4	0.1	0.2	0.25	0.11	<0.02	<0.02
"	0	48-60	6.8	39	332	74	18	0.9	0.1	0.2	0.22	0.09	<0.02	<0.02
Corn	64	6-12	6.3	66	774	110	40	0.9	0.6	0.2	0.40	0.09	<0.02	<0.02
"	64	12-24	6.0	43	376	59	29	0.3	0.1	0.2	0.31	0.09	<0.02	<0.02
"	64	24-36	5.9	31	326	43	32	0.4	0.1	0.2	0.22	0.09	0.05	<0.02
"	64	36-48	6.1	23	230	23	21	0.5	0.1	0.2	0.22	0.09	0.03	<0.02
"	64	48-60	6.6	12	238	28	18	1.2	0.1	0.3	0.34	0.09	<0.02	<0.02

Table 15. Effect of the application of a high rate of by-product lime on soil properties at the North site in Isanti County.

Crop Grown	Lime Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
				Soil Property										
	tons/A	inches		ppm										
Corn	0	6-12	4.9	82	382	49	82	8.4	0.9	0.5	1.13	0.35	<0.02	0.04
"	0	12-24	5.9	86	518	101	68	4.0	0.2	0.3	0.53	0.13	<0.02	0.03
"	0	24-36	6.0	39	314	50	42	1.1	0.1	0.2	0.64	0.09	<0.02	0.03
"	0	36-48	5.7	16	248	34	25	0.3	0.1	0.1	0.42	0.09	<0.02	<0.02
"	0	48-60	5.5	23	412	46	43	0.9	0.1	0.2	0.35	0.09	<0.02	<0.02
Corn	64	6-12	4.7	101	286	42	89	9.0	0.6	0.4	0.66	0.44	0.06	<0.02
"	64	12-24	5.3	94	336	74	74	2.0	0.1	0.2	0.22	0.12	<0.02	<0.02
"	64	24-36	5.3	12	320	46	39	0.5	0.1	0.1	0.35	0.09	<0.05	<0.02
"	64	36-48	5.6	35	282	48	51	0.7	0.1	0.1	0.22	<0.09	<0.02	<0.02
"	64	48-60	5.5	16	346	53	46	0.8	0.1	0.1	0.23	<0.09	<0.02	<0.02

Table 16. Effect of the application of a high rate of by-product lime on soil properties at the South site in Isanti County.

Crop Grown	Lime Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
				Soil Property										
	tons/A	inches		ppm										
Corn	0	6-12	4.8	47	184	20	66	7.6	0.6	0.2	<0.22	0.28	0.15	0.09
"	0	12-24	5.2	59	234	41	54	3.2	0.1	0.2	<0.22	0.11	0.02	<0.02
"	0	24-36	5.7	59	228	58	58	0.7	0.1	0.2	<0.22	<0.09	0.02	<0.02
"	0	36-48	5.7	47	288	64	48	0.6	0.1	0.1	0.45	0.11	<0.02	0.02
"	0	48-60	5.9	70	418	84	54	1.2	0.1	0.2	<0.22	<0.09	0.04	0.03
Corn	64	6-12	4.8	51	140	38	58	3.2	0.7	0.3	0.29	0.11	0.04	0.06
"	64	12-24	4.7	90	264	53	103	2.2	0.1	0.3	0.34	0.29	0.04	<0.02
"	64	24-36	5.3	90	290	74	60	0.8	0.1	0.2	<0.22	<0.09	<0.02	<0.02
"	64	36-48	6.5	74	494	94	45	1.1	0.1	0.2	<0.22	0.12	<0.02	<0.02
"	64	48-60	5.5	70	320	68	58	3.1	0.7	0.2	<0.22	<0.09	<0.02	<0.02

Table 17. Effect of the application of a high rate of by-product lime on soil properties at the Becker site where sweet corn was grown.

Crop Grown	Lime Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
				Soil Property										
	tons/A	inches		ppm										
S.Corn	0	6-12	4.9	62	632	82	53	11.7	0.6	0.6	0.93	0.77	<0.02	0.06
"	0	12-24	5.5	20	460	44	24	1.9	0.1	0.3	0.62	0.14	<0.02	0.03
"	0	24-36	5.9	12	234	18	17	4.5	0.1	0.2	0.24	<0.09	<0.02	<0.02
"	0	36-48	8.0	12	846	204	15	5.3	0.1	0.3	0.29	<0.09	<0.02	0.05
"	0	48-60	8.2	12	1858	222	14	4.5	0.1	0.3	0.42	<0.09	<0.02	<0.09
S.Corn	64	6-12	6.0	98	1114	167	41	4.0	0.5	0.6	0.53	0.46	<0.02	<0.02
"	64	12-24	5.5	31	456	52	22	1.5	0.1	0.3	0.53	0.13	<0.02	<0.02
"	64	24-36	6.1	12	208	20	14	3.0	0.1	0.2	0.51	<0.09	<0.02	<0.02
"	64	36-48	7.8	12	844	143	16	4.1	0.1	0.3	0.46	<0.09	<0.02	<0.02
"	64	48-60	8.0	12	932	160	15	3.9	0.1	0.3	0.31	<0.09	<0.02	<0.02

Table 18. Effect of the application of a high rate of by-product lime on soil properties at the Becker site where soybeans were grown.

Crop Grown	Lime Rate	Depth	pH	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	Cd	Cr
				Soil Property										
	tons/A	inches		ppm										
Soybeans	0	6-12	4.9	55	660	80	54	11.7	0.6	0.5	0.82	0.94	0.06	0.04
"	0	12-24	5.7	20	440	35	24	1.7	0.1	0.3	0.34	0.29	<0.02	0.03
"	0	24-36	6.0	12	268	22	17	3.6	0.1	0.3	0.39	<0.09	0.07	0.04
"	0	36-48	7.7	12	470	71	14	4.2	0.1	0.3	0.37	<0.09	<0.02	0.02
"	0	48-60	7.7	12	376	59	15	4.8	0.2	0.2	0.41	0.20	0.02	0.03
Soybeans	64	6-12	6.6	43	1692	232	42	3.5	0.4	0.6	0.32	0.63	0.02	0.03
"	64	12-24	5.6	12	510	41	26	1.7	0.1	0.5	0.57	0.27	<0.02	<0.02
"	64	24-36	7.1	12	562	59	16	3.0	0.1	0.3	0.33	<0.09	<0.02	<0.02
"	64	36-48	7.3	12	354	58	17	4.4	0.1	0.2	<0.22	<0.09	<0.02	<0.02
"	64	48-60	8.0	12	968	142	17	4.6	0.1	0.3	0.33	<0.09	<0.02	<0.02

Summary:

This study was conducted to monitor the effects of the use of high rates of by-product lime on crop yield, nutrient uptake by crops and soil properties. The data collected in 1989 lead to the following statements.

1. Use of high rates of by-product lime had no adverse effects on crop yield. Crops harvested in 1989 were sweet corn, field corn, and soybeans.

2. The high rates of by-product lime affected the uptake of some nutrients. Although changes in the concentration of some nutrients were noted, they did not affect yield.

3. Some changes in soil nutrient concentration were measured, but they had no negative effect on yield.

4. The high rates of by-product lime did not alter the concentration of heavy metals in soils.

From the data collected in 1989, it would appear that high rates of by-product lime can be applied without harm to either crop production or the environment. This study will be continued in an effort to monitor future changes.

Deep tillage and Tillage System Effects on Corn Growth and Yield on an Aquic Soil[1]

J.F. Moncrief, T.L. Wagar and J.J. Kuznia[2]

Conservation tillage and deep chiseling were evaluated on a somewhat poorly drained soil for a second year. Conservation tillage did not affect corn stand or early growth. Conservation tillage systems resulted in an average yield decline of 20 bushels per acre. Corn response to deep chiseling was an average 6 bushels per acre and not affected by tillage system.

This study is in it's third year. The purpose is to evaluate tillage system effects and deep chiseling on corn growth and yield. The soil at this site has a thin layer of loess over dense glacial till and is well tiled.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and four replications. All main tillage plots were split with a deep chisel plowing in the fall(table 1). Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot. Grain yields were estimated with a combine with a four row head.

Results and Discussion

Soil cover by corn residue is shown in table 2 and 3. These measurements were made after the first cultivation. Soil cover ranged from 8 to 50%. Deep chiseling reduced soil cover by about 5%. Early growth and plant stands were not affected by tillage (tables 4 and 5).

Grain yields were affected by tillage system and deep chiseling (table 6). Conservation tillage systems resulted in a 20 bu/acre reduction in yield. The deep chiseling response was not affected by tillage system. The average response to deep chiseling was 6 bushels per acre.

DODGE COUNTY

Table 1. Cultural practices at Dodge County, MN. 1989.

Tillage
Ridge Till
Fall Disc
Fall Chisel Plow
Fall Moldboard Plow

Preceding Crop
1985-1988 Corn

1989 Crop
Corn-Pioneer 3737

All plots split with a Mohawk chisel plow, 8-10 inches deep, done in the fall prior to fall tillage. Shanks are spaced on 28 inch centers and are a point type that run in the center of the row.
Secondary tillage, a light discing, on May 10.
All plots were rotary hoed on May 24, cultivated once on June 17 and ridged on July 6.

Planting and Harvest Date
A six row John Deere 7000 with 28 inch row spacing was used.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 10, 1989	28,000 plants/A	October 18, 1989

[1] *This project is supported by the Soil Conservation Service, the Minnesota Extension Service, and the Dodge County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by SCS, SWCD, MES field staff. Without their assistance this project would have not been possible.*

[2] *John F. Moncrief and Joe J. Kuznia are Associate Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108. Tim L. Wagar is an area Crops and Soils Extension Agent stationed at Rochester, MN.*

Fertilization History

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied	Method of Application
			--- lb/A ---				
Corn:	46-0-0	370 lbs/A	170	0	0	April 16, 1987	Broadcast
	7-21-7	10 gal/A	8	24	8	April 29, 1987	Applied with the seed
Corn:	82-0-0	213 lbs/A	175	0	0	April 5, 1988	Injected
	7-21-7	5.5 gal/A	4	13	4	April 20, 1988	Applied with the seed

1989 Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied	Method of Application
			--- lb/A ---				
Corn:	82-0-0	220 lbs/A	180	0	0	April 19, 1989	Injected
	7-21-7	6.3 gal/A	5	15	5	May 10, 1989	Applied with the seed

Soil

The soil at this site is a Skyberg silt loam (Udollic Ochraqualfs, fine-loamy, mixed mesic), with 0 to 2 percent slope and is somewhat poorly drained.

Weed Control

2.5 pt/A (2.5 lbs/A) Dual + 2 lbs/A (1.8 lbs/A) Bladex 90 DF + 1 lb/A (.9 lb/A) Atrazine 90 DF applied on May 11, 1989.

.75 pt/A (.375 lb/A) Banvel applied postemergence at 3-leaf stage.

Insecticide Control

8 lbs/A (1.2 lb/A) Broot 15G at time of planting.

Table 2. Effect of tillage and position relative to the row on soil covered by corn residue at Dodge Co. on June 20, 1989[1]

Location	Tillage: Mldbd	Ridge	Disc	Chisel	Avg.
	---------- % cover ----------				
In Row	7.5c	41.7a	40.2a	27.2b	29.1
Between Row	7.7c	50.7a	31.8b	27.0b	29.3
Average	7.6d	46.2a	36.0b	27.1c	

1. The p value for residue for location, tillage and tillage by location interaction are .928 (n=96), .001 (n=48), .012 (n=24) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage, position relative to the row, and deep chiseling on soil covered by corn residue in Dodge Co. on June 20, 1989[1].

Location	Moldboard Dp.Chisl	Moldboard None	Ridge Till Dp.Chisl	Ridge Till None	Disk Dp.Chisl	Disk None	Chisel Dp.Chisl	Chisel None	Average Dp.Chisl	Average None
	---------- % cover ----------									
In Row	7.3	7.7	36.7	46.7	34.3	46.0	26.3	28.0	26.2	32.1
Between Row	5.0	10.3	46.0	55.3	30.0	33.7	27.0	27.0	27.0	31.6
Average	6.2	9.0	41.3	51.0	32.2	39.8	26.7	27.5	26.6	31.9

1. The p value for deep chisel, tillage by deep chisel, deep chisel by location, tillage by location by deep chisel interactions are .050 (n=96), .707 (n=24), .716 (n=48), and .662 (n=12) respectively.

Table 4. Effect of tillage and deep chiseling on corn population at Dodge Co. on June 20, 1989[1].

	Tillage				
	Mldbd	Ridge	Disc	Chisel	
	plants/Ax10^{-3}				Avg.
Deep Chisel	28.6	25.2	25.6	25.2	26.2
No Deep Chisel	27.7	24.5	26.3	27.3	26.4
Average	28.2a	24.9a	25.9a	26.3a	

1. The p value for deep chisel, tillage, and tillage by deep chisel interaction are .794 (n=24), .269 (n=12), .672 (n=6) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 5. Effect of tillage and deep chiseling on early growth of corn at Dodge Co. on June 20, 1989[1].

	Tillage				
	Mldbd	Ridge	Disc	Chisel	
	leaves/plant				Avg.
Deep Chisel	7.2	7.5	6.8	6.5	7.0
No Deep Chisel	6.7	7.0	6.3	6.7	6.7
Average	6.9a	7.3a	6.6a	6.6a	

1. The p value for deep chisel, tillage, and tillage by deep chisel interaction are .211 (n=24), .337 (n=12), .749 (n=6) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 6. Effect of tillage and deep chiseling on corn yield and moisture at Dodge Co. on October 18, 1989[1].

	Tillage				
	Moldboard	Ridge Till	Disc	Chisel	
	bu/A				Avg.
Deep Chisel	168	155	151	146	155
No Deep Chisel	165	146	145	142	149
Average	167a	150b	148b	144b	
	%				
Deep Chisel	14.2	14.0	15.0	15.3	14.6
No Deep Chisel	14.4	14.5	14.8	14.5	14.6
Average	14.1a	14.3a	14.9a	14.9a	

1. The p value for deep chisel, tillage, and tillage by deep chisel interaction for yield are .022 (n=12), .004 (n=6), .803 (n=3) respectively. The p value for deep chisel, tillage and tillage by deep, chisel interaction for moisture are .671 (n=12), .435 (n=6), .132 (n=3) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Protein

Tillage System Effects on Nitrogen Availability and Small Grain Growth and Yield[1]

J.F. Moncrief, and J.J. Kuznia[2]

Conservation tillage was evaluated for wheat and barley production following soybeans on a on a well drained loam soil. Tillage did not affect wheat yields but reduced barley yields 6 bu/acre. Protein and N uptake was not affected by tillage.

This study is in it's fourth year. The purpose is to evaluate tillage system effects on growth and yield in a soybeans, barley, and wheat rotation.

Methods and Materials

The experimental design is a randomized complete block with three tillage treatments and three replications. Wheat and barley followed soybeans. Grain yields were estimated with a combine with a 22 foot head.

Results and Discussion

Grain yields were affected by tillage system for barley but not wheat (tables 2 and 3). Although wheat yields have been affected by tillage this is the first year barley yields have been affected (six site years). Test weight was not affected by tillage for either crop.

No till plots received 30 lbs/acre additional nitrogen. Tillage did not have statistically significant affects on grain nitrogen levels, protein, or N uptake of either crop (tables 4 and 5). The trend of less N available under conservation tillage systems is consistent with other sites and years however.

DOUGLAS COUNTY

Table 1. Cultural practices at Douglas County, MN. 1989

Tillage
No Till
Fall Chisel Plow-field cultivated once in spring
Fall Moldboard Plow-field cultivated once in spring

Preceding Crop
1985-Soybeans, 1986-Barley,
1987-Spring Wheat-Pioneer 2369 and Winter Wheat-Bighorn and Roughrider
1988-Soybeans-Pioneer 1082

1989 Crop
Spring Wheat-Pioneer 2369 Barley-Robust

Planting and Harvest Date
Planter was a Haybuster with 6 inch row spacing.

Crop	Planting Date	Planting Rate	Harvested
Wheat	April 26, 1989	1.5 bu/A	August 8, 1989
Barley	April 26, 1989	2.0 bu/A	July 26, 1989

Fertilization History

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			--- lbs/A ---			
Winter Wheat	18-46-0[1]	100 lbs/A	18	46	0	September 29, 1986
	46-0-0[2]	217 lbs/A	100	0	0	May 29, 1987
Spring Wheat	18-46-0[1]	100 lbs/A	18	46	0	April 21, 1987
	46-0-0[2]	217 lbs/A	100	0	0	May 29, 1987

1. Drill applied with seed.
2. Urea was broadcast.

[1] *This project is supported by the Soil Conservation Service, the Minnesota Extension Service, and the Douglas County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by SCS, and MES field staff. Without their assistance this project would have not been possible.*

[2] *John F. Moncrief and Joe J. Kuznia are Associate Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108.*

1989 Fertilizer

Tillage	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			--- lbs/A ---			
No Till	46-0-0[1]	130 lbs/A	60	0	0	May 2, 1988
All Others	46-0-0[1]	100 lbs/A	46	0	0	May 2, 1988
All	18-46-0[2]	100 lbs/A	18	46	0	April 26, 1989

1. Urea was broadcast.
2. Drill applied with seed.

Soil

Complex of: Barnes-Langhei loams (Udic Haploborolls, fine-loamy, mixed)-(Typic Udorthents, fine-loamy, mixed (calcareous) ,frigid) , 2 to 6 percent slopes, well-drained eroded. The Langhei occurs on eroded knobs and Barnes on uniform slopes and valleys.

Weed Control

.5 pt/A (.25 lb/A) 2,4-D applied May 26, 1989.

Table 2. Effect of tillage on barley yields, moisture, and test weight at Douglas Co. on July 26, 1989.

	Tillage NoTill	Chisel	Mldbd	Sig.
	--- bu/A ---			
Grain Yield	58b[1]	61ab	65a	.062
	--- % ---			
Moisture	17.2a	12.4b	12.2b	.005
	--- lb/bu ---			
Test Weight	43.7a	42.7a	43.7a	.309

1. Means within the same row with the same letter are not significantly different (α=.10, n=3).

Table 3. Effect of tillage on spring wheat yields, moisture, and test weight at Douglas Co. on August 8, 1989.

	Tillage NoTill	Chisel	Mldbd	Sig.
	--- bu/A ---			
Grain Yield	43a[1]	46a	43a	.663
	--- % ---			
Moisture	11.2a	11.0a	10.6a	.166
	--- lb/bu ---			
Test Weight	61.8a	62.2a	62.2a	.538

1. Means within the same row with the same letter are not significantly different (α=.10, n=3).

Table 4. Effect of tillage on barley protein, percent N in grain and N uptake by grain at Douglas Co. on July 26, 1989.

	Tillage NoTill	Chisel	Mldbd	Sig.
	--- % ---			
Protein	10.6a[1]	11.5a	11.6a	.542
	--- % ---			
Grain N	1.7a	1.8a	1.9a	.542
	--- lb/A ---			
Grain N Uptake	41.2a	47.4a	50.5a	.284

1. Means within the same row with the same letter are not significantly different (α=.10, n=3).

Table 5. Effect of tillage on Spring wheat protein, percent N in grain and N uptake by grain at Douglas Co. on August 8, 1989.

	Tillage NoTill	Chisel	Mldbd	Sig.
	--- % ---			
Protein	15.2a[1]	15.4a	14.9a	.637
	--- % ---			
Grain N	2.6a	2.7a	2.6a	.637
	--- lb/A ---			
Grain N Uptake	58.9a	64.9a	58.0a	.460

1. Means within the same row with the same letter are not significantly different (α=.10, n=3).

Tillage System and Cultivation Effects on Corn Growth and Yield on a Well Drained Silt Loam Soil[1]

J.F. Moncrief, T.L. Wagar and J.J. Kuznia[2]

Tillage and cultivation were evaluated for a fifth year of continuous corn production on a well drained silt loam soil. Giant Foxtail and Velvet Leaf were increased by less tillage. Cultivation reduced Giant Foxtail density but not Velvet Leaf. Grain yields were reduced by conservation tillage and increased by cultivation.

This study is in it's fifth year. The purpose is to evaluate tillage system interactions with row cultivation on corn growth and yield as well as changes in weed density. The soil at this site was developed in loess and is well drained.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and three replications. Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot. Weed measurements were made by visually estimating the amount of cover by weeds by species and assigning ratings based on a 1 to 6 range with: 1=0, 2=<15%, 3=15-25%, 4=25-50%, 5=50-75%, and 6=>75%. Grain yields were estimated with a combine with a four row head taking the center four rows 100 ft. long for yield estimates.

Results and Discussion

Soil cover by corn residue is shown in tables 2, 3, and 4. Soil cover by corn residue before cultivation in the row ranged from 4 to 51%. Soil cover residue between the row before cultivation ranged from 3 to 64%. The clearing discs on this planter did not decrease residue levels in the row. Cultivation reduced cover about 10% in all tillage treatments except the moldboard plowing system which was reduced about 3% (table 4).

Although corn stand establishment was not affected by tillage (June 5, table 7), early growth was delayed when "in row" cover was greater than 20% (table 5). Early growth of corn was delayed due to inadequate removal of crop residue in the row area. Stands later in the season (June 20, table 8) were affected differently under different tillage systems by the residual affects of cultivation from previous years. In the no till and chisel plowed plots there were higher levels of mortality of corn in the plots that were not cultivated in previous years. Residual effects from previous cultivation did not affect early growth, however (table 6).

Weed density data in table 9 suggest that the effects of previous cultivation on corn mortality between June 5th and 20th was due to foxtail populations that have developed over the lifetime of this study. The density of Giant Foxtail at harvest was reduced with cultivation but Velvet leaf was not affected (table 9). Cultivation effects on Giant Foxtail density does not appear to be consistent across tillage systems. The benefit of cultivation increased as tillage is reduced for foxtail control. Velvet leaf control was not enhanced by cultivation. Tillage system effects were greater than cultivation on velvet leaf density. Foxtail density was influenced about equally by cultivation and tillage. It should also be noted that the herbicide program at this site is fairly aggressive. The application of Banvel and Buctril in the middle of June should have pretty much taken care of any Velvet Leaf at this point in time.

Grain yields were affected by tillage system (table 10). Generally tillage reduction resulted in yield reduction. This is primarily due the ineffective row cleaning discs on the planter and increased weed densities. This has not been the case in previous years. With cultivation conservation tillage options were equal in yield to moldboard plowing.

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[1] *This project is supported by the Soil Conservation Service, the Minnesota Extension Service, and the Fillmore County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by MES, SCS, and SWCD field staff. Without their assistance this project would have not been possible.*

[2] *John F. Moncrief and Joe J. Kuznia are Associate Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108. Tim L. Wagar is an area Crops and Soils Extension Agent stationed at Rochester, MN.*

FILLMORE COUNTY

Table 1. Cultural practices at Fillmore County, MN. 1989.

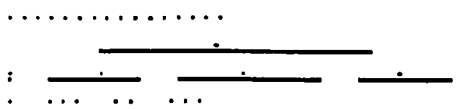
Tillage
No Till
Fall Disc
Fall Chisel Plow
Fall Moldboard Plow
Secondary tillage was done on May 7, 1989.

Cropping History
1985-1988 Corn

1989 Crop
Corn-Pioneer 3585

Cultivation
Each plot was split with cultivation on June 20, 1989.

Planting and Harvest Date



Fertilization History

1983-injected 5-6000 gal/A of liquid dairy manure.

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			--- lbs/A ---			
Corn:	16-41-8[1]	125 lb/A	20	51	10	May 6, 1985
	82-0-0	134 lb/A	110	0	0	May 22, 1985
Corn:	9-23-30[1]	125 lb/A	11	29	38	May 7, 1986
	82-0-0	244 lb/A	200	0	0	May 22, 1986
Corn:	9-23-30[1]	100 lb/A	9	23	30	April 29, 1987
	82-0-0	232 lb/A	190	0	0	May 12, 1987
Corn:	9-23-30[1]	100 lbs/A	9	23	30	May 3, 1988
	82-0-0	232 lb/A	190	0	0	June 9, 1988

1. Applied 2" beside and 2" below seed.

1989 Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			--- lbs/A ---			
Corn:	9-23-30[1]	150 lbs/A	14	35	45	May 7, 1989
	82-0-0	183 lbs/A	150	0	0	June 5, 1989

1. Applied 2" beside and 2" below seed.

Soil

Tama silt loam (Typic Argiudolls, fine-silty, mixed, mesic) and Downs silt loam (Mollic Hapludalfs, fine-silty, mixed, mesic), eroded, 2 to 6 percent slopes and is well drained.

Weed Control

2 pt/A (2 lb/A) Dual Preemergence.
3 pt/A (1.5 lbs/A) Prowl + 2.2 lbs/A (2 lbs/A) Bladex 90 DF at spike.
.5 pt/A (.25 lb/A) Banvel + 1 pt/A (.25 lb/A) Buctril + .94 lb/A (.75 lb/A) Atrazine 80 WP at 4 leaf stage.

Insecticide

6.9 lbs/A (1 lb/A) of Counter 15G at time of planting.

Table 2. Effect of tillage and position relative to the row on soil covered by corn residue in Fillmore Co. on June 5, 1989[1].

Location	Tillage: NoTill	Disc	Chisel	Mldbd	Avg.
	% cover				
In Row	51.0a	30.7b	22.3c	4.0d	27.0
Between Row	64.3a	33.7b	19.3c	3.3d	30.2
Average	57.7a	32.2b	20.8c	3.7d	

1. The p value for residue location, tillage, and tillage by location interaction are .147 (n=48), .001 (n=24), .638 (n=12) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage and position relative to the row on soil covered by corn residue in Fillmore Co. on June 20, 1989[1].

Location	Tillage: NoTill	Disc	Chisel	Mldbd	Avg.
	% cover				
In Row	36.0a	20.3b	13.3b	3.2c	18.2
Between Row	45.8a	21.5b	16.3b	2.5c	21.5
Average	40.9a	20.9b	14.8c	2.8d	

1. The p value for residue location, tillage, and tillage by location interaction are .351 (n=96), .001 (n=48), .405 (n=24) respectively. Means within the same row with the same letter are not significantly different (α=.10). Data collected after cultivation.

Table 4. Effect of tillage, position relative to the row, and cultivation on soil covered by corn residue in Fillmore Co. on June 20, 1989[1].

Location	Tillage: NoTill		Disc		Chisel		Mldbd		Average	
	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.	Cult.	No Cult.
	% cover									
In Row	35.7	36.6	15.7	25.0	9.7	17.0	1.0	5.3	15.5	20.9
Between Row	36.0	55.7	14.3	28.7	8.3	24.3	1.3	3.7	15.0	28.1
Average	35.8	46.0	15.0	26.8	9.0	20.7	1.2	4.5	15.3	24.5

1. The p value for cultivation, tillage by cultivation, cultivation by location, tillage by location by cultivation interactions are .001 (n=96), .319 (n=24), .368 (n=48), and .138 (n=12) respectively. Data collected after cultivation.

Table 5. Effect of tillage on early growth of corn at Fillmore Co.[1].

	Tillage: NoTill	Disc	Chisel	Mldbd	Sig.
	leaves/plant				
6/5/89	2.5c	2.9b	3.0a	3.1a	.001
6/20/89	4.9b	5.6a	5.6a	5.6a	.031

1. Means within the same row with the same letter are not significantly different (α=.10, n=30).

Table 6. Effect of tillage and cultivation in 1988 on early growth at Fillmore Co. on June 20, 1989[1].

	Tillage: NoTill	Disc	Chisel	Mldbd	Avg.
	leaves/plant				
Cultivation	5.0	5.6	5.6	5.6	5.4
No Cultivation	4.8	5.7	5.7	5.6	5.4
Average	4.9b	5.6a	5.6a	5.6a	

1. The p value for cultivation, tillage, and tillage by cultivation interaction are .842 (n=120), .031 (n=60), .265 (n=30) respectively. Means within the same row with the same letter are not significantly different (α=.10). Data collected before cultivation.

Table 7. Effect of tillage and cultivation in 1988 on corn population at Fillmore Co. on June 5, 1989[1].

	Tillage: NoTill	Disc	Chisel	Mldbd	Avg.
	plants/Ax10^{-3}				
Cultivation	27.7	27.1	26.8	29.1	27.7
No Cultivation	26.4	28.4	28.9	29.3	28.3
Average	27.1a	27.7a	27.9a	29.2a	

1. The p value for cultivation, tillage, and tillage by cultivation interaction are .454 (n=24), .494 (n=12), .411 (n=6) respectively. Means within the same row with the same letter are not significantly different (α=.10). Data collected before cultivation.

Table 8. Effect of tillage and cultivation on corn population at Fillmore Co. on June 20, 1989[1].

	Tillage: NoTill	Disc	Chisel	Mldbd	Avg.
	plants/Ax10^{-3}				
Cultivation	27.8	28.7	28.9	28.3	28.4
No Cultivation	24.7	29.1	26.5	28.9	27.3
Average	26.3b	28.9a	27.7ab	28.6a	

1. The p value for cultivation, tillage, and tillage by cultivation interaction are .065 (n=48), .014 (n=24), .061 (n=12) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 9. Effect of tillage and cultivation on weed severity[1] in corn at Fillmore Co. on October 23, 1989[2].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	Foxtail				Avg.
Cultivation	3.3	2.3	2.3	2.0	2.5
No Cultivation	4.0	2.7	3.0	2.0	2.9
Average	3.7a	2.5b	2.7b	2.0b	
	Velvetleaf				
Cultivation	4.0	2.7	1.7	1.3	2.4
No Cultivation	4.0	2.0	1.7	1.3	2.3
Average	4.0a	2.3b	1.7c	1.3c	

1. Weed severity ratings on scale 1 to 6, (percentage based on soil covered by weeds: 1 = 0%, 2 = <15%, 3 = 15-25%, 4 = 25-50%, 5 = 50-75%, and 6 = >75%).
2. The p value for cultivation, tillage, and tillage by cultivation interaction for foxtail are .020 (n=12), .061 (n=6), .613 (n=3) respectively. The p value for cultivation, tillage, and tillage by cultivation interaction for velvetleaf are .347 (n=12), .001 (n=6), .441 (n=3) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 10. Effect of tillage and cultivation on corn yield and moisture at Fillmore Co. on October 23, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	bu/A				Avg.
Cultivation	145	160	164	169	160
No Cultivation	142	153	157	164	154
Average	144c	157b	161ab	167a	
	%				
Cultivation	19.2	19.4	18.7	19.1	19.1
No Cultivation	20.8	20.4	18.7	19.2	19.8
Average	20.0a	19.9a	18.7a	19.2a	

1. The p value for cultivation, tillage, and tillage by cultivation interaction for yield are .132 (n=12), .011 (n=6), .997 (n=3) respectively. The p value for cultivation, tillage, and tillage by cultivation interaction for moisture are .411 (n=12), .547 (n=6), .871 (n=3) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Tillage System Effects on Corn Growth and Yield in East Central Minnesota[1]

J.F. Moncrief, and J.J. Kuznia[2]

Tillage was evaluated at two sites on well drained soils in a continuous corn cropping system. Tillage had variable effects on early growth and stand establishment. Grain yields were not affected at one site and reduced under no till conditions at the other.

This study is in it's third year. The purpose is to evaluate tillage system effects on corn growth and yield on the soils and climate of East Central Minnesota. Plots were established in Pine and Isanti counties in 1987. The soil at the Pine and Isanti site is a well drained loam and somewhat poorly drained fine sandy loam respectively.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and four replications at each site. Crop residue was measured using a line transect technique. Crop residue was characterized in and between the row. "In row" is defined as four inches centered over the row and "between row" the remainder. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot. Grain yields were estimated with a combine with a four and six row head.

Results and Discussion

Pine County

Soil cover by corn residue is shown in table 2. Soil cover in the row area ranged from 6 to 34%. Soil cover between the row area ranged from 12 to 66%. Stand establishment was not affected by tillage at this site (table 3). Final stands were lower with the no till treatment due to higher incidence of cutworms. Early corn growth was not affected by tillage. Soil cover in the row higher than 20% usually results in delayed early growth. It was unusual at this site for the no till system (38% in row cover) not to delay early growth.

Grain yields and moisture were not affected by tillage system (table 4).

Isanti County

Soil cover levels were higher at this site due to higher yields and better corn growth in the previous two years than the Pine County site (table 6). Stands were reduced about three thousand plants per acre in the no till system (table 7). Early corn growth showed about one leaf less development under no till conditions. Other conservation tillage systems had stands and early growth equal to moldboard plowing.

Grain yields were about 23 bushels per acre lower grown with the no till system. Other systems resulted in equal yields. Grain moisture was also about 2% higher under no till conditions. This reflects the early season delay in development. Test weight was lower with no tillage. This was due to the occurrence of frost before physiological maturity with this system. Again other systems were similar in grain moisture and test weight.

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[1] *This project is supported by the Soil Conservation Service, the Minnesota Extension Service, and the Soil and Water Conservation Districts of Isanti and Pine Counties. There support is greatly appreciated. Much of the data collection was aided by MES, SCS, and SWCD field staff. Without their assistance this project would have not been possible.*

[2] *John F. Moncrief and Joe J. Kuznia are Associate Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108.*

PINE COUNTY

Table 1. Cultural practices at Pine County, MN. 1989.

Tillage

No Till
Fall Disc-November 10, 1988
Fall Chisel Plow-November 10, 1988
Fall Moldboard Plow-November 10, 1988
On May 11, 1989 all fall tillage plots were disced with a spike tooth harrow attached.

Cropping History

1986-Corn
1987-Corn Land O'Lakes 1093
1988-Corn Land O'Lakes 1093

1989 Crop

Land O'Lakes 2093 Single cross hybrid (95 day)

Planting and Harvest Information

A four row 36 inch John Deere Max-Emerge planter with 2 inch fluted coulters was used.

Crop	Date	Rate	Harvested
Corn	May 4, 1987	26,700 plants/A	Oct. 6, 1987
Corn	May 6, 1988	25,700 plants/A	Oct. 14, 1988
Corn	May 13, 1989	26,700 plants/A	Oct. 20, 1989

Fertilizer 1987

Crop	Material Analysis (rate)	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
		--- lbs/A ---			
Corn	46-0-0[1] (250 lbs/A)	115	0	0	May 2, 1987
	10-15-35[2] (280 lbs/A)	28	42	98	May 4, 1987

1. Broadcast, incorporated with spring tillage.
2. Planter applied 2" beside and 2" below seed.

Fertilizer 1988

Crop	Material Analysis (rate)	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
		--- lbs/A ---			
Corn	46-0-0[1] (200 lbs/A)	92	0	0	April 25, 1988
	9-23-30[2] (200 lbs/A)	18	46	60	May 6, 1988

1. Broadcast, incorporated with spring tillage.
1. Planter applied 2" beside and 2" below seed.

Fertilizer 1989

Crop	Material Analysis (rate)	Actual N	Actual P_2O_5	Actual K_2O	Actual S	Date Applied
		----- lbs/A -----				
Corn	8-21-27-9[1] (200 lbs/A)	16	41	54	18	May 13, 1989
	82-0-0 (165 lbs/A)	135	0	0	0	June 25, 1989

1. Planter applied 2" beside and 2" below seed.

Soil Test April 7, 1987

Nutrient	Sig. of Tillage	No Till	Disc	Chisel	Moldboard
		---------- lb/A ----------			
P	(.193)	124	107	61	84
K	(.711)	471	411	464	422

Soil

The soil at this site is a Cushing loam, (Glossic Eutroboralfs, fine-loamy, mixed) and is well drained.

Weed Control

No Till-1.5 qt/A (1.5 lbs/A) Atrazine on May 12, 1989.
All other plots-3 qt/A (5 lbs/A) Eradicane + 1 qt/A (1 lb/A) Bladex applied and incorporated with a Lelly Roterra on May 12, 1989.

Table 2. Effect of tillage and position relative to the row on soil covered by corn residue in Pine Co. on June 12, 1989[1].

Location	NoTill	Disc	Chisel	Mldbd	Avg.
	---------- % cover ----------				
In Row	34.0a	10.8b	18.3ab	6.5b	17.4
Between Row	66.0a	19.0b	38.0ab	12.0b	33.8
Average	50.0a	14.9a	28.1a	9.3a	

1. The p value for residue location, tillage, and tillage by location interaction are .001 (n=16), .130 (n=8), .744 (n=4) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage on early growth, and population of corn in Pine Co., 1989.

	NoTill	Disc	Chisel	Mldbd	Sig.
	-------- plants/A X 10^{-3}			-----	
June 12	30.5a[1]	30.9a	32.3a	32.3a	.774
Oct. 20	21.6b	26.5a	27.2a	28.6a	.001
	-------- leaves/plant --------				
June 12	4.1a	4.2a	4.2a	4.2a	.321

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 4. Effect of tillage on corn yields and moisture at Pine Co. on October 20, 1989.

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	bu/A				Sig.
Grain Yield	70a[1]	73a	84a	78a	.604
	%				
Moisture	31.4a	31.5a	30.2a	30.4a	.393

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

ISANTI COUNTY

Table 5. Cultural practices at Isanti County, MN. 1989.

Tillage

No Till
Spring Disc
Spring Chisel and tandem disced twice
Spring Moldboard and tandem disced twice
Spring tillage was done on May 1, 1989.

Cropping History

1986-Soybeans
1987-Corn Pioneer 3790
1988-Corn Pioneer 3772

1989 Crop

Corn Pioneer 3751 (100 day)

Planting and harvest information

A six row John Deere 7000 planter with 30 inch row spacing and equipped with 2 inch fluted coulters.

Crop	Date	Rate	Harvested
Corn	May 6, 1987	27,200 plants/A	Oct. 6, 1987
Corn	May 3, 1988	28,500 plants/A	Oct. 14, 1988
Corn	May 3, 1989	29,000 plants/A	Oct. 26, 1989

Fertilizer 1987

Crop	Material Analysis (rate)	Actual N	P_2O_5	K_2O	S	Mg	Date Applied
		lbs/A					
Corn	12-14-26-4-3[1] (277 lbs/A)	33	39	72	11	8	May 6, 1987
	82-0-0 (146 lbs/A)	120	0	0	0	0	June 5, 1987

1. Planter applied 2" beside and 2" below seed.

Fertilizer 1988

Crop	Material Analysis (rate)	Actual N	P_2O_5	K_2O	S	Mg	Date Applied
		lbs/A					
Corn	12-14-26-4-3[1] (277 lbs/A)	33	39	72	11	8	May 3, 1988
	82-0-0 (220 lbs/A)	180	0	0	0	0	June 3, 1988

1. Planter applied 2" beside and 2" below seed.

Fertilizer 1989

Crop	Material Analysis (rate)	Actual N	P_2O_5	K_2O	S	Mg	Date Applied
		lbs/A					
Corn	12-14-26-4-3[1] (277 lbs/A)	33	39	72	11	8	May 3, 1989
	82-0-0 (146 lbs/A)	120	0	0	0	0	June 5, 1989

1. Planter applied 2" beside and 2" below seed.

1987 Soil Test

Organic Matter	pH	Bray 1 Phosphorus	Potassium	Sulfur	Zinc
		lbs/A		ppm	
Medium	7.0	115	238	15	1.1

Soil

The soil at this site is a Alstad fine sandy loam (Aquic Eutroboralfs, fine-loamy, mixed), 0 to 2 percent slope and is somewhat poorly drained.

Weed Control

1.5 pt/A (1.5 lbs/A) Dual + 1 qt/A (1 lb/A) Atrazine on May 5, 1989.

Table 6. Effect of tillage and position relative to the row on soil covered by corn residue in Isanti Co. on June 5, 1989[1].

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
Location	% cover				Avg.
In Row	55.3a[2]	16.3b	15.0b	1.7c	22.1
Between Row	83.7a	24.3b	20.7b	6.0c	33.7
Average	69.5a	20.3b	17.8b	3.8c	

1. The p value for residue location, tillage, and tillage by location interaction are .001 (n=24), .001 (n=12), .088 (n=6) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 7. Effect of tillage on population and early growth of corn in Isanti Co., 1989.

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
Date	plants/A X 10^{-3}				Sig.
June 5	23.7b[1]	27.6a	27.2a	26.3a	.020
	leaves/plant				
June 5	3.9b	4.9a	4.9a	5.0a	.001
June 12	6.8b	7.9a	7.9a	8.1a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=6).

Table 8. Effect of tillage on corn yield, moisture, and test weight at Isanti Co. on October 26, 1989.

	Tillage				
	NoTill	Disc	Chisel	Mldbd	
	bu/A				Sig.
Grain Yield	126b[1]	149a	150a	147a	.001
	%				
Moisture	18.6a	16.2b	15.6b	16.6b	.064
	lb/bu				
Test Weight	51.8b	55.0a	54.7a	55.1a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=6).

Tillage Effects on Corn Growth and Yield on a Somewhat Poorly Drained Fine Textured Soil[1]

J.F. Moncrief, T.J. Arlt, T.L. Wagar, and J.J. Kuznia[2]

Tillage was evaluated for corn production in a corn and soybean rotation for a fourth year on a moderately well drained to somewhat poorly drained glacial till soil. Plant stands were lower with a moldboard plowing system. Conservation tillage reduced early growth slightly but did not affect grain yields.

Conservation tillage is usually more difficult to manage on poorly drained soils. Plots were established on a Le Sueur clay loam soil to evaluate tillage effects in a corn-soybean rotation. Following are the results of the third year of this study.

Methods and Materials

The experimental design is a randomized complete block with five tillage treatments and three replications. Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples in each tillage plot. Grain yields were estimated with a combine with an eight row head.

Results and Discussion

Soil cover by soybean residue ranged from 6 to 18% in the row area due to tillage. Soil cover between the row ranged from 6 to 70% cover (table 2). There was a small but statistically significant reduction in early growth by the conservation tillage options (table 3). There was a reduction in stand with the moldboard and chisel plowing systems.

Grain yields and moisture were not affected by tillage.

STEELE COUNTY

Table 1. Cultural practices at Steele County, MN. 1989.

Tillage
- No Till
- Ridge Till
- Spring Disc
- Fall Chisel Plow
- Fall Moldboard Plow

Cultivated all tillage plots (except no till) and formed ridges on June 24, 1989.

Cropping History
1985-Corn, 1986-Soybeans, 1987-Corn, 1988-Soybeans

1989 Crop
Corn-Pioneer

Planting and Harvest Date

Planter used on was a six row Hiniker Econotill planter with 30 inch row spacing.

	Planting		
Crop	Date	Rate	Harvested
Corn	April 21, 1989	26,000 plants/A	October 25, 1989

Weed Control
1 qt/A (2 lbs/A) Dual + 2 qts/A (2 lbs/A) Bladex applied on April 30, 1989.

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[1] *This project is supported by the Minnesota Extension Service and the Soil Conservation Service. Much of the data collection was aided by MES, and SCS field staff. Without their assistance this project would have not been possible.*

[2] *John F. Moncrief and Joe J. Kuznia are Associate Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108. T.J. Arlt is the Agricultural Extension Agent in Steele County, MN. T.L. Wagar is an area crop and Soils Agent stationed at Rochester, MN.*

Soil

Le Sueur (Aquic Argiudolls, fine-loamy, mixed, mesic) clay loam, 2 to 4 percent slopes. Soil is moderately well drained to somewhat poorly drained.

Fertilization History

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied	Method of Application
			--- lbs/A ---				
	0-0-60	250 lbs/A	0	0	150	Fall 1984	Broadcast
Corn:	7-21-7	10 gals/A	8	24	8	April 29, 1985	Applied with the seed
	82-0-0	163 lbs/A	134	0	0	May 30, 1985	Injected
Corn:	0-0-60	250 lbs/A	0	0	150	pre-plant 1987	Broadcast
	82-0-0	159 lbs/A	130	0	0	June 5, 1987	Injected

1989 Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied	Method of Application
			--- lbs/A ---				
Corn:	82-0-0	173 lbs/A	142	0	0	May 25, 1989	Injected-Sidedress

Table 2. Effect of tillage and position relative to the row on soil covered by soybean residue in Steele Co. on April 28, 1989[1].

Location	Mldbd	Chisel	Ridge	NoTill	SprDsc	Avg.
	Tillage					
	% cover					
In Row	6.2b	18.3a	12.8a	15.5a	17.0a	13.9
Between Row	5.7d	16.7c	59.0b	70.7a	49.3b	40.3
Average	5.9d	17.5c	35.9b	43.1a	33.2b	

1. The p value for residue for location, tillage, and tillage by location interaction are .001 (n=30), .001 (n=12), .001 (n=6) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage on population and early growth in Steele Co. on June 21, 1989.

	Mldbd	Chisel	Ridge	NoTill	SprDsc	Sig.
	Tillage					
	plants/A X 10^{-3}					
Population (n=12)	19.3c[1]	22.8b	24.8ab	26.3a	24.4ab	.001
	leaves/plant					
Early Growth (n=60)	7.3a	7.1b	7.2ab	7.0bc	6.9c	.001

1. Means within the same row with the same letter are not significantly different (α=.10).

Table 4. Effect of tillage on weed severity[1] in corn at Steele Co. on June 21, 1989.

	Mldbd	Chisel	Ridge	NoTill	SprDsc	Sig.
	Tillage					
	severity					
Weed Count	1.0a[2]	3.0a	1.0a	1.0a	0.3a	.134

1. Weed severity rating on scale 1-10, (1=slight, 10=severe), species were foxtail, quackgrass, and Canada thistle.
2. Means within the same row with the same letter are not significantly different (α=.10, n=5).

Table 5. Effect of tillage on corn yield and moisture at Steele Co. on October 25, 1989.

	Mldbd	Chisel	Ridge	NoTill	SprDsc	Sig.
	Tillage					
	bu/A					
Grain Yield	165a[1]	161a	164a	160a	166a	.871
	%					
Moisture	12.5a	13.0a	13.0a	13.1a	12.2a	.900

1. Means within the same row with the same letter are not significantly different (α=.10, n=3).

Tillage Effects on Corn and Soybean Growth and Yield on Aquic Soils[1]

J.F. Moncrief, J.J. Kuznia, M.B. Kells[2]

This is the fourth year of a tillage study in a corn and soybean rotation. Conservation tillage reduced early growth of both corn and soybeans but yields were not affected. Neither did they respond to row applied phosphorus.

This study is in it's fourth year. The purpose is to evaluate tillage system effects on the cost of inputs and grain yields. The erosion control offered by conservation tillage options allow for reduced losses of sediment and phosphorus in the Clearwater River chain of lakes.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and four replications. All corn main tillage plots and the soybean ridge till plots were split with starter fertilizer (table 1). Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot. Grain yields were estimated with a combine with an four row head.

Results and Discussion

Soil cover by soybean residue is shown in tables 4 and 5. Soil cover by soybean residue ranged from 2% to 13% in the row area due to tillage. Soil cover by soybean residue between the row ranged from less than 2% to 67% cover (table 4). There was a reduction in early corn growth by the ridge and no tillage systems (table 6). Chisel and moldboard plowing systems had similar early corn growth. Atypically corn grown with the ridge till system responded the least amount to row applied fertilizer (table 7).

Although final stands were not affected by tillage conservation tillage systems delayed emergence 2 days with chisel plowing to greater than a week with no tillage (table 8). Starter fertilizer did not affect emergence or final stands (table 9).

Tillage and starter fertilizer did not affect corn yields (table 10). Tillage did have a large affect on ear leaf potassium level at 50% silk emergence (table 11).

Soil cover by corn residue was much higher than soybeans with similar tillage (table 12). Soybean stands were reduced with moldboard plowing. Differences in stands would not be expected to affect yields however. Soybean growth was not correlated well with soil cover in the row by corn residue (tables 13 and 14).

Grain yields and moisture of soybeans were not affected by tillage (table 15). Starter fertilizer did not affect soybean yields grown with ridge tillage (table 16).

MEEKER COUNTY

Table 1. Cultural practices at Meeker County MN. 1989.

Tillage
- No Till
- Ridge Till
- Fall Chisel Plowed-Field cultivated prior to planting
- Fall Moldboard Plowed-Field cultivated prior to planting
  - Ridged corn plots on June 29, 1989.
  - Ridged soybean plots on July 17, 1989.

Cropping History
- Corn-soybean rotation since 1978.

1988 Crop
- Corn-Pioneer 3737
- Soybeans-BSR 101

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[1] *This project is supported by the Central Minnesota Initiative Fund, the Minnesota Pollution Control Agency, the Soil Conservation Service, the Clearwater River Watershed District, the Minnesota Extension Service, and the Wright County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by SCS, SWCD, MES field staff. Without their assistance this project would have not been possible.*

[2] *John F. Moncrief and Joe J. Kuznia are Associate Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108. Mary B. Kells is project coordinator of the Tri-County Conservation Project, SCS-SWCD, 3700 W. Division St. Rm, 104, St. Cloud, MN. 56301*

Planting and Harvest Dates

Corn - was planted with a two row Hiniker Series 1 EconoTill planter with 30 inch row spacing.
Soybeans - ridge till was planted with a two row Hiniker Series 1 EconoTill planter with 30 inch row spacing and all other tillage treatments were planted with a Tye no till drill with 8 inch row spacing.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 10, 1989	32,000 plants/A	October 13, 1989
Soybeans	May 22, 1989	250,000 plants/A	October 13, 1989

Fertilizer History 1985-1988

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/A	---	Date Applied
Corn:	82-0-0	183 lbs/A	150	0	0	Spring 1985
	4-15-40[1]	250 lbs/A	10	38	100	Planting 1985
Corn:	4-15-40	300 lbs/A	12	45	120	October 27, 1986
	7-21-7[1]	17 gal/A	13	40	13	April 28, 1987
	82-0-0	159 lbs/A	130	0	0	May 15, 1987
Soybeans:	4-15-40	300 lbs/A	12	45	120	October 27, 1986
	0-46-0[2]	45 lbs/A	0	21	0	May 5, 1987
Corn:	10-34-0[3]	19 gal/A	22	76	0	April 28, 1988
	10-34-0[1]	9 gal/A	11	36	0	May 5, 1988
	82-0-0	183 lbs/A	150	0	0	June 7, 1988
Soybeans:	10-34-0[3]	10 gal/A	12	40	0	April 28, 1988
	10-34-0[1]	5 gal/A	6	20	0	May 5, 1988
	0-46-0[2]	358 lbs/A	0	165	0	May 5, 1988

1. Planter placement 2" beside and 2" below row.
2. Drill soybeans were split with row fertilizer which was surface banded ahead of and incorporated by the fluted coulters.
3. Broadcast applied.

1989 Fertilizer

			Actual				
	Material		N	P_2O_5	K_2O		
Crop	Analysis	Rate	---	lbs/A	---	Date Applied	Method of Application
Corn:	7-21-7	15 gal/A	12	35	12	May 10, 1989	Row placement 2" x 2" on 1/2 the plots
	82-0-0	183 lbs/A	150	0	0	May 31, 1989	Anhydrous applicator
Soybeans:	7-21-7	15 gal/A	12	35	12	May 22, 1989	Row placement 2" x 2" on 1/2 the plots Ridge Till only

Soil

The soils present at this site are as follows: 29% of plot area is Delft clay loam (Cumulic Haplaquolls, fine-loamy, mixed, mesic), 43% is Koronis fine sandy loam (Mollic Haplaudalfs, fine-loamy, mixed, mesic), and the remaining 28% is Marcellon loam (Aquic Argiudolls, fine-loamy, mixed, mesic).

Weed Control

Corn

3 pt/A (1.5 lbs/A) Prowl + 2.2 lbs/A (2 lbs/A) Bladex 90 DF applied on May 19, 1989.

Soybeans

1 pt/A (.5 lb/A) Basagran + .5 pt/A (.125 lb/A) Blazer + 1 qt/A oil concentrate on June 9, 1989.
1 pt/A (.5 lb/A) Basagran + 1 pt/A (.188 lb/A) Poast + 1 qt/A Dash oil concentrate + 3 qt/A 28% on June 23, 1989.

Soil Test

Table 2. Soil test results for corn following soybeans on April 7, 1987.

	Tillage					
	No Till	Ridge	Chisel	Moldboard		
Nutrient	---------- lbs/A ----------				Avg.	Sig.
P	21.2	25.2	27.9	22.8	24.4	.862
K	182.7	177.6	173.1	146.2	169.9	.258

Table 3. Soil test results for soybeans following corn on April 7, 1987.

	Tillage					
	No Till	Ridge	Chisel	Moldboard		
Nutrient	---------- lbs/A ----------				Avg.	Sig.
P	26.0	20.6	32.7	23.7	25.5	.262
K	208.7	234.9	200.1	173.1	204.2	.016

Table 4. Effect of tillage and position relative to the row on soil covered by soybean residue in corn at Meeker Co. on May 11, 1989[1].

Location	Tillage: NoTill	Ridge	Chisel	Mldbd	Avg.
	% cover				
In Row	13.3a	6.4b	5.8b	2.0c	6.8
Between Row	66.9a	47.9b	10.9c	2.4c	32.0
Average	40.1a	27.1b	8.3c	2.2c	

1. The p value for residue location, tillage, and tillage by location interaction are .001 (n=128), .001 (n=64), .001 (n=32) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 5. Effect of tillage, starter and position relative to the row on soil covered by soybean residue in corn at Meeker Co. on May 11, 1989[1].

Location	NoTill		Ridge		Chisel		Moldboard		Average	
	Strt	None	Strt	None	Strt	None	Strt	None	Strt	None
	% cover									
In Row	10.8	15.8	6.0	6.8	5.5	6.0	2.0	2.0	6.1	7.6
Btwn Row	64.8	69.0	49.8	46.0	9.0	12.8	2.3	2.5	31.4	32.6
Average	37.8	42.4	27.9	26.4	7.3	9.4	2.1	2.3	18.8	20.1

1. The p value for in starter, tillage by starter, and tillage by starter by location interactions are .267 (n=128), .415 (n=32), .559 (n=16) respectively.

Table 6. Effect of tillage on early growth of corn at Meeker Co. 1989.

Date	Tillage: NoTill	Ridge	Chisel	Mldbd	Sig.
	leaves/plant				
6/2/89	1.45c[1]	1.71b	2.02a	2.06a	.004
6/29/89	5.00b	5.27b	5.61a	5.81a	.005

1. Means within the same row with the same letter are not significantly different (α=.10, n=160).

Table 7. Effect of tillage and starter on early growth of corn at Meeker Co. 1989[1].

Date	NoTill		Ridge		Chisel		Moldboard		Average	
	Strt	None	Strt	None	Strt	None	Strt	None	Strt	None
	leaves/plant									
6/2/89	1.51	1.37	1.61	1.82	2.08	1.96	2.09	2.02	1.83	1.79
6/29/89	5.23	4.78	5.30	5.25	5.72	5.49	5.89	5.72	5.53	5.31

1. The p value for starter and tillage by starter interactions for 6/2/89 are .413 (n=320), .007 (n=80); for 6/29/89 are .001 (n=320), .079 (n=80) respectively.

Table 8. Effect of tillage on corn emergence at Meeker Co. 1989.

Date	Tillage: NoTill	Ridge	Chisel	Mldbd	Sig.
	plants/Ax10^{-3}				
5/19/89	13.1c[1]	18.2bc	22.3ab	26.2a	.053
5/22/89	23.5a	24.8a	27.4a	27.9a	.286
6/2/89	29.0a	29.2a	29.7a	29.9a	.631

1. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 9. Effect of tillage and starter on corn emergence at Meeker Co. 1989[1].

Date	NoTill		Ridge		Chisel		Moldboard		Average	
	Strt	None	Strt	None	Strt	None	Strt	None	Strt	None
	plants/Ax10^{-3}									
5/19/89	13.7	12.4	17.5	18.8	23.2	21.3	25.5	26.9	20.0	19.8
5/22/89	22.1	24.8	24.9	24.7	28.1	26.7	28.9	26.9	26.0	25.8
6/2/89	29.3	28.6	28.9	29.5	30.1	29.4	29.6	30.2	29.5	29.4

1. The p value for starter and tillage by starter interaction for 5/19/89 are .932 (n=64), .711 (n=16); 5/22/89 are .861 (n=64), .545 (n=16); 6/2/89 are .964 (n=64), .774 (n=16) respectively.

Table 10. Effect of tillage and starter on corn yield and moisture at Meeker Co. on October 13, 1989[1].

	Tillage: NoTill	Ridge	Chisel	Mldbd	Avg.
	bu/A				
Starter	111	104	111	102	107
No Starter	104	102	115	104	106
Average	108	103	113	103	
	%				
Starter	20.8	21.9	20.3	21.1	21.0
No Starter	21.3	22.1	21.0	21.2	21.4
Average	21.1	22.0	20.7	21.1	

1. The p value for tillage, starter and tillage by starter interactions for yield are .333 (n=8), .617 (n=16), .375 (n=4) respectively. The p value for tillage, starter and tillage by starter interactions for moisture are .442 (n=8), .167 (n=16), .851 (n=4) respectively.

Table 11. Effect of tillage and starter on corn ear leaf potassium on July 27, at Meeker Co.[1].

	Tillage: NoTill	Ridge	Chisel	Mldbd	Avg.
	% K				
Starter	0.76	0.84	1.26	1.28	1.04
No Starter	0.89	0.80	1.07	1.87	1.16
Average	0.83c	0.82c	1.16b	1.57a	

1. The p value for tillage, starter and tillage by starter interactions for ear leaf potassium are .002 (n=8), .203 (n=16), .133 (n=4) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 12. Effect of tillage and position relative to the row on soil covered by corn residue in soybeans at Meeker Co. on May 22, 1989[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Location	% cover				Avg.
In Row	52.6a	17.5b	22.8b	4.8c	6.8
Between Row	61.6a	40.3b	25.1c	4.4d	32.0
Average	57.1a	28.9b	23.9b	4.6c	

1. The p value for residue location, tillage, and tillage by location interaction are .002 (n=112), .001 (n=64), .052 (n=32) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 13. Effect of tillage on population of soybeans at Meeker Co. 1989.

	Tillage				
	NoTill	Ridge[1]	Chisel	Mldbd	
	plants/Ax10^{-3}				Sig.
7/6/89	247.7a[2]	177.6	242.6a	215.2b	.017

1. The ridge till treatment was excluded from statistical analysis because a different type of planter was used.
2. Means within the same row with the same letter are not significantly different (α=.10, n=32).

Table 14. Effect of tillage on early growth of soybeans at Meeker Co. 1989.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	nodes/plant				Sig.
7/6/89	5.44b	5.28c	5.73a	5.79a	.001

1. Means within the same row with the same letter are not significantly different (α=.10, n=160).

Table 15. Effect of tillage on soybean yield and moisture, at Meeker Co. on October 13, 1989[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	bu/A				Sig.
Yield	30a	30a	29a	28a	.452
	%				
Moisture	8.9a	8.5a	9.0a	9.1a	.799

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 16. Effect of starter fertilizer on early growth, yield, and moisture, on of of Ridge till grown soybeans at Meeker Co.

		Ridge Till		
		Starter	No Starter	
		nodes/plant		Sig.
Growth Stage (7/7/89)	n=80	5.26	5.28	.895
		bu/A		
Yield (10/13/89)	n=4	31	30	.775
		%		
Moisture	n-4	8.5	8.5	.846

Tillage Effects on Corn and Soybean Growth and Yield on a Coarse Textured Soil[1]

J.F. Moncrief, J.J. Kuznia, M.B. Kells[2]

This is the fourth year of tillage evaluation on corn and soybean production on a coarse textured soil. Although tillage affected early growth and stands in some cases, yields were not affected.

This study is in it's fourth year. The purpose is to evaluate tillage system effects on the cost of inputs and grain yields. The erosion control offered by conservation tillage options allow for reduced losses of sediment and phosphorus in the Clearwater River chain of lakes.

Methods and Materials

The experimental design is a randomized complete block with four tillage treatments and four replications. Soybean ridge till plots were split with starter fertilizer. Crop residue was measured using a line transect technique. Stand estimates were made on two ten foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot. Grain yields were estimated with a combine with an eight row head.

Results and Discussion

Soil cover by soybean residue ranged from less than 1% to 19% in the row area due to tillage. Soil cover by soybean residue between the row ranged from less than 1% to 50% cover (table 2). Soil cover by corn residue was slightly higher with similar tillage (table 3). There was a reduction in early corn growth by the no tillage system (table 4). Other tillage systems had similar early corn growth. This is consistent with soil cover levels in the row. Chisel plowing resulted in slightly higher corn stands. Soybean growth was not correlated with soil cover in the row by corn residue (tables 3 and 5). The chisel plowing system had slightly lower soybean stands. Stand differences between corn and soybeans due to tillage would not be expected to affect yields.

Grain yields and moisture of either corn or soybeans were not affected by tillage (tables 6 and 7). Starter fertilizer did not affect soybean yields grown with ridge tillage.

WRIGHT COUNTY

Table 1. Cultural practices at Wright County, MN. 1989.

Tillage
- No Till
- Ridge Till
- Chisel Plow
- Moldboard Plow
  - Corn-Cultivated June 1, 1989, ridged June 23, 1989
  - Soybeans-Cultivated June 15, 1989, ridged July 13, 1989

Preceding Crops
- Corn-soybean rotation since 1982.

1989 Crops
- Corn-Pioneer 3737
- Soybeans-BSR 101

[1] *This project is supported by the Central Minnesota Initiative Fund, the Minnesota Pollution Control Agency, the Soil Conservation Service, the Clearwater River Watershed District, the Minnesota Extension Service, and the Wright County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by SCS, SWCD, MES field staff. Without their assistance this project would have not been possible.*

[2] *John F. Moncrief and Joe J. Kuznia are Associate Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108. Mary B. Kells is project coordinator of the Tri-County Conservation Project, SCS-SWCD, 3700 W. Division St. Rm, 104, St. Cloud, MN. 56301*

Planting and Harvest Dates

Soybeans - Ridge till plots were planted with a John Deere Maxemerge planter equipped with Buffalo Till ridge cleaners with 10" sweeps. All other plots were planted with a Tye No Till drill with 8" row spacing equipped with 2" fluted coulters.
Corn - Ridge till plots were planted with a John Deere Maxemerge planter equipped with Buffalo Till ridge cleaners with 10" sweeps. All other plots were planted with the John Deere Maxemerge planter sweeps raised.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 11, 1989	29,900 plants/A	October 17, 1989
Soybeans	May 22, 1989	250,000 plants/A	October 17, 1989

Fertilization History

From 1983 to 1986 both corn and soybeans received 100 to 150 lbs/ac of a 5-12-36 fertilizer applied with the planter. Prior to that only the corn received fertilizer with the planter. Fertilizer since 1986 is as follows:

			Actual			
	Material		N	P_2O_5	K_2O	
Crop	Analysis	Rate	---	lbs/a	----	Date Applied
Corn:	8-23-30[1]	140 lbs/A	11	32	42	May 2, 1986
	28-0-0[2] UAN	37 gal/A	110	0	0	June 13, 1986
Corn:	8-20-32[1]	140 lbs/A	11	28	45	May 4, 1987
	82-0-0	183 lbs/A	150	0	0	June 15, 1987
Corn:	9-20-33[1]	140 lbs/A	13	28	46	May 6, 1988
	82-0-0	150 lbs/A	123	0	0	June 8, 1988

1. Planter placement 2" beside and 2" below row.
2. Surface banded between rows.

1989 Fertilizer

			Actual				
	Material		N	P_2O_5	K_2O	S	
Crop	Analysis	Rate	------	lbs/A	-----		Date Applied
Soybeans	4-10-47-7[1]	131 lbs/A	5	13	62	9	May 22, 1989
Corn	6-14-42-7[1]	143 lbs/A	9	20	60	10	May 11, 1989
	82-0-0	134 lbs/A	110	0	0	0	June 14, 1989

1. Planter placement 2" beside and 2" below row, soybean ridge till plots were split with starter.

Soil

Soybeans - Kanaranzi loam (Typic Hapludolls, fine-loamy over sandy or sandy-skeletal, mixed, mesic), 2 to 6 percent slope on 95 percent of the plot area. Fairhaven loam (Typic Hapludolls, fine-loamy over sandy or sandy-skeletal, mixed, mesic), 0 to 2 percent slope on 5 percent of the plot area. Both soils are well drained.
Corn - Kanaranzi loam (Typic Hapludolls, fine-loamy over sandy or sandy-skeletal, mixed, mesic), 2 to 6 percent slope on 90 percent of the plot area. Salida gravelly sandy loam (Entic Hapludolls, sandy-skeletal, mixed, mesic), 3 to 6 percent slope on 10 percent of the plot area. Both soils are well drained.

Weed Control

Corn

2 qts/A (2 lbs/A) Lasso + 1.6 lbs/A (1.44 lbs/A) Bladex 90 DF on May 11, 1989 with planter.
.25 pt/A (.125 lb/A) 2,4-D amine + .5 pt/A (.188 lb/A) Roundup spot spray on May 13, 1989.

Soybeans

1 lb/A (.5 lb/A) Lorox 50 DF + 1.5 pts/A (1.5 lbs/A) Dual applied with the planter for the ridge till system on May 12, 1988.
.25 pt/A (.125 lb/A) 2,4-D amine + .5 pt/A (.188 lb/A) Roundup on May 13, 1989.
1 pt/A (.5 lb/A) Basagran + .5 pt/A (.125 lb/A) Blazer + 1 qt/A oil concentrate on June 9, 1989.
1 pt/A (.5 lb/A) Basagran + 1 pt/A (.188 lb/A) Poast + 1 qt/A Dash oil concentrate + 3 qt/A 28% on June 23, 1989.

Table 2. Effect of tillage and position relative to the row on soil covered by soybean residue in corn at Wright Co. on May 11, 1989[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Location	% cover				Avg.
In Row	19.0a	2.3b	3.8b	0.3b	6.3
Between Row	49.5a	21.8b	9.3c	0.8d	20.3
Average	34.3a	12.0b	6.5c	0.5d	

1. The p value for residue location, tillage, and tillage by location interaction are .001 (n=64), .001 (n=32), .001 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 3. Effect of tillage and position relative to the row on soil covered by corn residue in soybeans at Wright Co. on May 22, 1989[1].

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Location	% cover				Avg.
In Row	34.3a	3.8c	10.8b	3.6c	16.2
Between Row	45.5a	14.5b	9.4b	3.4c	19.4
Average	39.9a	9.1b	10.1b	3.5b	

1. The p value for residue location, tillage, and tillage by location interaction are .008 (n=112), .001 (n=64), .001 (n=32) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 4. Effect of tillage on population (n=16) and early growth (n=80) of corn at Wright Co.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
Population	plants/A X 10^{-3}				Sig.
5/22/89	31.0a[1]	29.5a	31.4a	30.0a	.218
6/1/89	31.5b	29.9b	32.0a	30.2b	.066
Early Growth	leaves/plant				
6/1/89	1.74c	2.03a	1.92b	1.97ab	.001

1. Means within the same row with the same letter are not significantly different (α=.10).

Table 5. Effect of tillage on population (n=32) and early growth (n=160) of soybeans at Wright Co. on July 5, 1989.

	Tillage				
	NoTill	Ridge[1]	Chisel	Mldbd	
	plants/A X 10^{-3}				Sig.
Population	264.0a[2]	159.4	207.0b	239.3a	.003
	nodes/plant				
Early Growth	4.8a	4.5b	4.5b	4.8a	.001

1. The ridge till treatment was excluded from statistical analysis of population because a different type of planter was used.
2. Means within the same row with the same letter are not significantly different (α=.10).

Table 6. Effect of tillage on corn yields and moisture at Wright Co. on October 17, 1989.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	bu/A				Sig.
Grain Yield	79a[1]	104a	75a	85a	.203
	%				
Moisture	24.9a	23.6a	23.9a	25.0a	.653

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 7. Effect of tillage on soybean yields and moisture at Wright Co. on October 17, 1989.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	bu/A				Sig.
Grain Yield	28.2a[1]	25.9a	25.5a	26.3a	.455
	%				
Moisture	7.7a	7.5a	7.8a	7.6a	.899

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 8. Effect of starter fertilizer on yields and moisture of ridge till grown soybeans at Wright Co. on October 17, 1989.

	Ridge till		
	Starter[1]	No Starter	Sig.
	bu/A		
Yield	27.6a[2]	25.9a	.577
	%		
Moisture	7.3a	7.5a	.436

1. Starter was 131 lbs/A 4-10-47.
2. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Tillage Effects on Availability of Fresh and "Manure Pack" Sources of Dairy Manure on a Coarse Textured Soil[1]

J.F. Moncrief, J.J. Kuznia, M.B. Kells, and A. Eynard[2]

Two sources of dairy manure and a urea-ammonium nitrate solution were evaluated under conservation tillage on an excessively well drained soil. Yields were similar for all sources of nitrogen. Corn responded to potassium in manure however. Tillage reduced ear leaf concentration of potassium but did not affect yields.

There has been a recent effort by many farmers to more precisely utilize manure to minimize losses to groundwater on glacial outwash soils of central Minnesota. Availability of nitrogen from manure sources that contain appreciable amounts of organic nitrogen can be affected by tillage due to lower soil temperatures and changes in soil water. In an effort to evaluate nitrogen available to corn from dairy manure, plots were established on a coarse textured soil in Stearns County, Minnesota.

Methods and Materials

Two manure sources were evaluated: fresh manure from barn gutters and a manure pack around a hay rack in the barnyard. In addition to a 5 lbs/acre of nitrogen applied with the planter, commercial nitrogen treatments had two equal applications (33 lbs/acre) applied during cultivation as urea-ammonium nitrate solution (UAN). Manure treatments had additional nitrogen applied during the second cultivation. Tillage treatments evaluated were: spring moldboard and chisel plowing followed by a light discing, ridge till and no till systems. Manure applications were not made on the no till plots.

Manure was applied in the last two weeks of April prior to chisel plowing but following moldboard plowing. Results of manure spreader calibration are shown in figure 1. Two sets of five plastic sheets two feet wide and ten feet long were laid down side by side and driven over by the manure applicator for each source of manure. Each sheet was weighed and results converted to tons per acre. These data resulted in the spreader pattern in figure one.

Manure was applied to two 38 inch rows for each pass (center six feet of spreader pattern). Adjacent passes were overlapped to give a relatively uniform application. The rate of manure was calculated by adding the outside 2 two foot wide strips on each side of the spreader pattern to account for overlapping passes. Rates are shown in table 1.

The experimental design is a split plot with tillage main plots and manure/fertilizer subplots for each source of manure. Each source of manure was compared with UAN. The two sources of manure were not compared to each other.

Soil cover was estimated by a line transect method and characterized for "in" and "between row" areas at two monitoring sites within each subplot. At each monitoring site treatment responses were evaluated by observations on two adjacent corn rows. Soil cover measurements were made over 10 feet of row with a line with 25 points. "In row" is defined as a four inch strip centered over the row and "between row" the remainder. Early corn growth was estimated by tallying the leaves on the plants within the ten feet of row. Stands were similar estimated by tallying the number of plants in ten feet of row at each monitoring site.

Ear leaf samples were taken at 50% silk emergence and analyzed for nitrogen and potassium.

Grain yields were estimated by combining two rows of corn 300 feet long and weighing to the nearest 5 pounds with a weigh wagon. Subsamples were taken for moisture determination and nitrogen analysis.

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[1] *This project is supported by the Agricultural Utilization and Research Institute (AURI), the Central Minnesota Initiative Fund, the Minnesota Pollution Control Agency, the Soil Conservation Service, the Clearwater River Watershed District, the Minnesota Extension Service, and the Stearns County Soil and Water Conservation District. There support is greatly appreciated. Much of the data collection was aided by SCS, MES, and SWCD field staff. Without their assistance this project would have not been possible.*

[2] *John F. Moncrief and Joe J. Kuznia are Associate Professor and Assistant Scientist respectively in the Soil Science Department at the University of Minnesota, St. Paul, MN. 55108. Anna Eynard is a visiting scientist from Italy. Mary B. Kells is project coordinator of the Tri-County Conservation Project, SCS-SWCD, 3700 W. Division St. Rm, 104, St. Cloud, MN. 56301*

Results and Discussion

The response of corn to tillage without manure applied is shown in tables 2 to 5. Soil cover by soybean residue was similar with all tillage systems demonstrated except the no till system (table 2). The no till and ridge till systems resulted in adequate cover for erosion control. There was no effect of tillage on stand establishment (table 3). There was however about 1/3 leaf less growth with no till grown corn on June 1st.

Yield trends indicate higher yields with no till grown corn and lower with the ridge till system. Chisel and moldboard plowing were intermediate. The contrast in yield between the no till and ridge till systems probably reflects increased drought stress on the prominent ridges at this site. There were no differences in grain moisture indicating that the small early growth differences due to tillage were not measurable by this indicator of corn phenology.

There were no statistical differences in grain protein or N concentration due to tillage although the tendency was for reduced tillage to have lower levels of grain N (table 5).

The response of corn to tillage and barnyard manure is shown in tables 6 to 15. Tillage effects on soil cover trends were not affected by a barnyard manure application (tables 6 and 7). A barnyard manure application did not affect stand establishment or early growth (tables 8 and 9). Although tillage differences in grain yield means were large they were not statistically significant (table 10). There was a statistically significant 8 bu/acre higher yield with barnyard manure. This was likely due to the potassium applied with the manure. Tillage and barnyard manure did not affect grain moisture (table 11).

Tillage did not affect nitrogen concentrations in grain, protein, or N uptake (table 12, 13, and 14). Barnyard manure resulted in lower concentrations of N and protein in grain than the UAN N source however (tables 13 and 14). Barnyard manure resulted in higher N uptake by grain with chisel plowing than UAN (table 15). This is due to the incorporation with this treatment. Moldboard plowing was done before manure application (table 1).

Tillage effects on soil cover are shown in table 16. Barn gutter manure increased soil cover (table 17). Barn gutter manure application resulted in higher corn stands with moldboard plowing and ridge tillage but lower with chisel plowing (table 18). Early growth was increased by UAN with ridge tillage and moldboard systems but decreased with chisel plowing (table 19).
Yields were similar between both sources of nitrogen (table 20). Grain moisture was increased .5% by the barn gutter manure (table 21).

Tillage did not affect N concentrations in grain, protein, or N uptake by grain (table 22). There were no differences in these quality parameters between the two N sources (tables 23, 24, and 25).

STEARNS COUNTY

Table 1. Cultural practices at Stearns County, MN. 1989.

Tillage
No Till
Ridge Till
Spring Chisel Plowed-after manure application
Spring Moldboard Plowed-before manure application
All plots were cultivated on
June 15 and June 30, 1989.

Cropping History
1981-red clover and oats, 1982-corn,
1983-soybeans, 1984-corn, 1985-corn,
1986-soybeans, 1987-corn, 1988-Soybeans

1989 Crop
Corn - Johnson 475 (100 Day)

Planting and Harvest Dates

Plots were planted with a four row Buffalo Till planter equipped with 12" sweeps at a 38"row spacing.

	Planting		
Crop	Date	Rate	Harvested
Corn	May 11, 1989	23,900 plants/A	October 19, 1989

Fertilization History

The fertilization history at this site is as follows: 1981-none, 1982-low rate of dry starter, 1983-low rate of starter and 0-0-60, 1984-4 gal/A of 9-18-9 only, 1985-60 lbs/A of N and 4 gal/a of 9-18-9, 1986-all soybean plots were split with and without a row fertilizer treatment at planting, and in 1987-all corn plots were split with three rates of starter.

Crop	Material Analysis	Rate	Tillage	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
				--- lbs/A ---			
Soybeans	9-18-9[1]	4 gal/A	Ridge Till	4	8	4	May 16, 1986
	0-0-60[2]	90 lbs/A	All Others	0	0	54	May 16, 1986
Corn	Starter Fertilizer Treatments						
	9-18-9[1]	0 gal/A	All	0	0	0	April 29, 1987
	9-18-9[1]	4.9 gal/A	All	4.7	10	4.7	April 29, 1987
	9-18-9[1]	9.7 gal/A	All	9.3	18.5	9.3	April 29, 1987
	Nitrogen Management						
	28-0-0	11 gal/A	No Till[3]	33	0	0	June 1, 1987
	28-0-0	11 gal/A	All Others[4]	33	0	0	June 1, 1987
	28-0-0	11 gal/A	No Till[3]	33	0	0	June 25, 1987
	28-0-0	11 gal/A	All Others[4]	33	0	0	June 25, 1987

1. Planter placement 1" below the seed.
2. Potash was surface banded ahead of and incorporated by the fluted coulters.
3. Nitrogen was surface banded.
4. Nitrogen was surface banded and incorporated by cultivation.

1989 Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			--- lbs/A ---			
Corn	9-18-9[1]	5 gal/A	5	10	5	May 11, 1988
	28-0-0[2]	11 gal/A	33	0	0	June 15, 1989
	28-0-0[3]	11 gal/A	33	0	0	June 30, 1989

1. Planter placement 1" below the seed.
2. Urea-ammonium nitrate (UAN) solution was surface banded and incorporated by cultivation on all non-manure plots. Solution was surface banded with no incorporation on no till plots.
3. Urea-ammonium nitrate (UAN) solution was surface banded and incorporated by cultivation on all plots manured and non-manured. Solution was surface banded with no incorporation on no till plots.

1989 Manure Analysis

Analysis and rate of application of manure and available nitrogen.

Manure Source	Date Applied	Total NH_4	Total NO_3	Total Mineral	Total Organic	Available N	Available K	Nitrogen lbs/T	Nitrogen lbs/A	Potassium lbs/T	Potassium lbs/A	Manure Density lbs/ft³	Manure Rate T/A	Solids Total	Solids Volatile	Solids Fixed
		---------- % ----------												---------- % ----------		
Barn Gutter[1]	4/13/89	.260	.012	.272	.264	.536	.424	7.3	122	10	167	64.8	16.7	28.88	45.96	54.04
Barnyard[2]	4/25/89	.054	.003	.057	.656	.713	.346	5.7	86	8	120	33.8	15.0	16.50	64.62	35.38

1. Fresh daily manure collected every other day from barn gutters and applied the last two weeks of April.
2. A manure pack collected near a hay rack in the barnyard and applied April 25, 1989.

Rate of applied and available nitrogen[1].

Nitrogen Source	Nitrogen Fraction: Total Mineral	Total Organic	Total Nitrogen	Total Mineral	Total Organic	Total Nitrogen
	-- Applied N lbs/acre --			-- Avail. N lbs/acre ---		
Barn Gutter	91	88	179	91	31	122
Barnyard	19	213	232	19	74	93

1. It is assumed that all of the mineral N will be available during the year of application and 35% of the organic N.

Soil

The soils at the Stearns County site are Fairhaven loam (Typic Hapludolls) which is well drained on 54 percent of the plot. Estherville sandy loam (Typic Hapludolls) which is somewhat excessively drained on 36 percent of the plot, Hawick loamy sand (Entic Hapludolls), this soil is excessively drained on the remaining 10 percent of the plot. The slope average for all three soils is 2.5 percent with the highest being 4 percent.

Weed Control

6 lbs/A (.9 lb/A) Lasso II 15 G in a 15" band applied on May 11, 1989.
1.5 pts/A (.75 lbs/A) Prowl + 1.25 lbs/A (1 lb/A) Bladex 80 WP applied to 3-4 leaf corn.

Table 2. Effect of tillage and position relative to the row on soil covered by soybean residue in corn at Stearns Co. on June 1, 1989 with **no manure** applied[1].

	Tillage				
	NoTill[2]	Ridge	Chisel	Mldbd	
Location	% cover				Avg.
In Row	33.3a	3.3b	9.3b	4.0b	16.6
Between Row	37.8a	36.8a	6.3b	2.8b	24.3
Average	35.5a	20.0b	7.8c	3.4c	

1. The p value for residue location, tillage, and tillage by location interaction are .005 (n=80), .001 (n=32), .001 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).
2. The no till sample size is double the other treatments.

Table 3. Effect of tillage on population (n=16) and growth stage (n=80) of corn at Stearns Co. on June 1, 1989 with **no manure** applied.

	Tillage				
	NoTill[1]	Ridge	Chisel	Mldbd	
Population	plants/A X 10^{-3}				Sig.
	20.7a[2]	20.7a	21.1a	20.8a	.958
Growth Stage	leaves/plant				
	1.65b	1.92a	1.96a	2.0a	.001

1. The no till sample size is 32 and 160 for plant population and growth stage respectively.
2. Means within the same row with the same letter are not significantly different (α=.10).

Table 4. Effect of tillage on corn yields and moisture at Stearns Co. on October 19, 1989, with **no manure** applied.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	bu/A				Sig.
Grain Yield	82a[1]	53a	60a	63a	.108
	%				
Moisture	19.5a	19.0a	20.0a	19.7a	.263

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 5. Effect of tillage on corn ear leaf potassium on July 27, % grain N, protein, and grain N uptake on October 19, at Stearns Co. with **no manure** applied.

	Tillage				
	NoTill	Ridge	Chisel	Mldbd	
	% K				Sig.
Ear Leaf K	0.40ab[1]	0.29b	0.53a	0.61a	.085
	%				
Grain N	1.63a	1.69a	1.69a	1.71a	.376
	%				
Protein	10.2a	10.5a	10.5a	10.7a	.376
	lb/A				
Grain N Uptake	63.3a	42.5a	48.1a	51.3a	.180

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 6. Effect of tillage and position relative to the row on soil covered by soybean residue in corn at Stearns Co. on June 1, 1989 with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
Location	% cover			Avg.
In Row	2.8a	8.8a	4.5a	5.3
Between Row	35.3a	8.5b	1.3b	15.0
Average	19.0a	8.6b	2.9c	

1. The p value for residue location, tillage and tillage by location interaction are .001 (n=48), .042 (n=32), .001 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 7. Effect of tillage, N source and position relative to the row on soil covered by soybean residue in corn at Stearns Co. on June 1, 1989 with **barnyard manure** applied[1].

	Tillage							
	Ridge		Chisel		Moldboard		Average	
	UAN	Brnyd	UAN	Brnyd	UAN	Brnyd	UAN	Brnyd
Location	% cover							
In Row	2.5	3.0	8.5	9.0	4.0	5.0	5.0	5.7
Between Row	31.0	39.5	6.0	11.0	1.5	1.0	12.8	17.2
Average	16.8	21.3	7.3	10.0	2.8	3.0	8.9	11.4

1. The p value for N source, tillage by N source, N source by location, tillage by location by N source interactions are .280 (n=48), .862 (n=16), .533 (n=24) .362 (n=8) respectively.

Table 8. Effect of tillage on population of corn on June 1, 1989 at Stearns Co. with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	-- plants/A X 10^{-3} -			Ave.
UAN	20.7	20.7	21.1	20.8
Barnyard + UAN	22.0	21.4	19.6	20.9
Average	21.3a	21.0a	20.3a	

1. The p value for N source, tillage, and tillage by N source interactions are .816 (n=24), .178 (n=16), .327 (n=8) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 9. Effect of tillage on early growth of corn on June 1, 1989 at Stearns Co. with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	--- leaves/plant ---			Ave.
UAN	1.93	2.01	2.04	1.99
Barnyard + UAN	1.68	2.01	2.09	1.93
Average	1.80b	2.01a	2.06a	

1. The p value for N source, tillage, and tillage by N source interactions are .407 (n=120), .043 (n=80), .214 (n=40) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 10. Effect of tillage on corn yields at Stearns Co., on October 19, 1989, with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	-------- bu/A ------			Avg.
UAN	46	58	72	59
Barnyard + UAN	51	80	71	67
Average	49a	69a	72a	

1. The p value for tillage, N source, and tillage by N source interactions are .564, (n=4), .025, (n=6), .034 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 11. Effect of tillage on corn moisture at Stearns Co. on October 19, 1989 with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	--------- % --------			Avg.
UAN	18.2	19.7	18.9	19.0
Barnyard + UAN	19.0	18.7	19.5	19.1
Average	18.6a	19.2a	19.2a	

1. The p value for tillage, N source, and tillage by N source interactions are .810, (n=4), .864, (n=6), .373 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 12. Effect of tillage on corn ear leaf potassium on July 27, % grain N, protein, and grain N uptake on October 19, at Stearns Co. with **barnyard manure** applied.

	Tillage			
	Ridge	Chisel	Mldbd	
	------- % K --------			Sig.
Ear Leaf K	0.41a[1]	0.55a	0.93a	.147
	--------- % --------			
Grain N	1.62a	1.66a	1.70a	.525
	--------- % --------			
Protein	10.1a	10.4a	10.6a	.525
	-------- lb/A ------			
Grain N Uptake	37.2a	53.6a	57.3a	.498

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 13. Effect of tillage on corn ear leaf potassium on July 27, grain N on October 19, at Stearns Co. with **barnyard manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	------- % K --------			Avg.
UAN	0.31	0.53	0.71	0.51
Barnyard + UAN	0.52	0.58	1.15	0.75
Average	0.41a	0.55a	0.93a	
	--------% N -------			
UAN	1.66	1.73	1.74	1.71
Barnyard + UAN	1.57	1.58	1.65	1.60
Average	1.62a	1.66a	1.70a	

1. The p value for % K for tillage, N source, and tillage by N source interactions are .147, (n=4), .048, (n=6), .378 (n=2) respectively. The p value for % N for tillage, N source, and tillage by N source interactions are .525, (n=4), .041, (n=6), .731 (n=2). Means within the same row with the same letter are not significantly different (α=.10).

Table 14. Effect of tillage on corn grain protein at Stearns Co. on October 19, 1989, with **barnyard manure** applied[1].

Protein	Tillage: Ridge	Chisel	Mldbd	Avg.
	%			
UAN	10.4	10.8	10.9	10.7
Barnyard + UAN	9.8	9.9	10.3	10.0
Average	10.1a	10.4a	10.6a	

1. The p value for tillage, N source, and tillage by N source interactions are .525, (n=4), .041, (n=6), .731 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 15. Effect of tillage on corn grain N uptake at Stearns Co. on October 19, 1989, with **barnyard manure** applied[1].

Grain N Uptake	Tillage: Ridge	Chisel	Mldbd	Avg.
	lb/A			
UAN	36.5	47.6	59.9	1.71
Barnyard + UAN	37.9	59.6	54.7	1.60
Average	37.2a	53.6a	57.3a	

1. The p value for tillage, N source, and tillage by N source interactions are .498, (n=4), .092, (n=6), .018 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 16. Effect of tillage and position relative to the row on soil covered by soybean residue in corn at Stearns Co. on June 1, 1989 with **barn gutter manure** applied[1].

Location	Tillage: Ridge	Chisel	Mldbd	Avg.
	% cover			
In Row	4.3a	16.0a	4.0a	8.1
Between Row	52.0a	12.3b	4.5c	22.9
Average	28.1a	14.1b	4.3c	

1. The p value for residue location, tillage and tillage by location interaction are .001 (n=48), .114 (n=32), .001 (n=16) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 17. Effect of tillage, N source and position relative to the row on soil covered by soybean residue in corn at Stearns Co. on June 1, 1989 with **barn gutter manure** applied[1].

Location	Tillage: Ridge		Chisel		Moldboard		Average	
	UAN	Brngt	UAN	Brngt	UAN	Brngt	UAN	Brngt
	% cover							
In Row	4.0	4.5	10.0	22.0	4.0	4.0	6.0	10.2
Between Row	42.5	61.5	6.5	18.0	4.0	5.0	17.7	28.2
Average	23.3	33.0	8.3	20.0	4.0	4.5	11.8	19.2

1. The p value for N source, tillage by N source, N source by location, tillage by location by N source interactions are .046 (n=48), .153 (n=16), .883 (n=24) .946 (n=8) respectively.

Table 18. Effect of tillage on population of corn on June 1, 1989 at Stearns Co. with **barn gutter manure** applied[1].

	Tillage: Ridge	Chisel	Mldbd	Ave.
	plants/A X 10^{-3}			
UAN	20.7	21.6	20.5	20.9
Barn Gutter + UAN	22.0	18.7	23.4	21.4
Average	21.3a	20.1a	22.0a	

1. The p value for N source, tillage, and tillage by N source interactions are .586 (n=24), .156 (n=16), .008 (n=8) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 19. Effect of tillage on early growth of corn on June 1, 1989 at Stearns Co. with **barn gutter manure** applied[1].

	Tillage: Ridge	Chisel	Mldbd	Ave.
	leaves/plant			
UAN	1.91	1.91	2.04	1.90
Barn Gutter + UAN	1.73	1.65	2.32	1.96
Average	1.82a	1.78a	2.18a	

1. The p value for N source, tillage, and tillage by N source interactions are .392 (n=120), .442 (n=80), .040 (n=40) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 20. Effect of tillage on corn yields at Stearns Co. on October 19, 1989, with **barn gutter manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	------- bu/A -------			Avg.
UAN	61	63	54	59
Barn Gutter + UAN	60	67	57	61
Average	60a	65a	55a	

1. The p value for tillage, N source, and tillage by N source interactions are .366, (n=4), .766, (n=6), .954 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 21. Effect of tillage on corn moisture at Stearns Co. on October 19, 1989, with **barn gutter manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	--------- % --------			Avg.
UAN	19.7	20.3	20.4	20.2
Barn Gutter + UAN	20.8	20.7	20.7	20.7
Average	20.3a	20.5a	20.6a	

1. The p value for tillage, N source, and tillage by N source interactions are .847, (n=4), .056, (n=6), .302 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 22. Effect of tillage on corn ear leaf potassium on July 27, % grain N, protein, and grain N uptake on October 19, at Stearns Co. with **barn gutter manure** applied.

	Tillage			
	Ridge	Chisel	Mldbd	
	------- % K --------			Sig.
Ear Leaf K	0.46b[1]	0.72b	1.24a	.088
	--------- % --------			
Grain N	1.69a	1.63a	1.67a	.683
	--------- % --------			
Protein	10.6a	10.2a	10.5a	.683
	-------- lb/A ------			
Grain N Uptake	47.9a	50.1a	43.4a	.421

1. Means within the same row with the same letter are not significantly different (α=.10, n=4).

Table 23. Effect of tillage on corn ear leaf potassium on July 27, grain N on October 19, at Stearns Co. with **barn gutter manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
	------- % K --------			Avg.
UAN	0.27	0.54	0.52	0.44
Barnyard + UAN	0.64	0.90	1.97	1.17
Average	0.46b	0.72b	1.24a	
	--------% N -------			
UAN	1.71	1.64	1.69	1.67
Barnyard + UAN	1.68	1.63	1.66	1.66
Average	1.69a	1.64a	1.67a	

1. The p value for % K for tillage, N source, and tillage by N source interactions are .147, (n=4), .048, (n=6), .378 (n=2) respectively. The p value for % N for tillage, N source, and tillage by N source interactions are .525, (n=4), .041, (n=6), .731 (n=2). Means within the same row with the same letter are not significantly different (α=.10).

Table 24. Effect of tillage on corn grain protein at Stearns Co. on October 19, 1989, with **barn gutter manure** applied[1].

	Tillage			
	Ridge	Chisel	Mldbd	
Protein	--------- % --------			Avg.
UAN	10.7	10.2	10.5	10.5
Barn Gutter + UAN	10.5	10.2	10.4	10.3
Average	10.6a	10.2a	10.5a	

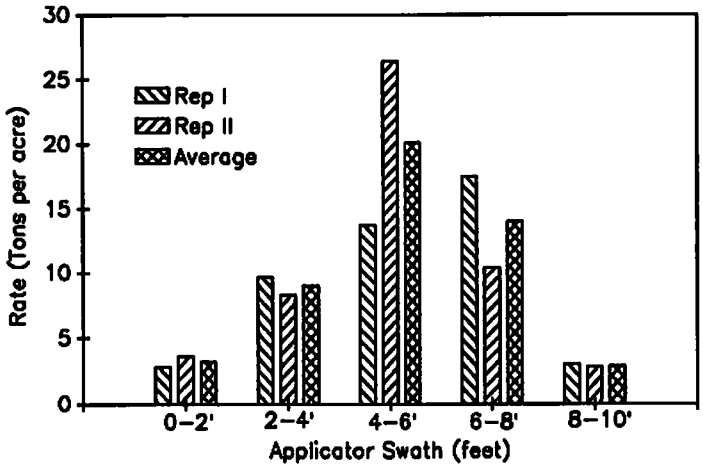
1. The p value for tillage, N source, and tillage by N source interactions are .683, (n=4), .332, (n=6), .824 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

Table 25. Effect of tillage on corn grain N uptake at Stearns Co. on October 19, 1989, with **barn gutter manure** applied[1].

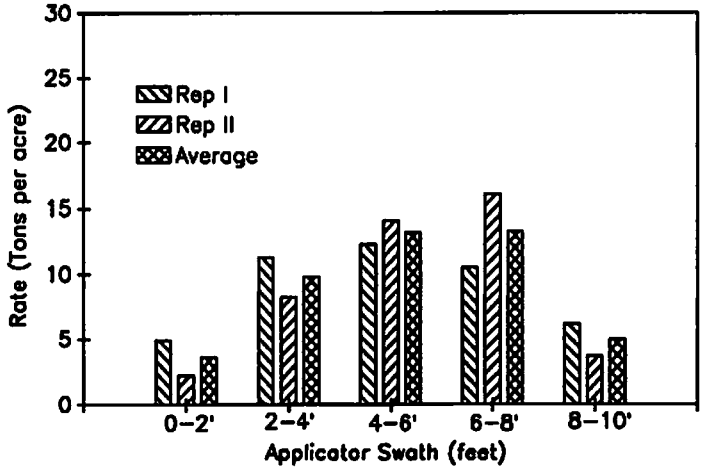
	Tillage			
	Ridge	Chisel	Mldbd	
Grain N Uptake	------- lb/A -------			Avg.
UAN	48.6	48.5	42.8	46.6
Barn Gutter + UAN	47.2	51.7	44.0	47.6
Average	47.9a	50.1a	43.4a	

1. The p value for tillage, N source, and tillage by N source interactions are .421, (n=4), .866, (n=6), .943 (n=2) respectively. Means within the same row with the same letter are not significantly different (α=.10).

BOX TYPE APPLICATOR CALIBRATION WITH FRESH DAIRY MANURE FROM BARN GUTTERS, STEARNS COUNTY, 1989



BOX TYPE APPLICATOR CALIBRATION WITH DAIRY MANURE FROM MANURE PACK NEAR HAY RACK, STEARNS COUNTY, 1989



EFFECT OF TILLAGE AND FREQUENCY OF LIQUID DAIRY MANURE APPLICATION ON THE AVAILABILITY OF N TO CORN, SOIL N DISTRIBUTION AND N CONCENTRATION IN SOIL WATER[1]

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Abstract: A summary of the results of 1989 season of a study to determine the effects of tillage and the frequency of liquid dairy manure application on corn yield, N uptake and soil N distribution initiated in 1982 are summarized in this report. Tillage treatments included no tillage and chisel plowing. N treatments included manure applied at the rate of 202 lb/A annually, biennially, and triennially. Tillage effects were not significant in most yield characteristics except in total dry matter at harvest, no till yielding more dry matter than chisel plowing. Manure applied annually yielded more grain followed by annual fertilizer, biennial manure in the year of application, and biennial manure in the year following application. The residual effects of additional K at the rate of 200 lbs K_2O in previous years was not observed in grain yield but still had an effect on stover dry matter yield. N uptake was higher by 10 lbs/A in no till grown corn than in chisel plowed, by annual manure and fertilizer than by biennial manure, and by additional K application.

Cover by surface residue was higher in no till than chisel plow, in fertilized treatments than in manure treatments, and in between the rows than in the rows. Soil profile was drier in the fall than in the spring. Chisel plowed treatments had about 10 lbs/A more N than no till. About 1/2 to 3/4 of the total inorganic N was in ammonium form. Ammonium-N decreased with depth while nitrate-N increased with depth. There was more N in nitrate form in between the rows than in the rows. Nitrate levels in soil water sampled at 5 ft. depth were higher in chisel plowed treatments than in no till, and in treatments applied with fertilizer and annual manure than the biennial manure. The concentration did not vary much with time between May and September.

INTRODUCTION

The objective of the study is to determine the effects of tillage and frequency of manure application on corn yield, N uptake, and soil nitrogen levels. The site is located on a Timula silt loam soil on the Dale Flueger Farm near Red Wing in Goodhue Co., MN. The study was initiated in 1982.

Liquid dairy manure is injected either annually, biennially or triennially on chisel-plowed treatments and annually or biennially on no-till treatments. A check treatment which does not receive any nitrogen and a fertilized check treatment which until 1988 received ammonium nitrate annually at the rate of 210 lbs N/A on no till plots and 170 lbs N/A on chisel plots are included in the study. In 1989, the fertilized check received anhydrous ammonia ,instead of ammonium nitrate, injected at the rate of 170 lbs N/A. Most cultural practices are similar to previous years (Table 1).

From 1982-1986 the manure treatments were split with 0 and 200 lbs K_2O/A and the fertilizer treatments with 0, 200, and 400 lbs K_2O/A. The application of this extra potassium has been stopped since 1987. To evaluate residual effects of additional potassium, data in this report are presented on split basis with respect to K_2O whenever applicable.

The experiment is laid out in a randomized complete block split-split plot design with three replications. Tillage is the main plot and N source is the subplot. Manure as N source is further split by the year of N application as a sub-sub plot.

The results of the analyses on yield and soil characteristics done for 1989 are included in this report.

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[2] Graduate research assistant, professor, and associate professors, respectively, Soil Science Department, Univ. of Minnesota, St. Paul, MN, 55108.

RESULTS AND DISCUSSION

Grain Yields, Grain Moisture and Total Dry Matter. Tillage did not significantly affect grain yields and grain moisture (Table 2), but had a significant effect on total dry matter. The total dry matter was higher with no tillage than chisel plowing. Annual manure application had greatest average grain and total dry matter yield , about 30 bu/A more grain yield than the manure treatment in the year after its application. Manure in the year of application and annual fertilizer treatments had intermediate grain yields. Grain moisture at harvest was not affected by tillage, N treatments, or previous application of additional K. The moisture was greater in no till receiving no additional K in previous years than in the treatments receiving additional K, or in chisel plowing (Table 4). Previous K split had a significant effect on total dry matter: those with additional K had higher dry matter than those without it (Table 8).

Plant Population and Stover Yield. Although the plant population at harvest was not affected by tillage, N application, or K rates (Table 5), no tillage had slightly lower population than chisel plowing (Table 3). In general, there was a lower stand in 1989 by about 1500 plants/A than in 1988. Stover dry matter yield was not affected by tillage and N treatments. Additional K resulted in higher average stover dry matter by 0.4 ton/A (Table 8). The stover dry matter was higher in most N treatments receiving additional K except those receiving manure in the previous year when it was higher without additional K (Table 10). The stover moisture at harvest was highest in biennial manure applied in 1989 followed by annual manure and fertilizer, and manure applied in the previous year.(Table 7). The moisture was higher in no till in the year of application of manure. In the other treatments it was greater in chisel plowing (Table 9).

Harvest Index. An analysis of harvest index, a ratio of total grain dry matter to that of total dry matter (grain and stover), shows a significant effect of K treatments (Table 6). Higher stover dry matter associated with previous K addition resulted in a lower harvest index (Table 8). Annual manure produced the highest ratio followed by annual fertilizer and the biennial manure applied in 1988 and 1989, respectively, though the results were not significant.

Grain N, Stover N, and N Uptake. Although no till had higher N concentration in grain and stover (Table 11) the difference was not significant. The total N uptake in grain and stover was significantly higher in no till by 10 lbs/A than chisel plowed treatments. Both grain and stover N was highest in annual fertilizer followed by annual manure, biennial manure in the year of application, and biennial manure in the year after its application, respectively. Since the grain yields and stover yields were higher in the annual manure, the total N uptake with annual manure was higher by 13 lbs/A than with the fertilized treatments. Previous application of K resulted in higher grain N and N uptake in the biennial manure in the year of application but lower grain N and N uptake in the biennial manure in the year following application (Table 13). Grain N was found to be higher in no till without additional K; whereas, it was higher in chisel plow with additional K (Table 14).

Residue Cover. Residue measurements were made both in and between the rows in duplicate in manure, fertilizer and check treatments in both tillages on June 13, 1989. Residue was higher in no tillage than in chisel plowing (Table 15). The anhydrous applied treatments had highest residue followed by those in the year after application of manure, check, and those that received manure 1989 . The difference in residue cover between the fertilized treatments and the other treatments was most pronounced in no till and had about 20% more residue than the other treatment. There was about 10% more residue in between the rows than in the rows.

Soil Profile Moisture. Gravimetric soil moisture determination made on soil samples taken to a depth of 5 ft. in the spring and fall are given in Table 16. The soil samples were taken from selected treatments in all three replications in and between the rows separately with 3 core composites per sample. There was a higher soil moisture in the profile in the spring than in the fall, indicating little recharge by fall precipitation at the time of sampling. At both times of soil sampling, the soil moisture was higher in the upper 3 ft. depth than the depth below. No till treatments had higher moisture in the profile in the spring samples; whereas, the moisture was not affected by tillage in the fall (Table 17).

Soil Profile Nitrogen. Soil samples were taken to a depth of 5 ft. in 1 ft. increment from selected treatments in all three replications in and between the rows separately with 3 core composites per sample. Total inorganic N and ammonium-N determinations were made on these samples. There was more total inorganic soil nitrogen in chisel plow than in no till treatments in the spring, although the difference was not significant (Table 18). About 3/4 of the total inorganic nitrogen was in ammonium form. The total N was highest in fertilizer treatment. Manure in the year of application had about 8 lbs/A more N than manure in the year after application of manure (Table 19). Total N was higher in the top 0-1 ft. and bottom 4-5 ft. increments than those in the middle (Table 20). About 3/4 of N in the top 1 ft. was in ammonium form; whereas, about 1/2 of N in the bottom 4-5 ft. increment was in nitrate form. There was more nitrate N in between the rows in manure and check treatments and more nitrate N in the row in fertilized treatments (Table 21). The total N was more in the rows than in between the rows in the fertilizer and manure in the year of application. The manure in the year after its application and the check had more N in between the rows than in the rows (Table 22). The significance values for various main effects and interactions for soil moisture and N in fall and spring are given in Table 23.

Soil Water N. Suction water samplers were established on manure (annual and biennial) and fertilizer treatments to monitor nitrate-nitrogen in soil water at 5 ft depth. The data obtained in 1989 are presented in Fig. 1. Among the N treatments, both fertilizer and annual manure treatments yielded consistently higher nitrate-nitrogen at 5 ft depth than the biennial manure treatments. The difference was not much in the biennial treatments due to the year of application. The chisel plowing produced considerably higher nitrates in the water than no till system. The nitrate levels, however, were fairly uniform throughout the sampling period indicating little movement of water and N during that period. The suction samplers in the fertilizer treatments were established in the second week of July. There is an initial rise in nitrate levels in these treatments. The lower nitrate levels initially may have been caused by flow of water along the samplers because of the poor contact between the samplers and the soil.

Table 1. Cultural practices at the Fluegers Farm in Goodhue County, MN in 1989.

Tillage

No Till

Chisel Plow-Chiseled on May 11,1989.

Cropping History

Corn since 1981-P 3906.

1989 Corn Pioneer 3737

Manure Application

Injected liquid dairy manure at the following rate and analysis on May 9, 1989.

		1989 rate	
		Mean	Std. Dev.
Manure	(gal/A)	8300	370
Total-N	(lbs/A)	202	11
NH_4-N	(lbs/A)	124	14
K	(lbs/A)	149	9
Soilids:Total	(%)	7.6	0.7
Volatile	(%)	62.3	6.0
Fixed	(%)	37.7	6.0

Planting Information

A four row 38 inch Hinecker Series 1 Econo Till planter with clearing disks raised.

Planting Date	Rate	Harvested
May 12, 1989	32,000 plants/A	October 4, 1989

Fertilizer

Material Analysis	Tillage	Actual N -lbs/A-	Date Applied	Method of Application
82-0-0	Both tillages	170	May 16, 1989	Injected after planting

(In the previous years, no till and chisel plow received 210 lbs/A and 170 lbs/A, as ammonium nitrate, respectively)

Soil

Timula silt loam (Typic Eutrochrepts, coarse-silty, mixed, mesic), 2 to 12% slope. Soil is well drained.

Insect Control

8.7 lbs/A Counter applied in furrow on May 12, 1989.

Weed Control

3 pt./A Prowl, 2.5 lb/A 90 DF Bladex applied in 20 lb/A carrier on May 23, 1989.

Table 2. Corn grain yield, grain moisture, and total dry matter as influenced by tillage, and N source and frequency of application in Goodhue Co., MN in 1989.

Frequency[1] & Source of N	K_2O lb/A	GRAIN YIELDS No Till	Chisel	Mean	GRAIN MOISTURE No Till	Chisel	Mean	TOTAL DRY MATTER No Till	Chisel	Mean
		---bu/A---			---%---			---tons/A---		
Manure	0	150.5	135.7	143.1	28.2	24.5	26.3	5.82	4.96	5.40
(Yr. after)	200	135.6	133.4	134.5	24.5	24.5	24.5	5.31	5.11	5.21
	Mean	143.1	134.5	138.8	26.3	24.5	25.4	5.57	5.04	5.30
Manure	0	141.4	155.0	148.2	26.5	23.8	25.2	4.67	5.57	5.12
(Yr. of)	200	160.3	145.4	154.3	23.7	24.8	24.1	6.98	6.36	6.73
	Mean	154.0	149.5	152.0	24.6	24.4	24.5	6.21	6.02	6.13
Manure	0	160.3	159.0	161.8	25.2	21.9	24.1	6.30	6.00	6.20
(Annual)	200	177.5	167.4	174.1	23.5	22.6	23.2	6.82	6.14	6.60
	Mean	170.4	163.2	168.0	24.3	22.2	23.6	6.56	6.07	6.40
Anhydrous Ammonia	200	162.8	166.6	164.7	27.4	25.8	26.6	6.16	6.15	6.16

	Pr>F						
	Till(T)	Freq.(F)	T*F	K rate(K)	K*T	K*F	K*F*T
Grain Yields	.318	.066	.929	.770	.491	.426	.348
Grain moisture	.322	.291	.910	.174	.023	.756	.857
Total dry matter	.042	.401	.913	.004	.071	.003	.009

[1] Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 3. Tillage effects on corn plant population in Goodhue Co., MN in 1989[1].

Tillage	PLANT POPULATION -plants/A*10^{-3} -
No till	24.3
Chisel	25.9
Pr>F (Till)	.115

[1] Averaged over N and K treatments (Table 2).

Table 4. Effects of tillage and K application on corn grain moisture in Goodhue Co., MN in 1989[1].

K_2O lb/A	GRAIN MOISTURE No Till	Chisel
	---%---	
0	26.3	23.4
200	24.4	24.4
Pr>F (K rate*Till)	.023	

[1] Averaged over N and tillage treatments (Table 2).

Table 5. Corn plant population, stover yield, and moisture at harvest as influenced by tillage, and N source and frequency of application in Goodhue Co., MN in 1989.

Frequency & Source of N	K_2O lb/A	PLANT POPULATION No Till	Chisel	Mean	STOVER DRY MATTER No Till	Chisel	Mean	STOVER MOISTURE No Till	Chisel	Mean
		-- plants/A*10^{-3} ---			------ tons/A -----			-------- % --------		
Manure[1]	0	25.9	23.6	24.8	2.35	1.70	2.03	0.47	0.55	0.51
(Yr. after)	200	24.7	25.2	24.9	1.85	1.84	1.85	0.53	0.53	0.53
	Mean	25.3	24.4	24.9	2.10	1.77	1.94	0.50	0.54	0.52
Manure	0	22.2	24.9	23.6	1.70	2.06	1.88	0.58	0.52	0.55
(Yr. of)	200	23.3	26.4	24.6	3.51	2.73	3.20	0.61	0.59	0.60
	Mean	23.0	25.8	24.2	2.90	2.44	2.70	0.60	0.56	0.58
Manure	0	23.9	26.6	24.8	2.31	1.99	2.20	0.54	0.56	0.55
(Annual)	200	25.6	27.1	26.1	2.33	2.24	2.30	0.56	0.56	0.56
	Mean	24.7	26.9	25.4	2.32	2.11	2.25	0.55	0.56	0.56
Anhydrous-Ammonia	200	24.9	27.2	26.1	2.31	2.21	2.26	0.52	0.52	0.52

	Till (T)	Freq. (F)	T*F	K rate (K)	K*T	K*F	K*F*T
Plant population	.115	.463	.558	.484	.850	.932	.707
Stover dry matter	.368	.160	.839	.007	.377	.001	.004
Stover moisture	.839	.002	.054	.066	.284	.281	.155

[1]Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 6. Harvest index of corn as influenced by tillage, and N source and frequency of application in Goodhue Co., MN in 1989.

Frequency[1] & Source of N	K_2O lb/A	HARVEST INDEX No Till	Chisel	Mean
Manure	0	0.56	0.66	0.61
(Yr. after)	200	0.64	0.64	0.64
	Mean	0.60	0.65	0.63
Manure	0	0.64	0.63	0.64
(Yr. of)	200	0.50	0.58	0.54
	Mean	0.55	0.60	0.57
Manure	0	0.63	0.67	0.64
(Annual)	200	0.66	0.64	0.66
	Mean	0.65	0.65	0.65
Anhy. ammon.	200	0.63	0.64	0.63

Source	Pr>F
Tillage (T)	.504
Freq (F)	.157
T*F	.810
K Rate (K)	.096
K*T	.508
K*F	.004
K*F*T	.005

[1] Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 7. Corn stover yield, stover moisture, total dry matter, grain yield and grain moisture as influenced by N source and frequency of application in Goodhue Co., MN in 1989[1].

Frequency & Source of N	STOV. DRY MATTER	ST. MOISTURE	TOTAL DRY MATTER	GRAIN YIELD	GRAIN MOISTURE
	---- tons/A ---	----- % ----	---- tons/A ---	----bu/A----	-----%-----
Manure[2] (Yr. after)	1.94	.52	5.30	138.8	25.4
Manure (Yr. of)	2.70	.58	6.13	152.0	24.5
Manure (Annual)	2.25	.55	6.40	168.0	23.6
Anhydrous Ammonia (annual)	2.26	.52	6.16	164.7	26.6
Pr>F (N Source & Freq.)	.160	.002	.401	.066	.291

[1] Averaged over tillage and K treatments (Table 5).
[2]Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 8. Corn stover yield, total dry matter, harvest index, plant population, and grain moisture as influenced by previous K application in Goodhue Co., MN in 1989[1].

K_2O lb/A	STOVER DRY MATTER ----- tons/A ----	TOTAL DRY MATTER -----tons/A-----	HARVEST INDEX	PLANT POPULATION - plants/A*10^{-3} -	GRAIN MOISTURE -------%------
0	2.06	5.66	0.63	24.4	25.0
200	2.46	6.27	0.61	24.4	24.4
Pr>F (K rate)	.007	.004	.096	.484	.174

[1] Averaged over tillage and N treatments (Table 5).

Table 9. Corn stover moisture as influenced by tillage and N application in Goodhue Co., MN in 1989[1].

Frequency & Source of N	STOVER MOISTURE No Till	Chisel
	------%--------	
Manure[1] (Yr. after)	50.2	53.8
Manure (Yr. of)	59.9	55.8
Manure (Annual)	55.2	55.9
Anhydrous Ammonia	51.7	52.1
Pr>F (Till.*N Source & Freq.)	.054	

[1] Averaged over K treatments (Table 5).

Table 10. Corn stover yield, and stover moisture and total dry matter as influenced by K rate, N source and frequency of application in Goodhue Co., MN in 1989[1].

Frequency & Source of N	K_2O lbs/A	STOVER DRY MATTER ------ tons/A ---	STOVER MOISTURE ------ % ------	TOTAL DRY MATTER ---- tons/A ----
Manure[2] (Yr. after)	0	2.03	51	5.39
	200	1.85	53	5.21
Manure (Yr. of)	0	1.88	55	5.12
	200	3.20	60	6.73
Manure (Annual)	0	2.20	55	6.20
	200	2.30	56	6.60
Anhydrous Ammonia	200	2.26	52	6.16
Pr>F (N source & freq.*K)		.001	.281	.003

[1] Averaged over tillage treatments.
[2]Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 11. The effect of tillage on corn grain N, stover N, and total N uptake in Goodhue Co., MN in 1989[1].

Tillage	GRAIN N ---%---	STOVER N ----%----	TOTAL N UPTAKE ----lbs/A----
No Till	1.45	.63	135.0
Chisel Plow	1.39	.59	125.0
Pr>F (Till)	.141	.310	.033

[1] Averaged over N and K treatments (Table 5).

Table 12. The effect of N source and frequency on corn grain N, stover N, and total N uptake in Goodhue Co., MN in 1989[1].

Frequency & Source of N	GRAIN N	STOVER N	TOTAL N UPTAKE
	---%---	---%----	-----lbs/A----
Manure[2] (Yr. after)	1.31	.49	98.4
Manure (Yr. of)	1.42	.59	129.6
Manure (Annual)	1.45	.64	149.1
Anhydrous Ammonia (annual)	1.50	.72	136.5
Pr>F (N source and Freq)	.001	.000	.013

[1] Average over tillage and K treatments (Table 5).
[2] Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 13. The effect of N source and frequency, and K application on corn grain N, stover N, and total N uptake in Goodhue Co., MN in 1989[1].

Frequency & Source of N[2]	K_2O lb/A	GRAIN N	STOVER N	TOTAL N UPTAKE
		---%---	----%----	---lbs/A----
Manure (Yr. after)	0	1.33	.53	101.1
	200	1.28	.45	95.7
Manure (Yr. of)	0	1.37	.58	109.4
	200	1.46	.60	141.8
Manure (Annual)	0	1.51	.64	149.0
	200	1.40	.64	149.2
Anhydrous Ammonia (annual)	200	1.50	.72	136.5
Pr>F (N source and Freq*K)		.018	.583	.020

[1] Averaged over the tillage treatments.
[2]Manure applied in the spring of 1988 (year after) and 1989 (year of).

Table 14. The effect of tillage and K application on corn grain N, stover N, and total N uptake in Goodhue Co., MN in 1989[1].

Tillage	K_2O lb/A	GRAIN N	STOVER N	TOTAL N UPTAKE
		---%---	----%----	---lbs/A----
No Till	0	1.48	.62	129.1
	200	1.43	.63	138.3
Chisel Plow	0	1.33	.55	117.1
	200	1.42	.61	129.3
Pr>F (Till*K)		.005	.628	.720

[1] Averaged over the N treatments (Table 13).

Table 15. Effects of tillage, and N source and frequency, and row position on residue cover in Goodhue Co., MN, on 6/13/89.

N source	Row	Residue (%) No Till	Residue (%) Chisel
Manure(Year after)	In	44.0	15.3
	Bet.	56.0	34.7
Manure(Year of)	In	26.7	27.7
	Bet.	34.0	39.3
Manure(Annual)	In	26.6	40.0
	Bet.	39.8	41.6
Anhydrous amm.	In	74.7	23.7
	Bet.	65.7	43.7
Check	In	33.3	34.7
	Bet.	40.7	36.0

Pr>F

Till(T)	Freq.(F)	T*F	Row(R)	K*R	K*F	K*F*R
.039	.019	.013	.002	.212	.640	.581

Table 16. Gravimetric soil moisture by depth in Goodhue Co., MN in 1989.

Depth (ft.)	Moisture(%, wt./ wt.) April 26-May 2	Moisture(%, wt./ wt.) Oct 24-Nov 2
0-1	23.7	18.1
1-2	23.3	18.1
2-3	22.0	17.0
3-4	19.5	*
4-5	17.5	16.9
Pr>F (Depth)	.000	.000

[1] Averaged over N treatments (Table 19) and row position.
* The depth increment in the Fall samples was 3-5 ft.

Table 17. Gravimetric soil moisture as affected by tillage in Goodhue Co., MN[1].

Depth (ft.)	Moisture(%, wt./wt.) April 26-May 2 No Till	April 26-May 2 Chisel	Oct. 24-Nov. 2 No Till	Oct. 24-Nov. 2 Chisel
0-1	24.0	23.4	18.2	18.0
1-2	23.6	23.0	18.8	17.3
2-3	22.8	21.2	17.2	16.8
3-4	20.9	18.1	*	*
4-5	18.7	16.3	17.5	16.2
Pr>F (Till*Depth)	.022		.695	

[1] Averaged over N treatments (Table 19) and row position.
* The depth increment in the Fall samples was 3-5 ft.

Table 18. The effect of tillage on inorganic nitrogen in 5 ft. soil profile in Goodhue Co., MN on April 26- May 2, 1989[1].

Tillage	TOTAL N	NH_4-N	NO_3-N
	----------lbs/A----------		
No Till	104.5	75.0	26.5
Chisel Plow	115.5	81.5	34.0
Pr>F (Till)	.162	.534	.311

[1] Averaged over N treatments (Table 19) and row position.

Table 19. The effect of N source and frequency on inorganic nitrogen in the top 5 ft. soil profile in Goodhue Co., MN (April 26- May 2)[1].

N Source & Frequency	TOTAL N	NH_4-N	NO_3-N
	----------lbs/A----------		
Manure (Yr. of)[2]	85.5	75.0	10.5
Manure (Yr. after)	93.0	71.0	22.0
Ammonium Nitrate (annual)	151.0	96.0	55.0
Check	69.0	60.5	8.5
Pr>F (N source & Freq)	.162	.534	.311

[1] Averaged over tillage and row position.
[2]Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 20. Inorganic nitrogen by depth in the top 5 ft. soil profile in Goodhue Co., MN on April 26- May 2, 1989[1].

Depth (ft.)	TOTAL N	NH_4-N	NO_3-N
	----------lbs/A----------		
0-1	26.0	19.6	6.4
1-2	19.5	16.5	3.1
2-3	19.9	17.6	2.4
3-4	18.1	12.9	5.2
4-5	26.3	13.0	13.3
Pr>F (Depth)	.001	.014	.000

[1] Averaged over tillage and row position on on selected N treatments (Table 19)

Table 21. Total nitrate-N (averaged over tillage) by row position in the top 5 ft. soil profile in Goodhue Co., MN on April 26- May 2, 1989.

N Source & Frequency	NO_3-N (lbs/A) In Row	Bet Row
Manure (Yr. of)[1]	9.5	12.0
Manure (Yr. after)	15.5	29.0
Ammonium Nitrate (annual)	74.0	36.5
Check	7.0	10.5
Pr>F (N source and Freq*Row)	.005	

[1]Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 22. Total inorganic N (averaged over tillage) by row position and depth in the top 5 ft. soil profile in Goodhue Co., MN on April 26- May 2, 1989.

N Source & Frequency	Row	Total inorg. N (lb/A) 0-1 ft.	1-2 ft.	2-3 ft.	3-4 ft.	4-5 ft.	0-5 ft.
Manure(Yr. of)[1]	In	32.0	14.7	20.5	9.5	15.3	**92.0**
	Bet.	16.1	13.0	19.4	15.6	15.0	**79.1**
Manure (Yr. after)	In	22.9	13.8	18.2	16.3	15.1	**86.3**
	Bet.	41.9	15.8	13.2	12.4	16.2	**99.5**
Ammonium Nitrate (annual)	In	25.9	32.8	23.9	26.1	56.3	**165.0**
	Bet.	30.5	22.4	26.3	23.2	34.4	**136.8**
Check	In	20.5	14.0	16.5	13.6	8.8	**73.4**
	Bet.	13.7	13.8	11.2	14.6	11.7	**65.0**
Pr>F (N source & Freq.*Row*Depth)					.096		

[1]Manure applied in the spring of 1987 (year after) and 1988 (year of).

Table 23. Significance table for spring and fall soil moisture, and spring soil N.

	Till(T)	N Freq(F)	T*F	Row(R)	T*R	F*R	T*F*R	Depth(D)	T*D	F*D	T*F*D	R*D	T*R*D	F*R*D	T*F*R*D
Soil moisture															
Spring	.212	.567	.741	.621	.896	.894	.838	.000	.022	.428	.488	.907	.952	.999	.999
Fall	.419	.874	.228	.065	.714	.464	.357	.158	.695	.352	.624	.501	.658	.544	.641
Spring N	.162	.009	.992	.305	.806	.355	.939	.011	.346	.001	.584	.910	.796	.096	.686
NH_4-N	.534	.532	.945	.515	.787	.514	.369	.014	.504	.825	.601	.798	.849	.277	.590
NO_3-N	.311	.000	.323	.484	.967	.005	.530	.003	.755	.000	.220	.351	.578	.562	.506