in August (Table 2). Corn yields of individual tillage, residue and in-row residue management treatments were significantly different at the 2.5 percent level (Table 1). Yields of the two highest yielding treatments, paraplow mulch (TW) and conventional normal (C), were significantly greater than the two lowest yielding treatments no till bare (C) and (TW). Average corn yields of the four replicates were significantly different at the 1 percent level; as in 1983 and 1984 average corn yield increased as average depth of rooting increased (Table 3). Depth of rooting was measured as the depth to red clay residuum. In 1985 rep average corn yields increased 12.1 bu/ac as average depth increased from 28 to 62 inches. In 1984 and 1983 the comparable yield increases were approximately 13 and 38 bu/ac respectively. In 1981 and 1982 when water stress was minimal there was no relationship between depth to clay layer and average yield per rep. Thus the effect of rooting depth and available water holding capacity in the root zone on yield depends greatly on the climatic conditions in the individual year as well as the crop grown.

Seedbed Conditions

Average planting depth and the standard deviation of the planting depth both were significantly different. Paraplow and no-till treatments planted with trash whip attachments (TW) had a greater planting depth than those planted with the fluted coulter (C). Similarly the standard deviation was less for no-till treatments planted with the trash whip unit compared to the same treatment planted with the coulter unit. The trash whip unit was adjusted for no-till and paraplow conditions and consequently ran excessively deep in the looser soil conditions of the moldboard and chisel treatment.

In-row residue cover was reduced by about one half by the trash whip attachment (TW) compared to in-row cover resulting from the coulter unit (C) (Table 1). The regression equation

Eq. 1: % cover TW = -3.2 + 0.50 (% cover C)

explained 89% of the variation in % cover of the TW treatments for 1984 and 1985. Percent in-row cover was closely related to grain moisture and air GDD summed to 6-leaf:

Eq. 2: % Grain moisture = 20.5 + 1.97 X 10^{-2} (% in-row cover); $R^2 = 0.87$

Eq. 3: Air GDD (planting to 6-leaf) = 273 + 0.47 (% in-row cover); $R^2 = 0.91$

Thus the effect of increasing amounts of in-row cover was to delay phenologic development. Two measures of this delay were the increased number of air GDD required to reach 6-leaf stage and increased grain moisture at harvest. In-row cover was related to population at harvest by the equation:

Eq. 4: Harvest population = 25890-29. (% cover in-row); $R^2 = 0.54$

In both 1984 and 1985 the trash whip units significantly increased final population compared to the coulter units on the no-till and paraplow treatments. The average increase was approximately 1200 plants/acre.

For each tillage treatment the effect of mulch treatment (C) was to increase the number of days post plant required to reach 95% emergence, to delay the data that 50% plants silked, and to increase average grain moisture. Decreases in population were significant only on the chisel and moldboard treatments (Tables 1 and 4).

The effect of in-row surface residue cover and tillage on soil temperature and on corn growth was evaluated at Lancaster in 1983, 1984, and 1985. Hourly soil temperatures were recorded for 1, 5, 10, 15, 50, and 100 cm depths under the row on the chisel normal and mulch, no-till bare and mulch and the paraplow normal and mulch treatments in 1984 and 1985. Soil temperatures were measured on paraplow and no-till mulch treatments. Soil temperatures were measured using 4-couples in parallel for 15 cm and shallower depths. Leaf stage observations were taken periodically. Eq. 3 was developed using leaf stage observations and station air temperature measurements; the results agree closely with our previous research results.

Large differences in "final" (50 to 60 minute average) infiltration rates were measured between treatments (Tables 5 and 6). All mulch treatments tested had greater "final" infiltration rates than the bare treatments except for moldboard mulch treatment (E) which had a "final" infiltration rate of only 0.52 inches/hour. Based on tensiometer and infiltration rate measurements the conductivity of the 6 to 12 inch depth on this treatment was between 0.1 to 0.2 inches/hour; the tensiometer measurements showed a positive pressure head at the 6-inch depth indicating ponding of water within the plow layer. This is the first positive evidence obtained on these plots of the presence of a flow restricting layer below normal plowing depth; other circumstantial evidence is the consistently high infiltration rates measured with mulch treatments & tillage below the plow layer (no-till mulch in 1983, Table 6) and paraplow mulch in 1984 and 1985).

Final infiltration rates for 1981-1985 are given in Table 6. The ratio of (bare/mulch) infiltration rates for the conventional treatment was 0.65 which is within the range previously measured; the infiltration rate of over 3 inches/hour for the no-till mulch treatment is much higher than previous measurements except for 1983 following distrubance by spring injection of anhydrous ammonium

The implication is that the no-till mulch treatment had no major flow restricting layer in contrast to the no-till bare where a conductivity of 0.2 inches/hour was measured for the surface 0-2 inch layer. These results again illustrate the requirement of 1) a porous surface layer with high saturated conductivity, 2) a protective mulch cover, 3) absence of any flow restricting layer within the depth involved in infiltration. Residue cover by itself is not sufficient to produce a high infiltration rate when significant restrictions to flow occur within the infiltrating profile.

Summary

Five and seven year results with continuous corn at Lancaster show nearly equal yields from conventional, chisel and ridge-till treatments; no-till (slot plant) yields were slightly lower in some years (Table 7).

To evaluate tillage-residue management practices, a simple tillage-management model was developed which quantifies the effects of the major physical factors of planting date, final plant population, net growing degree days (GDD), and estimated water stress. GDD are included only when below a threshold value required to mature the crop. The net GDD are calculated as the cumulative air temperature GDD from planting to frost minus any residue management caused delay in growth up to the 6-leaf stage. Lancaster data from 1972 through 1983 was used to develop the model, which has an R^2 of 82 percent and a standard error of approximately 12 bu/acre. For the years of 1982-83 the model accounted for 89 percent of the variation with a standard error of 10 bu/ac. The major effect of tillage on yield was through the effect of tillage on seedbed conditions and water management. Seedbed conditions were affected by seed-soil contact and depth and accuracy of seed placement which affect final plant population as well as in-row residue cover which strongly affects the rate of phenological development of corn up to the 6-leaf stage. The between row surface residue cover and soil conditions strongly affect water infiltration and runoff from the soil surface. Staricka, J.A. 1985. Tillage-crop management models for corn production in southeast Minnesota. M.S. Thesis, Univ. of MN.

Thus farmers in the driftless soil area can choose between a variety of tillage options which have yields comparable with conventional tillage, but which are superior in soil and water conservation and also offer savings in time, labor, and fuel compared to the conventional moldboard plow tillage method.

Table 1. Effect of tillage and mulch treatments on percent cover, planting depth, emergence, silking date, population and grain yield - 1985 Lancaster.

Treatments Tillage	Residue	In Row Residue Mtg.	Percent Cover In-Row	Percent Cover Entire Area	Planting Depth Ave mm	Planting Depth S.D. mm	Days Post Plant To 95% Emergence	Date 50% Plants Silked July	Ave. Pop. At Harvest Plants/Ac	Ave. Grain Yield Bu/Ac	Ave. Grain Moisture %
Paraplow	Normal (N)	C	35	45	21	7.3	18.5	16.5	24,400 abcd	124.8 abcd	21.1 cde
		TW	11	33	27	7.3			25,800 abd	125.8 abc	20.9 de
	Mulch (1X+N)	C	88	86	24	6.3	22.5	18.3	23,000 d	124.3 abcd	22.1 ab
		TW	37	60	25	6.6			25,500 abc	136.7 a	22.0 abc
No Till	Bare (0)	C	8	13	23	6.2	16<	15.8	24,600 abcd	115.3 cd	20.6 de
		TW			28	5.8			23,900 bcd	110.2 d	20.3 e
	Normal (1X)	C	55	72	22	5.1	19	16.8	24,100 bcd	119.9 bcd	21.4 bcd
		TW	26	40	25	4.8			26,400 ab	126.8 abc	21.1 cde
	Mulch (2X)	C	89	92	23	7.4	21.	18.5	23,800 cd	121.0 bcd	22.2 ab
		TW	50	71	26	4.1			25,800 abc	127.7 abc	21.4 bcd
Fall Chisel	Normal (N)	C	6	9	25	6.7	16<	15.8	27,000 a	125.2 abc	20.6 de
	Mulch (1X+N)	C	89	88	28	7.0	22.	18.0	22,500 d	119.9 bcd	22.0 abc
Conv. (Sp. Plow)	Normal (0)	C	1	2	26	4.6	16<	15.5	25,800 abc	133.3 ab	20.2 e
	Mulch (1X)	C	93	89	22	7.3	24.5	17.8	22.800 d	129.2 abc	22.5 a
Significance Level					0.05	0.05			0.01	0.025	0.01

Table 2. 1985 Weather Summary, Lancaster Experiment Station.

Month	Precipitation inches Total	Precipitation inches Departure	Growing degree days °F 1985	Growing degree days °F Departure	Temperature Avg. Max	Temperature Avg. Min	Temperature Avg.	Temperature Depart
					----------	F	----------	
April	1.90	-1.25	---	---	62.7	40.5	51.6	+4.9
May	4.95	+1.42	366	+67	72.7	49.3	61.0	+3.2
June	1.32	-3.23	434	-79	75.2	52.6	63.9	-3.0
July	2.11	-2.18	637	-19	84.2	58.3	71.2	-0.1
August	3.34	-1.08	504	-90	77.5	55.0	66.2	-2.7
Sept.	6.89	3.34	381	+27	69.6	52.6	61.1	+0.2
October	2.94	+0.51	---	---	58.6	39.3	48.9	-1.6
Sum April thru Oct.	23.45	-2.47	2322	-94				

First Fall Low Temperatures
Sept. 28 (32 °F)
Oct. 16 (28 °F)

Table 3. Average yields and depth to clay residuum by replicate and precipitation for 1981, thru 1985, Lancaster, Wisconsin.

Year	Number 1	Number 2	Number 3	Number 4	Monthly Precipitation May	June	July	August
	---------Bu/Ac----------				----------Inches----------			
1981	146.8	146.7	142.1	147.1	0.85	4.28	2.91	11.35
1982	150.0	143.4	142.8	147.3	5.46	3.45	5.29	4.06
1983	72.8	85.2	96.4	111.2	5.18	3.28	3.34*	3.12*
1984	107.3	110.4	118.0	120.1	3.92	7.77	2.57**	1.37**
1985	118.5	121.1	129.6	130.6	4.95	1.32***	2.11***	3.34***
Avg. depth to clay residuum in inches	29	41	46	62				

1981 - Subplots with population < 17,000 omitted.
1982 - Missing values estimated for 8 plots out of a total or 48 plots.
1983 - Subplots with population < 18,000 omitted Rep. II, III, IV.
* 1983 - 1.13 inches precipitation from July 3 to Aug. 25 (53 days).
** 1984 - 1.52 inches precipitation from July 18 to Aug. 31 (45 days).
*** 1985 - 1.59 inches precipitation from May 28 to July 25 (57 days)
Largest rain was 0.36 inches.

Table 4. Influence of tillage method and residue management on rate of emergence.

Treatment Tillage	Residue	Days Post Plant 16	19	23	26
		----------Percent of final emergence---------			
Paraplow	Normal	89	97	100	100
	Mulch	51	82	97	100
No Till	Bare	99	100	100	100
	Normal	85	96	100	100
	Mulch	56	90	100	100
Chisel	Normal	100	100	100	100
	Mulch	64	87	99	100
Conventional	Normal	100	100	100	100
Moldboard	Mulch	63	75	91	100

Table 6. Infiltration rate 55 minutes after runoff begins (Paired observations).

Tillage	Treatment Residue	1981	1982	1983	1984	1985	Ave.
		----------inches/hour----------					
No Till	Mulch	1.46	1.10	3.53*	0.60	3.02	(1.55)+
	[No Till Mulch]	[1.51]	[0.72]	[6.53]	[0.35]	[2.16]	(1.11)+
	Conv. Bare						
No Till	Bare	--	--	--	1.68	1.00	
Conventional	Bare	0.97	1.52	0.54	1.70	1.40	1.23
	Mulch	2.72	2.34	1.49	2.90	2.14**	2.32
	(Bare/Mulch)	(0.36)	(0.65)	(0.36)	(0.58)	(0.65)	(0.53)

* Soil disturbed prior to planting by anhydrous ammonia injection.
** 1-observation only.
\+ Omit 1983

Table 7. Continuous corn tillage yield results to Lancaster, WI 1979-1985

Tillage	1979	1980	1981	1982	1983	1984	1985	1979-83	1979-85
	----------Bu/Ac----------								
Ridge Plant	162	157	157	147	100	---	---	145	---
Slot Plant	163	146	151	141	85	108	120	137	131
Chisel	160	150	167	154	95	115	125	145	138
Conventional	169	159	168	151	89	121	133	147	141
Paraplow	---	---	---	---	---	106	125	---	---

Table 5. 1985 Lancaster Infiltration rate measurement.

Tillage	Residue		Application rate in one hour inches	Water applied before runoff inches	Infiltration rate X minutes after runoff commences - in/hour											
					2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5
No Till	Bare	E	5.28	0.40	3.14	1.44	1.68	1.92	1.56	1.32	0.72	1.44	1.20	0.96	0.72	1.20
		W	5.36	0.40	2.96	1.04	1.52	1.28	2.00	1.68	0.80	1.68	1.04	1.27	1.04	1.04
	Mulch	E	5.28	0.44	3.12	2.88	2.64	3.36	3.12	2.64	3.12	3.36	3.36	3.60	3.36	3.84
		W	4.96	0.50	1.12	2.08	2.56	3.04	2.32	2.80	2.56	2.56	2.56	2.32	2.56	---
Conventional	N	E	4.88	1.06	0.08*	1.04*	2.00	2.00	2.00	2.00	1.78	1.28	1.52	1.28	1.52	---
(Moldboard		W	4.88	1.14	2.00	2.48	2.48	1.76	2.12	2.12	1.40	1.28	1.16	1.28	1.52	---
Plow)	Mulch	E	4.96	0.50	2.56	1.60	0.88	0.16	0.88	0.40	0.88	1.12	0.64	0.64	0.64	0.40
		W	4.72	1.18	3.76	1.24	1.48	---	---	---	---	1.24	2.20	2.20	2.08	---
Paraplow	Mulch	E	4.88	0.94	4.52	4.28	3.92	3.20	3.20	2.96	3.68	3.56	3.08	3.20	3.44	3.20
		W	4.72	0.45	4.60	4.48	3.88	4.00	3.76	3.28	3.28	3.28	3.52	3.28	3.16	2.92

*Data Questionable:

The Effect of Tillage and Potassium Placement on the Availability of Potassium to Corn

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Cooperator: Dale Flueger

Farmers are looking for ways to reduce production inputs. Because of this there is increased interest in conservation tillage, and along with this the need for more information on fertilizer requirements for crops grown with reduced tillage systems. Therefore, the objectives of this study are:

1. To determine the effects of tillage on K availability to corn.
2. To determine the effects of row applied K and tillage on availability and growth of corn over a range of soil test K levels resulting from broadcast K treatments.
3. And to characterize the effect of tillage on the spacial distribution of broadcast K, and determine how this relates to soil test interpretation.

This study was initiated in 1982, but only 1985 results will be discussed, with the exception of soil test K, in which case results from 1983, and 1984 will also be presented.

METHODS AND MATERIALS

The experimental site is located on approximately three and one third acres of land in Sec. 15 of Haycreek Township of Goodhue County, Minnesota on a deep loess soil over limestone. The soil is a Typic Eutrochrept (Timula silt loam) with initial soil test ranges of 20.7 ± 5.3 ppm phosphorus (Bray-1), and 83.0 ± 18.1 ppm potassium (ammonium acetate extraction). Initial pH was 6.5 ± 0.5 with about 2.5 percent organic matter. Three T/ac of limestone were applied in 1980.

Oats and alfalfa were grown at the site in 1978, followed by two years of alfalfa. Corn as silage was grown in 1981 and corn for grain from 1982 to 1985. A 95 day single cross hybrid (Pioneer 3906) was planted at a rate of 29,900 plants/ac at a row spacing of 38 inches.

Equipment used consisted of: a chisel plow (Glencoe Soil Saver) with chisels 3.5 inches wide and spaced 13.3 inches apart with twisted shovels, a field cultivator (Bushog), and a planter (Hinicker) equipped with 2 inch fluted coulters. Planting and tillage dates are given in Table 1. Pest control at the study site is given in Table 2.

Table 1. Dates of planting and tillage.

Activity	Date
Planting	18 May 1985
Chisel plowing	11 May 1985
Soil Finisher	16 May 1985

Table 2. Insect and weed control used in 1985.

Pesticide	Rate of a.i. Applied
Terbufos (Counter)	1.3 lb/ac
Atrazine	2.5 lb/ac
Alachlor (Lasso)	2.5 lb/ac
Bucktril[1] (Bromoxynil)	.38 lb/ac

1. Applied post emergence for control of lambsquarter.

Please refer to the title page of this publication for information regarding application and use of this article.

This study was designed as a randomized complete block with six replications. Tillage treatments used were, spring chisel plowing (7-9 inches deep) followed by a field cultivator and no-till. Broadcast K applications were made in the spring prior to tillage. Potassium was applied in the row at planting (0-0-7.3) every other row to determine the effects of row applied K on early growth and yield. Nitrogen and phosphorus were also applied (7-21-0) to all rows. The placement depth of these row applied fertilizers was 1 to 2 inches with no-till and 3 to 4 inches with chisel plowing. The date and application rates of the fertilizer treatments are given in Table 3. The actual application rate of K_2O in the two row applied fertilizers is in Table 4. Potassium present in the 7-21-0 was due to contamination in the fertilizer. Nitrogen as ammonium nitrate was applied to the entire plot area at a rate of 300 lb/ac to ensure that N was non limiting to crop growth.

Table 3. Fertilizer treatment application schedule.

Fertilizer Type	Date Applied	Method	Rate Applied
Potassium Chloride (KCl)	30 April 1985	Broadcast	0, 200 and 400 lb K_2O/ac
ammonium polyphosphate+ urea (7-21-0)	18 May 1985	Row	20 gal/ac (18 lb N ac, 53 lb P_2O_5/ac)
Potassium Chloride (0-0-7.3)	18 May 1985	Row	15 gal/ac (11.0 lb K_2O/ac)

Table 4. K applied in the row.

0-0-7.3 K_2O	7-21-0 K_2O
----lb/ac----	
11.0	.05

Ten core composite soil samples were taken, for the 0 to 6, and 6 to 12 inch depths. Ten core composite soil samples were also taken for the 0 to 2, 2 to 4, and 4 to 6 inch depths. Soil samples were taken in this way in 1983, 1984, and 1985 before broadcast K applications and tillage, and after broadcast K applications and tillage. Soil sampling dates are given in Table 5. All soil samples were dried at 99° C, and ground to pass a .08 inch sieve.

Table 5. Dates of soil sampling.

	------Date of Sample------		
	1983	1984	1985
Prior to broadcast K applications and tillage	26 April	10 April	30 April
After broadcast K applications and tillage	16 June	2 July	11 July

Whole plant samples were taken at approximately the 6-10 leaf stage of development. Plants were cut at ground level (10 plants/plot) on 1 July 1985. Grain and stover samples were taken at harvest (4 November 1985). All plant samples were dried at 140° F and ground to pass a .04 inch sieve.

The K levels in the soil tested were determined using ammonium acetate extraction (Carson, 1980). Statistical analysis was done using the Statistical Package for the Social Sciences (Norusis, 1986). Residue was measured by the line intersect method (Laflen et al., 1981).

RESULTS AND DISCUSSION

The effects of tillage on soil cover are shown in Table 6. In the row, no-till resulted in approximately four times the level of soil cover as chisel plowing, and between the row no-till had approximately three times the soil cover of chisel plowing. Within tillage treatments soil cover was slightly greater between the row than in the row. Variability of the soil cover is due to variability of stover distribution by the combine.

Table 6. The effect of tillage on soil cover in and between the row on 1 July 1985. [1] In and between the row are defined as the 20 cm area centered over the row and the remainder,respectively.

Tillage	In Row[1]	Between Row[1]
	----------%	----------
No-till	55.9 (15.42)[2]	65.1 (12.56)
Chisel	13.0 (6.44)	22.9 (9.75)

[2] Values in parenthesis represent the standard deviations, N=18.

Weather conditions at the study site are summarized in Table 7 and Figure 1. Precipitation was very limited throughout May, June and July in 1985. There was a total of 1.59 inches of rain from May 23 to 4 July. July was also dry with a total rainfall of 2 inches, 1.4 of which fell on 24 July. With an average temperature of 68.4 C in July, and little moisture, pollination may have been affected.

Table 7. Monthly growing degree days and average temperatures[1]

Month	Growing Degree Days (base 50/86-°F)	Average Temp.(°F)
May	769	56.5
June	783	58.1
July	1129	68.4
August	877	60.3
September	646	53.6
October	241	39.6

[1] Data is from the Rosemount, MN weather station which is approximately 40 miles from the experimental site.

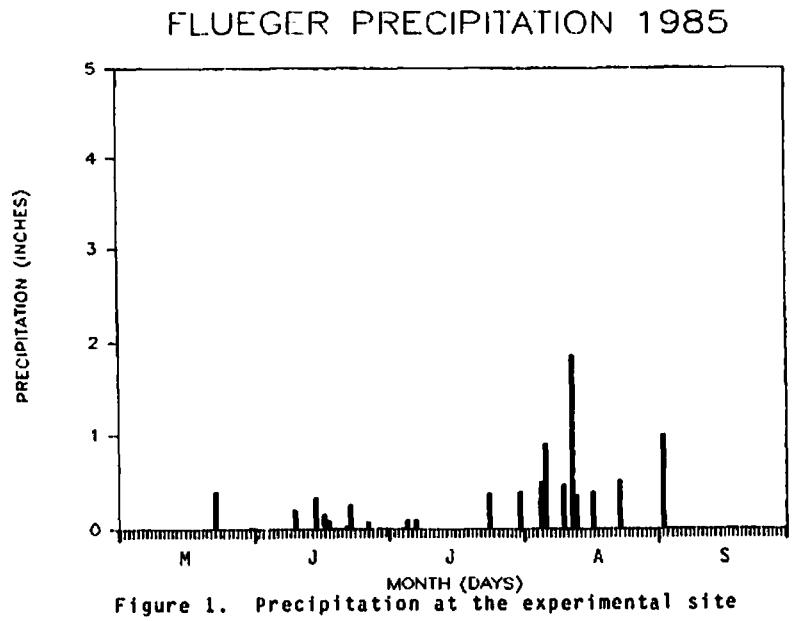

Figure 1. Precipitation at the experimental site during the 1985 growing season.

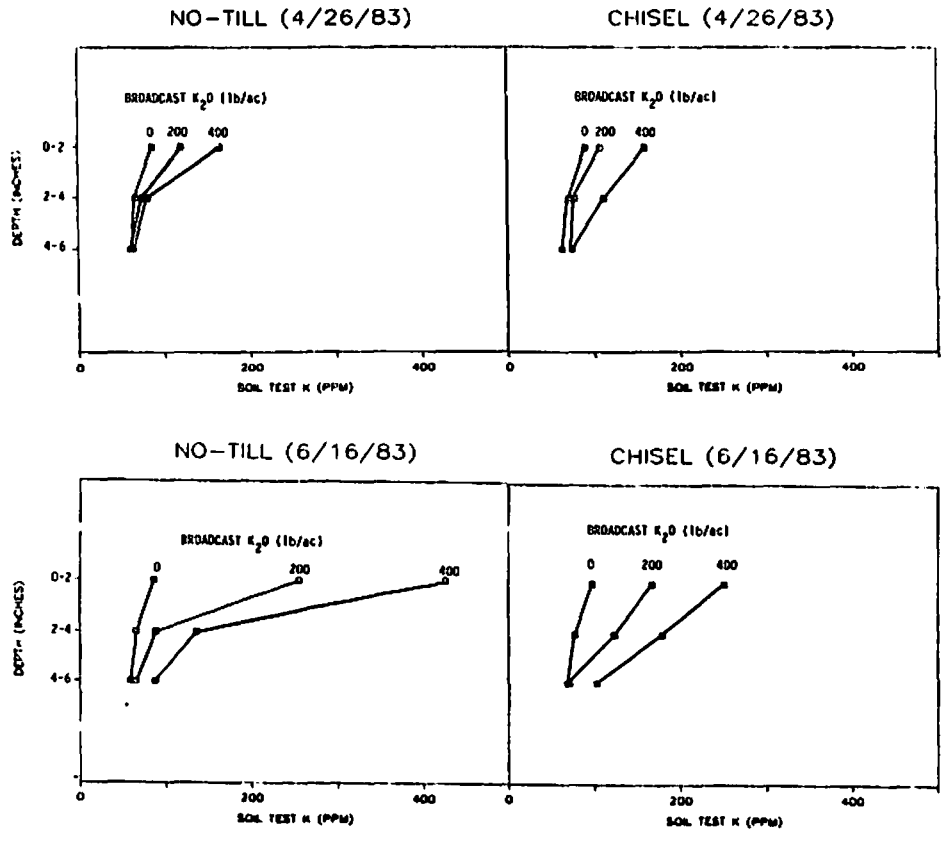

Figure 2. The effect of tillage on the distribution of soil test K before (4/26/83), and after (6/16/83) broadcast K applications, and tillage.

Tables 8 and 9 show the effects of tillage on soil moisture on 30 April 1985 and 11 July 1985, respectively. Analysis of variance was used to determine treatment differences (Table 10). Tillage significantly affected soil moisture on 30 April in the 0 to 2, and 0 to 6 inch depths with no-till having greater soil moisture than chisel plowing. The 11 July samples were significantly affected by tillage at all depths. It was much drier on 11 July than on 30 April because of the low levels of rainfall which occurred prior to sampling (only .43 inches of rain from 23 May to the July sampling date compared to spring snow thaw). The greater soil moisture with no-till than chisel plowing can be attributed to the greater soil cover with no-till than chisel plowing.

Table 8. The effect of tillage and depth on soil moisture on 4/30/85.

Depth of Sample (Inches)	Tillage	Soil Moisture (% by Wt.) mean	standard deviation
0 to 2	No-till	23.1	(2.73)
	Chisel	20.0	(3.86)
2 to 4	No-till	22.4	(1.52)
	Chisel	21.8	(1.93)
4 to 6	No-till	22.7	(1.56)
	Chisel	22.6	(2.52)
6 to 12	No-till	22.7	(.80)
	Chisel	22.2	(1.19)
0 to 6	No-till	22.9	(2.04)
	Chisel	21.6	(2.39)

Table 9. The effect of tillage and depth on soil moisture on 7/11/85.

Depth of Sample (inches)	Tillage	Soil Moisture -(% by wt)- mean	standard deviation
0 to 2	No-till	13.5	(2.34)
	Chisel	11.1	(1.16)
2 to 4	No-till	16.0	(.65)
	Chisel	15.4	(1.23)
4 to 6	No-till	16.6	(.68)
	Chisel	15.2	(1.26)
6 to 12	No-till	16.4	(1.03)
	Chisel	14.5	(3.12)
0 to 6	No-till	14.9	(.81)
	Chisel	14.0	(1.0)

Table 10. Significance of tillage effects on soil moisture.

Depth	Date of soil Sampling 4/30/85	7/11/85
(Inches)	-Significance level-	
0 to 2	.008	.000
2 to 4	.358	.082
4 to 6	.876	.000
6 to 12	.124	.021
0 to 6	.081	.005

Figures 2,3, and 4 show the distribution of soil test K to a depth of 6 inches before and after broadcast K applications and tillage for 1983, 1984, and 1985, respectively. Tables 11, and 12 show the soil test k levels in the 0 to 6 and 6 to 12 inch depths, respectively. Analysis of variance was done to determine treatment differences, the results of which can be found in Table 13, 14, 15, 16, and 17 for the 0 to 2, 2 to 4, 4 to 6, 0 to 6 and 6 to 12 inch depth increments respectively.

There were no significant effects due to tillage on the distribution of soil test K on 26 April 1983. The rate of K affected soil test K levels to a depth of 4 inches at this time, indicating little movement or mixing (with chisel plowing) of K below this depth at this time. The 16 June 1983 (51 days after broadcast K applications) samples showed significant tillage affects in the 0 to 2, 2-4, and 4-6 inch depths. This significant tillage effect which occurred was due to the gradient of K which developed after the broadcast K applications with no-till having the steeper gradient of the two tillage treatments. No-till resulted in greater soil K in the 0 to 2 inch depth than chisel plowing. Chisel plowing resulted in greater soil K from 2 to 6 inches than the no-till treatment. The tillage by K rate interaction which existed at this time in the 0 to 2 inch depth was the result of differing tillage effects on soil test K levels with different K applications (check treatment soil test K levels were similar between tillage treatments).

In 1984 similar results to 1983 occurred, with soil K levels prior to broadcast K applications and tillage (10 April 1984) being generally unaffected by tillage (with the exception of the 0 to 2 inch depth). The rate of broadcast K significantly affected the soil K levels at all but the 6 to 12 inch depth. Eighty-three days after broadcast K applications and tillage (2 July 1983) a steep gradient in soil K was still present. Tillage affected the soil K levels significantly in the 0 to 2, and 4 to 6 inch depth. No-till resulted in greater soil K in the 0 to 2 inch depth than chisel plowing. Chisel plowing resulted in greater soil K in the 4 to 6 inch depth than no-till. It is likely that there was movement of K to the 2 to 4 inch depth, since tillage did not affect soil K levels at this time. Again rate of broadcast K significantly affected soil K levels at all but the 6 to 12 inch depth. There was again a tillage by K rate interaction in 1984.

In 1985 prior to broadcast K applications and tillage (30 April 1985) movement of K deeper in the soil profile was evident. As in 1983 there were no significant tillage effects at any depth other than the 0 to 2 inch depth. No-till had greater soil test K than the chisel plow treatment. It is interesting to note the K rate effect even in the 6 to 12 inch depth at this time indicating that at the 400 lb K_2O/ac rate of broadcast K, soil K at this depth was greater than at the 0 rate. The K rate effected soil K levels significantly at all depths at this time, indicating movement of K in the soil profile even to the 6 to 12 inch depth. Soil K levels taken 72 days after broadcast K applications (11 July 1985) were significantly affected by tillage in the 0 to 2. No-till again had greater soil K than chisel plowing in the 0 to 2 inch depth. Rate of broadcast K affected the

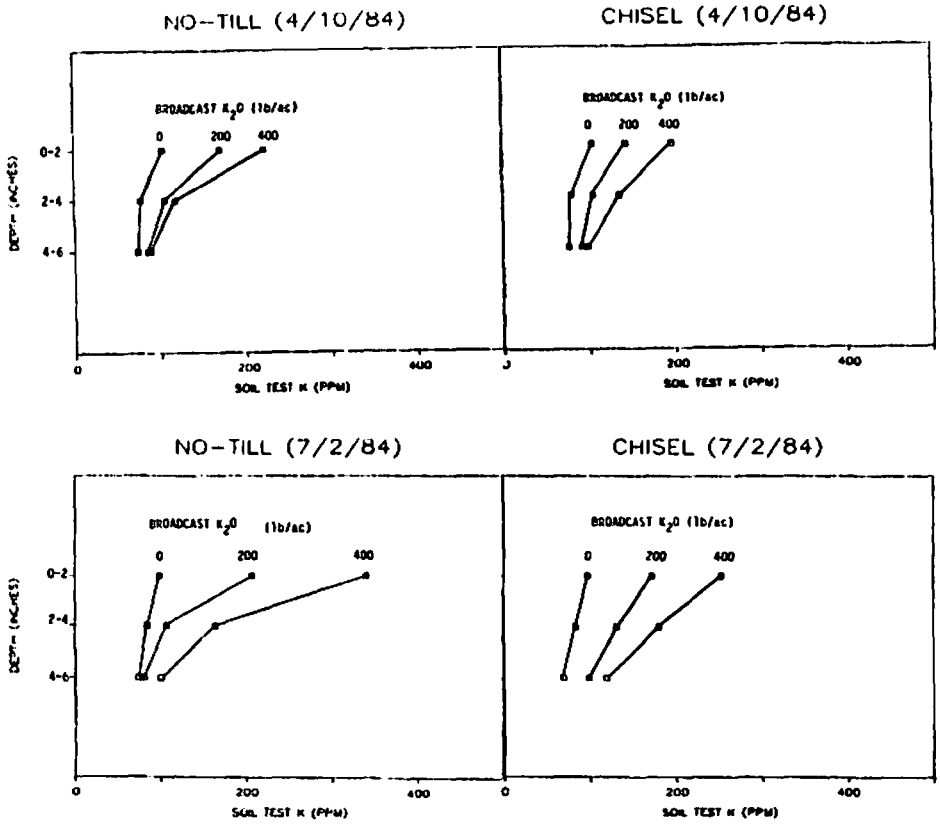

Figure 3. The effect of tillage on the distribution of soil test K before (4/10/84) and after (7/2/84) broadcast K applications, and tillage.

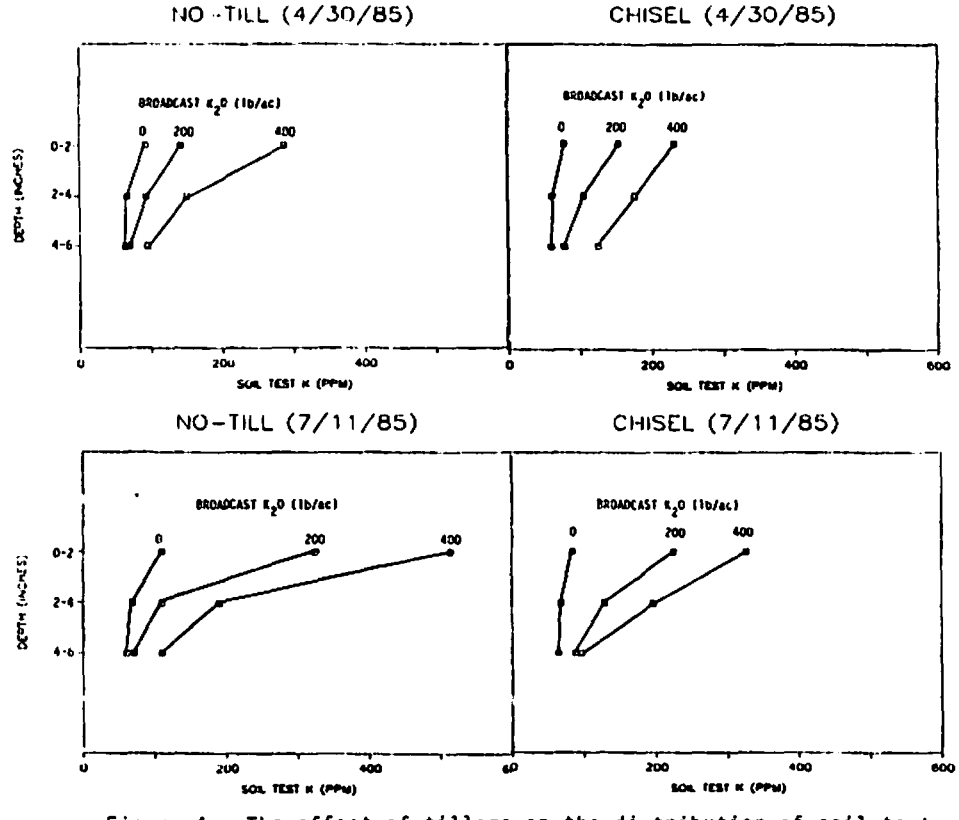

Figure 4. The effect of tillage on the distribution of soil test K before (4/30/85), and after (7/11/85) broadcast K applications, and tillage.

soil K levels in all depths. The tillage by K rate interaction in the 0 to 2 inch depth is due to the check treatment. The significant effects of replication and interactions with replication reflect, in part, the field's slope, which caused soil conditions to vary.

Analysis of variance done on the 0 to 6 inch soil test K levels showed that tillage was not a factor affecting the total amount of extractable soil K in this depth except on the 11 July 1985 sampling date. This may be a reflection of the dry soil conditions in the 1985 growing season which would slow the reactions in the soil. The greater concentration of soil K in the 0 to 2 inch depth with the no-till treatment is reflected in the higher 0 to 6 inch soil tests.

Table 11. The effect of tillage and applied K on soil test K in the 0 to 6 inch depth from 1983 to 1985.

Date of soil sample	NO-TILL			CHISEL		
	Rate of Broadcast K_2O applied annually (lb/ac)					
	0	200	400	0	200	400
	Soil Test K ppm					
4/26/83	70.5 (12.7)[1]	84.5 (16.4)	101.7 (11.0)	68.5 (15.3)	75.8 (18.8)	111.8 (29.8)
6/16/83	65.2 (13.8)	124.5 (29.1)	175.5 (6.2)	72.0 (18.0)	111.5 (30.9)	152.7 (36.3)
4/10/84	81.2 (11.1)	112.7 (21.8)	140.2 (30.9)	83.7 (12.4)	102.2 (25.3)	138.0 (28.7)
7/2/84	81.8 (13.0)	127.8 (13.6)	173.7 (40.4)	79.8 (10.0)	131.7 (18.6)	174.5 (36.3)
4/30/85	73.5 (10.6)	112.5 (11.0)	176.0 (35.2)	69.5 (12.9)	100.3 (33.0)	183.7 (39.3)
7/11/85	78.2 (12.5)	158.3 (14.9)	266.0 (56.2)	71.5 (10.9)	142.5 (30.6)	204.3 (42.9)

[1] Values in parenthesis represent the standard deviations, N=6.

Table 12. The effect of tillage and applied K on soil test in the 6 to 12 inch depth from 1983 to 1985.

Date of Soil Sample	NO-TILL			CHISEL		
	Rate of broadcast K_2O applied annually (lb/ac)					
	0	200	400	0	200	400
	Soil Test K ppm					
4/26/83	54.0 (19.6)[1]	60.9 (23.1)	55.8 (17.6)	55.8 (10.0)	53.5 (16.0)	59.5 (22.2)
6/16/83	54.7 (22.5)	62.6 (22.8)	58.2 (6.2)	54.8 (12.4)	55.3 (15.2)	59.5 (24.8)
4/10/84	70.2 (14.5)	72.8 (26.1)	74.2 (8.1)	72.5 (12.1)	78.0 (10.0)	72.7 (22.9)
7/2/84	76.8 (13.8)	81.0 (17.3)	82.7 (15.4)	80.3 (14.9)	87.0 (18.4)	82.3 (19.7)
4/30/85	62.3 (13.8)	72.7 (24.7)	71.8 (8.1)	61.0 (12.3)	68.3 (11.6)	75.7 (9.5)
7/11/85	58.8 (16.7)	78.2 (18.0)	91.5 (7.2)	63.2 (13.0)	67.7 (12.9)	71.5 (21.0)

[1] Values in parenthesis represent the standard deviations, N=6.

Table 13. Analysis of variance results for soil test K in the 0 to 2 inch depth from 1983 to 1984.

	4/26/83	6/16/83	4/10/84	7/2/84	4/30/85	7/11/85
Main[1] Effects						
Tillage	.683	.002	.099	.007	.043	.000
K rate	.000	.000	.000	.000	.000	.000
Rep	.008	.647	.163	.175	.039	.104
Interactions						
T x K	.267	.009	.207	.047	.329	.017
T x R	.094	.527	.083	.235	.371	.662
K x R	.337	.988	.903	.838	.236	.619

[1]Main effects are defined as follows: Tillage (T) is no-till and chisel plowing, K rate (K) is the broadcast K treatment of 0, 200, and 400 lb/ac of K_2O, and rep (R) is the six replications in the study.

Table 14. Analysis of variance results for soil test K in the 2 to 4 inch depth from 1983 to 1984.

	4/26/83	6/16/83	4/10/84	7/2/84	4/30/85	7/11/85
Main[1] Effects						
Tillage	.135	.016	.285	.236	.381	.536
K rate	.020	.000	.000	.000	.000	.000
Rep	.188	.088	.008	.186	.298	.074
Interactions						
T x K	.188	.506	.230	.700	.440	.938
T x R	.290	.845	.073	.055	.166	.228
K x R	.637	.933	.510	.794	.631	.504

[1]Main effects are defined as follows: Tillage (T) is no-till and chisel plowing, K rate (K) is the broadcast K treatment of 0, 200, and 400 lb/ac of K_2O, and rep (R) is the six replications in the study.

Table 15. Analysis of variance results for soil test K in the 4 to 6 inch depth from 1983 to 1984.

	4/26/83	6/16/83	4/10/84	7/2/84	4/30/85	7/11/85
Main[1] Effects						
Tillage	.160	.013	.158	.101	.310	.974
K rate	.659	.000	.008	.001	.001	.002
Rep	.024	.001	.024	.670	.205	.024
Interactions						
T x K	.637	.228	.419	.250	.252	.499
T x R	.812	.125	.302	.613	.500	.478
K x R	.232	.175	.168	.834	.842	.600

[1]Main effects are defined as follows: Tillage (T) is no-till and chisel plowing, K rate (K) is the broadcast K treatment of 0, 200, and 400 lb/ac of K_2O, and rep (R) is the six replications in the study.

Table 16. Analysis of variance results for soil test K in the 0 to 6 inch depth from 1983 to 1984.

	4/26/83	6/16/83	4/10/84	7/2/84	4/30/85	7/11/85
Main[1] Effects						
Tillage	.951	.220	.613	.867	.794	.012
K rate	.000	.000	.001	.000	.000	.000
Rep	.001	.013	.117	.896	.228	.299
Interactions						
T x K	.180	.377	.747	.978	.848	.207
T x R	.102	.182	.302	.271	.311	.110
K x R	.813	.820	.966	.999	.825	.838

[1]Main effects are defined as follows: Tillage (T) is no-till and chisel plowing, K rate (K) is the broadcast K treatment of 0, 200, and 400 lb/ac of K_2O, and rep (R) is the six replications in the study.

Table 17. Analysis of variance results for soil test K in the 6 to 12 inch depth from 1983 to 1984.

	4/26/83	6/16/83	4/10/84	7/2/84	4/30/85	7/11/85
Main[1] Effects						
Tillage	.983	.833	.718	.678	.619	.097
K rate	.902	.789	.805	.755	.065	.017
Rep	.059	.010	.038	.323	.011	.044
Interactions						
T x K	.841	.846	.952	.925	.684	.176
T x R	.937	.734	.737	.865	.759	.833
K x R	.567	.977	.690	.894	.545	.869

[1]Main effects are defined as follows: Tillage (T) is no-till and chisel plowing, K rate (K) is the broadcast K treatment of 0, 200, and 400 lb/ac of K_2O, and rep (R) is the six replications in the study.

Figure 5 shows the effects of tillage, soil test K levels and row applied K on the early growth of corn on 1 July 1985. Non significant regressions are accompanied by NS. Table 18 gives the regression equations used to calculate the lines which represent the least squares fit of the data. Early growth was not affected significantly by soil test K levels with the no-till treatment. With the chisel plow treatment soil test K affected early growth significantly when row applied K was not used. Early growth at high and low soil K levels was suppressed. Row applied K increased the variability in early growth and eliminated significance with soil K. The chisel plow treatment resulted in greater early growth than the no-till plants. This is due to the temperature effects of soil cover (Gupta et al. 1984). Cooler soil temperatures with the no-till treatment slowed emergence, and early growth.

Figure 6 shows the responses of grain yields to soil test K levels, row applied K and tillage. The lines represent the least squares fit of the data. Regression equations can be found in Table 19. Grain yields were significantly affected by soil test K levels. Row applied K increased yields approximately 30 bu/ac with the chisel plow treatment at a soil test K level of 70 ppm of K. With the no-till treatment the response to row applied K at this soil test was about 10 bu/ac. This may be the result of the depth the row applied K was applied (1 to 2 inches with no-till compared to 3 to 4 inches with chisel plowing) since, the soil moisture (Table 9) was greater with chisel plowing in the 2 to 4 inch depth than with no-till in the 0 to 2 inch depth, the row applied K may have been more available for corn utilization.

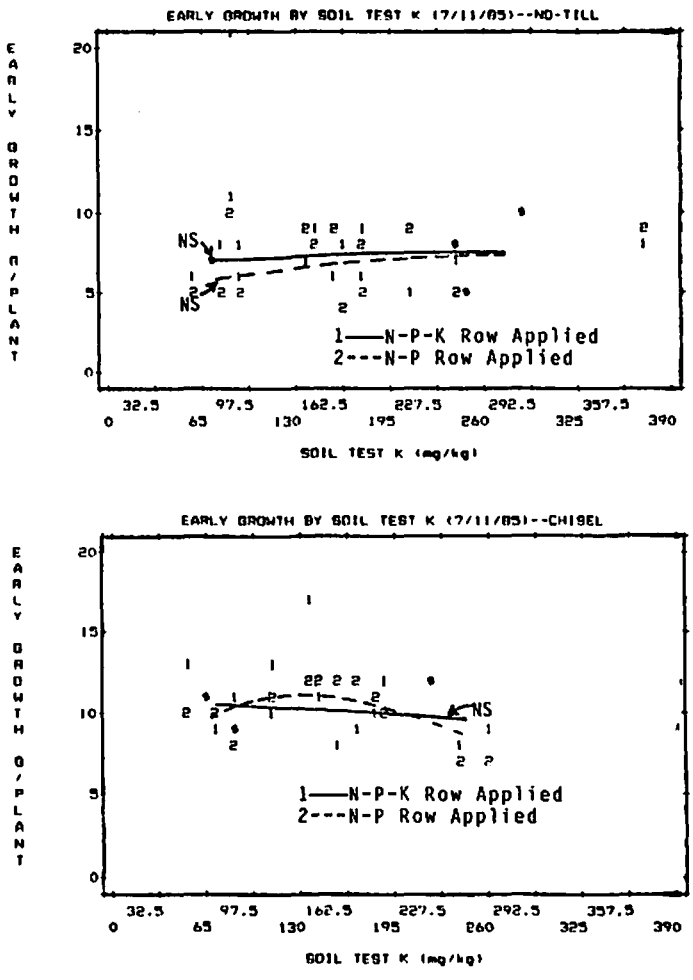

Figure 5. The effect of tillage, row applied K, and soil test K on early growth (7/1/85).

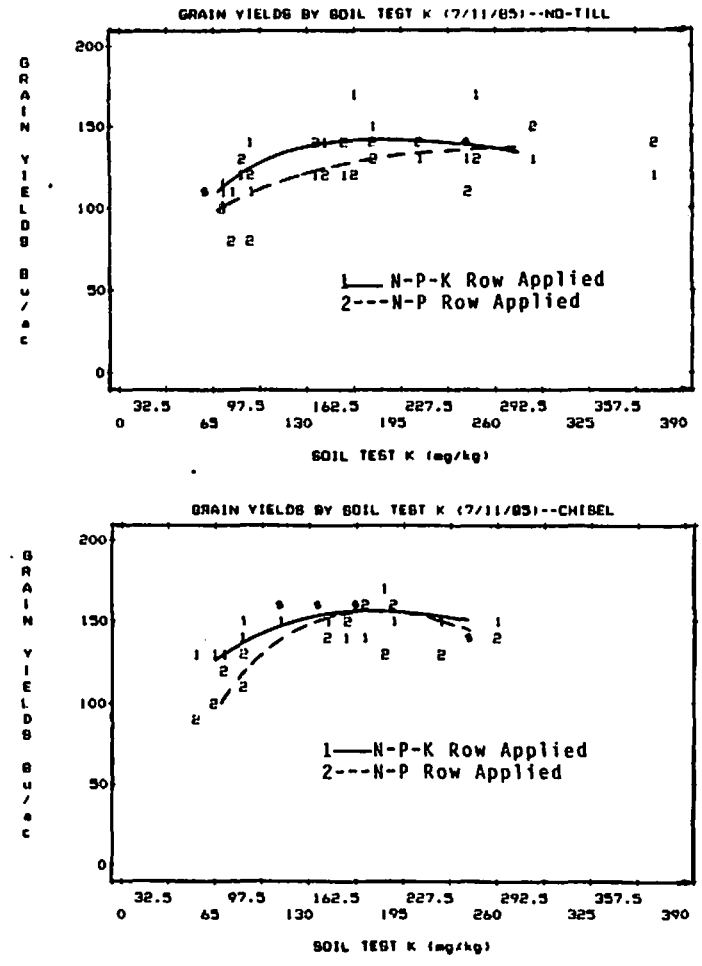

Figure 6. The effect of tillage, row applied K, and soil test K on grain yields.

Table 18. Coefficients of equations used to describe the response of early growth to soil test K levels.

Equation used: $Y=e^a K^b$
Y = Early Growth (g/plant)
K = Soil test K (ppm)

Row Applied Fertilizer	Equation exponents		R^2	p	Stn. Error of Est.
No-till	a	b			
N-P	.94178	.19098	.107	.19	.305
N-P-K	1.8046	.03653	.009	.71	.215
Chisel					
N-P	-8.4988	(4.6193 - .48797)	.316	.07	.161
N-P-K	2.6642	-.06870	.029	.52	.201

Table 19. Coefficients of equations used to describe the response of grain yields to soil test K levels.

Equation used: $Y=e^a K^b$
Y = grain yields (Bu/ac)
K = Soil test K (ppm)

Row Applied Fertilizer	Equation exponents		R^2	p	Stn. Error of Est.
No-till	a	b			
N-P	1.3591	(1.1818 - .09727 lnK)	.432	.01	.122
N-P-K	-2.0579	(2.6953 - .25880 lnK)	.531	.00	.010
Chisel					
N-P	-9.50615	(5.7084 - .56024 lnK)	.747	.00	.015
N-P-K	-.38059	(2.1482 - .21308 lnK)	.614	.00	.003

Summary

There was four, and three times the soil cover with no-till than chisel plowing in and between the row, respectively.

Soil moisture was greater with no-till in the surface 2 inches than chisel plowing on 4/30/85. On 7/11/85 soil moisture was greater with no-till than chisel plowing at all depths down to 12 inches. The late season sample was preceded by dry weather conditions.

The distribution of soil K was affected significantly by tillage, and rate of broadcast K applications. No-till had significantly greater soil test K than chisel plowing in the 0 to 2 inch depth all three years of this study after broadcast K applications and tillage. The chisel plow treatment had greater soil test K than the no-till treatment in the 2 to 4 and 4 to 6 inch depths after broadcast K applications in 1983. In 1984 there was significantly greater soil K with chisel plowing in the 4 to 6 inch depth. After broadcast K applications in 1985 the only significant tillage effect was in the 0 to 2 inch depth, indicating movement of K even in the no-till treatment to the 6 inch depth.

Chisel plowing had greater early growth than no-till. This is due to cooler spring temperatures with no-till than chisel plowing caused by greater soil cover. Row applied K did not significantly affect early growth.

Grain yields responded significantly to soil test K levels, and to row applied K up to approximately 150 ppm of soil K. Corn grown with chisel plowing responded to row applied K (11 lbs/ac) by increased grain yields of 30 bu/ac at a 70 ppm soil test K. At this soil test the response was 10 bu/ac with no tillage.

CONSERVATION TILLAGE DEMONSTRATION IN SE MINNESOTA-1985

John F. Moncrief, Tim L. Wagar, Dave D. Brietbach, Mike J. O'Leary, Fritz R. Breitenbach, and Ken R. Ostlie

Conservation tillage (as an opportunity to check erosion and reduce production inputs) continues to be adopted by innovative farmers. According to the 1984 survey by the SCS there is about 20% of the corn, soybeans and small grain grown with conservation tillage (CTIC, 1984). What is needed are site specific recommendations which offer a relatively low risk approach under local conditions. In an effort to help disseminate research findings and fine tune them to local conditions a series of statewide tillage demonstrations are being established. In 1985 this effort was focused in southeastern Minnesota primarily due to the lack of Experiment Station data for these soils and the erosive nature of the soil in this area. Following is a summary of some of the findings for the 1985 growing season.

Stand

Although there were several exceptions, for the most part corn planted "no till" after corn resulted in substantial stand reductions. Conversely if other tillage strategies with this crop sequence or corn following low residue crops was opted for there were no stand problems. It appears that the following three causal factors were responsible: 1.) poor seed to soil contact due to residue pushed into the seed furrow during planting, followed by dry conditions; 2.) possible germination inhibition due to crop residue exudates (alleopathy) and; 3.) cutworm activity at some sites. The stand reduction associated with the "no till" approach (the only in row tillage was done by a fluted coulter) is rare on these well drained soils in this part of the state. Two of the four sites with corn grown after corn (for grain) had substantial stand reduction with this treatment (data only shown for the Dodge county site in table 13). More favorable rains eliminated this problem at the other two sites. To eliminate this risk, it is advisable to use clearing discs or sweeps to keep the row area clean when planting corn in heavy corn residue.

When corn was planted after soybeans there was no effect of tillage on stand. This is shown in tables 6, 9, and 18 for Fillmore, Steele, and Wabasha counties respectively.

Primary tillage and cultivation

At the Fillmore County site half the plots were cultivated (16 rows, 100ft. long). Researchers in Ohio and Indiana have shown an advantage to cultivation on silt loam soils. The soil at this site is a Tama, silt loam. Benefits from cultivation on these soils are due to: 1.) weed control; 2.) improved infiltration and retarded runoff from roughness and; 3.) improved aeration (after crusting conditions are present followed wet period). The effect of cultivation and tillage on corn yields and weed pressure are shown in tables 3 and 4 respectively.

There were significant main effects and an interaction of tillage and cultivation on grain yields at this site. The moldboard and no till treatments resulted in a significant cultivation response. There was no effect of cultivation on yields with chisel plowing or discing. Weed pressure generally decreased with less primary tillage and in the presence of cultivation although the interaction was not significant with this variable. The dominant weed at this site was velvet leaf followed by giant foxtail. The response to cultivation was likely due to a combination of weed control and improved water infiltration under no till and moldboard conditions with the latter factor being the dominant influence. This is supported by the lack of response with the chisel treatment although weed pressure differences due cultivation were similar.

Please refer to the title page of this publication for information regarding application and use of this article.

Cultivation but not primary tillage had a small but significant effect on grain moisture at Fillmore County (table 7.). No one has offered a plausible hypothesis for this at this time.

The effect of tillage on corn grain yields for Steel and Wabasha was similar (tables 9. and 19 respectively.). There was no effect of tillage strategy on corn yields at these two sites. Soils at these sites were a Le Sueur, clay loam and Fayette, silt loam respectively. Corn was grown following soybeans. At Dodge County there was a large difference in grain yield due to tillage favoring the moldboard plow treatment (table 13.). The soil at this site is a Skyberg, silt loam. This soil formed in a thin mantle of silt loam cap over dense glacial till which serves to create poor internal drainage. The crop sequence at this site is continuous corn. These three sites illustrate the importance of the interaction of soil texture, drainage, and level of crop residue. It is important to realize that this is an establishment year for Steele and Dodge Counties so the ridge till and no till treatments are the same with the exception of a ridging operation.

Lodging

The effect of tillage (both primary and cultivation) affected corn lodging at the Fillmore but not the Steele County site (tables 5. and 10. respectively). Even though lodging due to severe winds was as high as 63% (Fillmore County) it did not result in harvest losses and was not correlated to grain yields.

Cutworm and Rootworm Activity

Tillage was related to cutworm activity (table 1.) for Fillmore, Wabasha, and Steele Counties (all corn after soybeans). The cutworm activity at Fillmore and Wabasha counties resulted in an application of an insecticide. It was not deemed necessary (economic threshold was not reached) to treat the corn at the Steele, or Dodge, County sites. Even though tillage had a significant effect on cut plants at sites where corn followed soybeans it did not relate to final plant population. At Fillmore County there was no effect of tillage on final stand (table 6.). At the Steele County site there was an effect of tillage on final stand but it was not the same earlier trend on cut plants (table 9.). Tillage strategies that resulted in more residue had more cut plants early. Final stands were lower with the moldboard plow treatment.

Dodge County had plots split with insecticide source treatments (Counter, Furadan, and Lorsban). This site had corn planted after corn. The results of this comparison is shown in table 14. Insecticide source approached significance (.115) with corn yields favoring the Furadan but did not effect grain moisture or final stand. The increased effectiveness of Furadan over the other two insecticides at this site is probably the result of the dry conditions favoring it's higher mobility.

Soybeans

The effects of tillage and weed control strategy on soybean yields at the Wabasha county site is shown in table 20. The major weed at this site was lambsquarter. A burndown of 2,4-D ester (.5 lbs/A) plus Poast (.19 lbs/A) was used on the post emergence treatment. The preemergence treatment was preceded by an application of Roundup (2 lbs/A).

There is significant main effects and a tillage by herbicide interaction. Herbicide option is of little consequence with a ridge till system due to the weed control provided by cultivation with this treatment. There is a sizeable advantage with the narrow rows (8 inches) over the 38 inch rows with the ridge till treatment, however. The lower yields with the post emerge treatment under the subsoil and no till treatment is due to giant foxtail pressure. Lambsquarter exerted the most pressure with the chisel plow treatment. Since this tillage treatment received a spring field cultivation it did not receive the burndown. The field cultivation was not completely effective in controlling emerged lambsquarter.

This is the reason for the lower yield with the preemerge treatment with this tillage strategy. It's obvious that under 1985 conditions if weeds are controlled there is a sizeable advantage to 8 inch rows over 38.

Cutworms

Table 1. The effect of tillage and previous crop on cutworm damage to corn in southeast MN., 1985.

Tillage	Cut corn plants			
	Steele[1]	Fillmore[1]	Wabasha[1]	Dodge[2]
	%			
No till	1.33ab	7.83a	2.33a	.33a
Ridge till	1.73a	----	1.92a	.11a
Spring Disc	----	2.37b	----	----
Subsoil	0.00c	----	1.58ab	----
Chisel	0.00c	1.23b	0.58b	----
Moldboard	0.27bc	1.30b	----	0.00a
Significance[3]	.01	.01	.07	.26

1. Preceding crop was soybeans.
2. Preceding crop was corn.
3. Means followed by the same letters within a column are not statistically different (Duncans Multiple Range Test - .05). The significance values at the bottom of each column are the result of an analysis of variance.

Fillmore County

Table 2. Cultural practices at Fillmore County, MN., 1985.

Soil Type Tama silt loam (Typic Argiudoll)

Soil Test pH - 6.6 P - 69 lbs/A K - 416 lbs/A
11/15/84

Fertilizer
Nitrogen - 110 lbs N/A as anhydrous ammonia on 5/22/85
Starter - 125 lbs/A of 16-41-8 (2"x2" placement)

Tillage - All plots were split with a cultivation treatment (conventional cultivator) on 6/10/85.

No till
Spring Disc on 5/6/85
Spring Chisel on 4/19/85
Spring Moldboard on 4/19/85

Planted on 5/6/85 with a John Deere Maximerge 4 row (38") planter equipped with John Deere row cleaners at 28,300 plants/A. Soybeans were the previous crop.

Corn hybrid - Pioneer 3732

Weed Control - Cyanazine (Bladex) at 2 lbs/A + Alachlor (Lasso) at 2 lbs/A preemerge on 5/13/85. A post emergence application of Dicamba (Banvel) at 1/3 pt/A on 5/18/85.

Insecticide - Ambush was applied to control cutworms on 6/12/85.

Harvested on 10/15/85 with a four row combine.

Table 3. The effect of tillage and cultivation on grain yields at Fillmore County, 1985.

	Cultivation (.004)[1]			
	yes		no	
Tillage(.001)[1]	Mean	Standard Deviation	Mean	Standard Deviation
	Bu/a			
No till	168	6.0	158	8.4
Disc	175	7.8	171	7.0
Chisel	171	5.3	174	4.9
Moldboard	177	4.8	170	3.9

1. the number in parenthesis following the treatment is the level of significance (the tillage x cultivation interaction is .021).

Table 4. The effect of tillage and cultivation on weed pressure at Fillmore County on July 23, 1985.

	Cultivation (.003)[1]	
Tillage (.009)[1]	Yes	No
No till	1.0	2.7
Disc	1.0	1.7
Chisel	1.7	3.3
Moldboard	1.7	3.3

1. The number in parenthesis following the treatment is the level of significance.

Table 5. The effect of tillage and cultivation on percent lodging at Fillmore County, September 14, 1985.

	Cultivation (.025)[1]	
Tillage (.005)[1]	Yes	No
	%	
No till	10.0	3.3
Disc	20.0	6.7
Chisel	45.0	30.0
Moldboard	63.0	33.3

1. The number in parenthesis following the treatment is the level of significance.

Table 6. The effect of tillage on plant population at Fillmore County, May 21, 1985.

Tillage	Mean	Standard Deviation
	plants/a x 10^3	
No till	25.7	1.5
Disc	26.3	1.4
Chisel	26.5	1.4
Moldboard	26.0	1.4
Significance	NS (.745)	

Table 7. The effect of tillage on grain moisture at Fillmore County, 1985.

Tillage (.207)	Cultivation (.067)1 Yes	No
No till	30.9	30.9
Disc	30.9	30.6
Chisel	30.9	29.7
Moldboard	30.6	30.2

1. The number in parenthesis following the treatment is the level of significance.

Steele County

Table 8. Cultural practices at Steele county, MN., 1985.

Soil type Le Seuer clay loam 2-4% slope Aquic Argiudoll (well tiled)

Soil test 9/25/84 pH - 6.4 P - 46 lbs/A K - 208 lbs/A

Fertilizer
- Nitrogen - 134 lbs N/A as anhydrous ammonia on 5/30/84
- Starter fertilizer - 10 gal/A of 7-21-7 (with the seed)
- Potassium - 150 lbs K_2O/A as KCl fall applied

Tillage - all plots were cultivated on 6/6/84
- No till
- Ridge till 6/21/85 ridges formed
- Chisel 10/25/84 field cultivated on 4/29/85
- Moldboard 10/25/84 " " " "
- Sub soil 10/25/84 " " " "
- Minimum till plow bottom was used (12" deep)

Planted on 4/29/85 with a conventional John Deere Maximerge 8 row (30") planter at 28,000 plants/A. The previous crop was soybeans.

Corn Hybrid - Pioneer 3737

Weed Control - Alachlor (Lasso) at 4 lbs/A + Cyanazine (Bladex) at 2 lbs/A preemerge. All plots were cultivated on 6/6/85.
Excellent weed control was obtained in all tillage systems.

Harvested - 10/17/85 with a 4 row combine

Table 9. The effect of tillage on grain yields at Steele County, 1985.

Tillage	Yield Bu/a	% Moisture	Plant Population plants/acre x 10^3
No till	162	25.1	27.0
Ridge till	167	25.2	27.2
Chisel	167	24.7	28.8
Moldboard	169	25.7	24.5
Sub Soil	171	25.7	27.0
Significance	NS (.604)	NS (.622)	(.091)

Table 10. The effect of tillage on percent lodged plants at Steele County, October 12, 1985.

Tillage	%
No till	5
Ridge till	22
Chisel	23
Moldboard	22
Sub Soil	27
Significance	NS (.601)

Table 11. The effect of tillage on soil cover and emergence at Steele County, 1985.

Tillage	% Cover April 30	May 10 Emerged Plants/a x 10^3
No till	48.3	23.5
Ridge till	45.3	24.8
Chisel	5.0	19.7
Moldboard	0.0	21.5
Sub Soil	1.7	19.2
Significance	(.000)	NS(.175)

Dodge County

Table 12. Cultural practices for Dodge County, MN., 1985.

Soil type Skyberg silt loam (Udollic Ochraqualf)

Soil test pH - 5.9 P - 38 lbs/A K - 342 lbs/A
11/16/84

Fertilizer
Nitrogen - 170 lbs/A as anhydrous ammonia spring preplant
Starter - 8 gal/A of 7-21-7 (with the seed)

Tillage - All plots were cultivated on 6/4/85
No till
Ridge till 6/24/85 ridged formed
Fall Moldboard field cultivation on 5/2/85

Planted on 5/3/85 with a Series one Hiniker conservation tillage planter 6 row (30") at 31,000 plants/A. The previous crop was corn.

Corn Hybrid - Pioneer 3732

Weed Control - Cyanazine (Bladex 80w) at 2 lbs/A applied at spike stage on 5/15/85.

Harvested - 10/18/85 by hand (20 foot of row)

Table 13. The effect of tillage on grain yields and moisture at Dodge County, 1985 (averaged over insecticide treatments).

Tillage[1]	Bu/a	% moisture	Population Plants/acre x 103
No till	118	38.3	30.2
Ridge till	123	38.4	30.6
Moldboard	150	33.6	31.3
Significance	.003	.000	NS (.793)

1. This is an establishment year so the ridge till and no till differ in a ridging operation only.

Table 14. The effect of tillage and insecticide on grain yields and moisture, and plant population at Dodge County, 1985.

	Tillage[1]								
	No till			Ridge till			Moldboard		
	Insecticide[2]								
Variable	C	F	L	C	F	L	C	F	L
Yield Bu/a[3]	121	130	105	118	131	119	143	158	150
% moisture[4]	37.4	37.1	40.2	38.7	37.7	38.8	34.1	33.5	33.1
Population[5] Plants/a x 10^3	29.7	29.0	33.3	30.3	31.3	30.0	30.7	33.3	30.0

1. This is an establishment year so the ridge till and no till differ by a ridging operation only.
2. Insecticide treatments are: C=Counter, F=Furadan, and L=Lorsban.
3. Tillage and insecticide are significant at .003 and .115 respectively.
4. Tillage and insecticide are significant at .000 and .212 respectively.
5. Tillage and insecticide are significant at .793 and .680 respectively.

Wabasha County

Table 15. Cultural practices at wabasha county MN., 1985.

Soil Type Fayette silt loam (Typic hapludalf)

Soil Test pH - 6.6 P - 70 lbs/A K - 275 lbs/A
4/9/84

Fertilizer
  Nitrogen - 140 lbs/A as anhydrous ammonia on 6/19/85.
  Starter fertilizer - 25 gal/A 7-21-7 (2"x2" placement)

Tillage
  No till
  Ridge till - Corn-7/8/85 Soybeans-8/1/85
  Chisel on 11/7/84
  Subsoil on 11/14/84
  Paraplow was used (14" deep)
  Cultivation - all plots except no till on 7/2/85.

Corn planted on 5/13/85 with a Hiniker Series 1 conservation tillage 2 row (38") planter at 29,900 plants/A.

Corn Hybrid - Pioneer 3737

Soybeans planted on 5/14/85 with a Tye no till drill (8" spacing) at 225,000

plants/A. Ridge till soybeans were planted with a Hiniker Series 1 conservation tillage 2 row (38") planter at 350,000 plants/A.

Soybean variety - Pioneer 1677

Weed control
Burndown - corn plots - Glyphosate (Roundup)at 2 lbs/A
(5/13/85) soybean plots
preemerge treatment - Glyphosate at 2 lbs/A
post emerge treatment - 2,4-D ester at .5 lbs/A
+ Poast at .1 lbs/A + Crop oil at 1 qt./A
Corn - Metolachlor (Dual 8E) at 2 lbs./A + Cyanazine (Bladex)at 1.5 lbs/A on 5/17/85.
Soybeans:

Preemerge treatment - Metolachlor (Dual 8E) at 2 lb/A + Metribuzin (Sencor) at .25 lbs/A + Chloramben (Amiben) at 2 lbs/A on 5/17/85

Post emerge treatment - Bentazon (Basagran) at 1 lb./A + Crop oil at 1 qt./A on 6/12/85

Insecticide - 3 pts/A of Lorsban 4E with 21 gal/A water on 6/4/85

Table 16. The effect of tillage and preceding crop on residue distribution with a ridge till tillage system on June 6, 1985 at Wabasha County.

Position of Measurement	Preceding Crop: Corn mean	Corn stdev	Soybeans mean	Soybeans stdev
	%			
In row	18.3	10.3	9.8	6.4
Between row	65.3	8.0	39.8	15.4
Weighted Avg.[1]	55.5	7.2	33.5	12.6
Perpendicular[1]	51.5	5.8	35.3	10.3

1. A paired t test was used to test the difference in the weighted average of the "in" and "between" the row measurements and a measurement perpendicular to the row. The p values were .102 and .578 for the corn and soybean residue respectively (n=16).

Table 17. The effect of tillage and preceding crop on soil cover by crop residue on June 6, 1985 at Wabasha County (measured perpendicular to the row).[1]

Tillage (.000)	Preceding Crop (.000): Corn mean	Corn stdev	Soybeans mean	Soybeans stdev
	%			
No till	63.8	10.2	53.8	12.7
Paraplow	57.3	10.2	37.0	8.3
Ridge till	51.5	5.8	35.3	10.2
Chisel	27.5	8.7	7.3	3.6

1. Tillage and preceding crop were highly significant. In addition to this there was a tillage x preceding crop interaction (.089).

Table 18. The effect of tillage on population on June 6, 1985 at Wabasha County.

Tillage	Crop: Corn mean	Corn stdev	Soybeans mean	Soybeans stdev
	-----plants/acre x103-----			
No till	23.8	2.17	143	56.4
Paraplow	24.4	3.43	142	61.2
Ridge till	23.7	4.13	248	72.7
Chisel	25.7	3.24	128	55.3
Significance	NS(.286)		(.000)	

Table 19. The effect of tillage on corn grain yields, and moisture at Wabasha County, 1985.

Tillage	Yield Bu/a	%moisture
No till	108	22.7
Ridge till	102	22.3
Chisel	109	23.1
Sub Soil	106	22.6
Significance	NS(.442)	(.075)

Table 20. The effect of tillage and weed control strategy on soybean yields at Wabasha County, 1985.[1]

Weed control	Tillage: No till	Ridge till	Chisel	Sub Soil
	----------Bu/a----------			
Preemerge	43.2	28.1	26.5	43.4
Post emerge	34.7	25.7	33.9	34.0

[1]Tillage is significant at .000, weed control at .007, and a tillage x weed control interaction at .000.

Table 21. The effect of tillage and previous crop on soil nitrates on 4/18/85 at Wabasha County.

Depth (ft.)	Previous Crop: Corn 0-1	Corn 1-2	Corn 2-4	Corn total	Soybeans 0-1	Soybeans 1-2	Soybeans 2-4	Soybeans total
	----------lbs NO_3-N/A----------							
Tillage								
No till	68	39	55	161	84	53	48	185
Sub Soil	73	56	61	190	82	57	48	187
Ridge	59	44	89	192	63	50	48	162
Chisel	71	47	43	161	96	57	51	204
			Average	176			Average	184

Summary

1. It is advisable to keep the row area clean when planting corn after corn no till.

2. Tillage had no effect on yield when corn was grown after soybeans at two of three sites. No till corn after corn, resulted in lower yields than chisel or

moldboard plowing in two of two sites.

3. Cultivation improved corn yield with no till and moldboard plowing.

4. Increased tillage resulted in more weed pressure at two sites (velvet leaf and lambsquarter).

5. There was a large response to narrow row soybeans. No till and subsoil treatments with preemerge herbicide resulted in the highest yield. Post emergence herbicide strategy in other years has proved to be as effective. In 1985 only broadleaf control was used resulting in foxtail pressure.

6. Cutworms were related to tillage and previous crop (no till following soybeans). This resulted in a necessary application of an insecticide at one out of three sites for no till corn following soybeans.

7. At all sites there was no measurable effect of cutworms on final stand or grain yields including the treated site.

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The effect of tillage and manure application frequency on corn growth.

Patricia Burford, John Moncrief, James Swan, and Brian Schrieber
Cooperator: Dale Flueger

In todays farming systems, economics is of primary importance. Farmers must use all resources available in order to control rising costs of inputs. Manure is one resource that should not be underestimated. No longer should manure be considered a waste problem rather: a valuable asset to farmers with access to it.

The nitrogen applied in manure is not all available for plant use the year it is applied. A decay series has been developed for types of manure in which approximately fifty percent of the N present is in the form of urea or uric acid. Approximately 75% of the N present in the manure was determined to be available the year of application with 15, 10, and 5% of the remaining N being available each subsequent year. This suggests that nutrients may be available for crop utilization in years other than the application year, which could be of significant benefit to farmers who want to the make most efficient use of the nutrients available in the manure.

The objectives of this study were to:

1) determine the effects of tillage and frequency of manure application on the growth and yields of corn, and
2) to determine tillage effects on the ability of manure to supply adequate potassium and nitrogen for corn growth by measuring yields and uptake levels.

METHODS AND MATERIALS

The experimental site was located on approximately one and one-third hectares of land in Sec. 15 of Haycreek Township in Goodhue County, Minnesota on a deep loess soil over limestone. The soil is a Typic Eutrochrept (Timula silt loam) with initial soil test ranges of 20.7 $\pm$ 5.3 ppm of phosphorus (Bray-1), and 83.0 $\pm$ ppm of potassium, a pH of 6.5 $\pm$ 2.5, and organic matter levels of approximately 2.5%. Dolomitic limestone was applied in 1980 at a rate of 2.9 T/ac. Prior to the initiation of the study, oats and alfalfa were grown in 1979, followed by alfalfa until 1982. Corn as silage was grown in 1981, and corn as grain from 1982 to 1984. Although, this study was initiated in 1982 only 1983 to 1985 results will be discussed since 1982 did not contain the entire set of treatments to be analyzed.

Pesticides used on the study area are given in Table 1. Equipment used during this study consisted of the following:
1. chisel plow (Glencoe Soil Saver) with chisels 3.5 inches wide, and spaced 13 inches apart with twisted shovels, 2. a field cultivator (Bushog), 3. two planters (John Deere maxemerge in 1982, and Hiniker in 1983, 1984, and 1985), 4. and a manure injector (Calumet). The injector consisted of a tractor drawn tandem axil tank with a 3000 gallon capacity. A rotary pump driven by the power take off delivered the slurry through injection hoses and also agitated the slurry to insure its uniformity. Manure injection bands were 38 inches apart and placement depth was approximately 8 to 10inches (depending on soil conditions at the time of injection).

Corn was planted at a rate of 29 thousand plants/ac in rows spaced 38 inches apart. Table 2 is a list of the hybrids used and their planting dates.

This study was designed as a randomized complete block with three replications. Manure was injected as a slurry annually, biennially, or triennially prior to tillage. In addition, plots were split with 0 and 200 lb/ac of broadcast K_2O. The check treatment received only broadcast K applications at a rate of 200 lb/ac of K_2O. In addition a fertilizer treatment was established as a comparison to the manure treatments. This fertilizer treatment received 300 lb/ac of broadcast N each year in the form of ammonium nitrate, and split applications of 200 and 400 lb/ac of broadcast K_2O. The rates of broadcast K used with the fertilizer treatment were selected to correspond closely with the rates of K supplied by the annual manure injection treatments with 0 and 200 lb/ac of broadcast K_2O. Small amounts of N and P were supplied in the row at planting to all treatments. Table 3 gives the dates of fertilizer applications and manure

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Table 1. Pesticide applications at the study site.

Pesticide	Rate of active ingredient	Year
Terbufos (Counter)	1.3 lb/ac	1984, 1985
Fonofos (Dyphonate)	2.5 lb/ac	1983
Atrazine/Alachlor (Atrazine/Lasso)	2.5 lb/ac	1983, 1984, and 1985
[1]Bucktril (Bromoxynil)	.38 lb/ac	1985

[1]Applied post emergence for control of lambsquarter.

Table 2. Dates of tillage, soil sampling, and planting.

Activity	Date
Chisel plowing	18 May 1983
	15 May 1984
	11 May 1985
Planting[1]	23 May 1983
	20 May 1984
	18 May 1985
Soil Sampling 0 to 12 inches[2]	
	26 April 1983
	4 July 1984
	11 July 1985
0 to 2 and[3] 2 to 5 feet	16 April 1984
	25 April 1985

1A 95 day single cross hybrid was used (Pioneer 3906).
2These soil samples were taken to determine the levels of soil test K, P and pH.
3These soil samples were taken for soil nitrate and soil moisture determinations.

Table 3. Nutrients supplied by liquid dairy manure and the rates of application from 1982 to 1985.

DATE	TOTAL N	NH_4-N	P_2O_5	K_2O	RATE APPLIED
	----------(lb/ac)---------				--(gal/ac)--
4 May 1982	375	190	111	217	12,700
16 May 1983	232	195	125	224	9,100
17 Nov 1983	310	158	136	263	10,700
3 May 1985	261	122	111	217	9,200

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injections. Zinc, and sulfur were applied to all treatments to eliminate any possible effects shortages of these nutrients may cause, and were applied at rates of 1 and 38 lb/ac of Zn and S, respectively.

Tillage treatments used were spring chisel plowing (7 to 9 inches deep) followed by a field cultivation (2 to 5 inches deep), and no-till. The injection of manure can also be considered a form of tillage. Dates of tillage can be found in Table 2.

Soil samples were taken 0 to 12 inches deep after manure injection, broadcast K applications and chisel plowing. Ten samples per plot were taken, composited, and subsampled. Soil samples were taken to a depth of 5 feet on 12 April 1984, and 25 April 1985 to determine soil nitrate levels. These deep samples were incremented 0 to 2 and 2 to 5 feet. All soil samples were dried at 95°F, and ground to pass a .08 inch sieve. Dates of these samplings are also given in Table 2.

At harvest grain and stover samples were taken, dried at 140°F, and ground to pass a .04 inch sieve. Stover was chopped and returned to the soil surface.

Surface residue was measured by the line intersect method. The K levels in the soil were determined by ammonium acetate extraction, phosphorus was determined by the Bray-1 method and pH was determined using 1:1 soil to water ratio. Total Kjeldahl nitrogen was done to determine soil nitrate levels.

RESULTS AND DISCUSSION

Table 3 shows that the ammonia N present in this manure is approximately 50 percent of the total N present, therefore, the decay series developed by other researchers may apply to this study with modifications being made for climate, and soil type.

Table 4 shows the effects of tillage, and method of fertilization on soil cover measured on 1 July 1985. Analysis of variance results are given in Table 5. Method of fertilization and tillage were both significant in their effects on soil cover, due to the reduction of soil cover with manure injection and/or when chisel plowing was done. The effects of manure injection on reducing soil cover are most evident when looking at the treatments where manure was not injected (check, fertilizer, and in non application years for biennial manure treatments) and comparing these to those with manure injected in 1985. No-till resulted in greater soil cover than chisel plowing in and between the row when manure was not injected in 1985. In the injection year there were smaller differences in soil cover due to tillage and in some cases levels were similar between tillage treatments. Variability in soil cover is due to poor distribution of stover by the combine (note standard deviations) making specific numerical differences difficult to determine. Greater soil cover has been shown to have effects on soil temperature, soil moisture, and nitrification rates. This may be useful information when determining how tillage affects N.

Table 6 shows some of the monthly climatic data near the study site, and figure 1 gives the distribution of precipitation from 1983 to 1985. This weather data helps to explain some of the treatment effects to be discussed.

The effects of tillage, manure application frequency, and depth on soil nitrate levels on 16 April 1984 and 25 April 1985 are shown in Tables 7, and 8, respectively. Table 9 gives the combined analysis of variance results for 1984-1985, and Table 10 the individual 1984, 1985 analysis of variance results. Since manure was injected either in the fall shortly before frost, or in the spring, nitrate levels in the soil were most likely not influenced in the year of manure application. Soil nitrates reflect release of N from the previous year. Annual manure applications resulted in the greatest levels of soil nitrates. Soil nitrates with the check treatment were not affected by tillage either year. The 0 to 2 foot depth had greater accumulations of soil nitrates than the 2 to 5 foot depth within any given manure application treatment. There were significant tillage by frequency of manure application interactions both years of measurement. In 1984 there were greater accumulations of nitrates in the 0 to 2 foot depth with the chisel plow treatment than with no-till when manure was applied annually, and the with biennial manure applications in the year of application. There were similar levels of nitrates between tillage treatments the year after application of manure at this depth. The tillage by depth interaction reflected the greater nitrate levels which were present with chisel plowing than no-till in the 0 to 2 foot depth in the year manure was applied, and greater soil nitrate levels with no-till than chisel plowing in the 2 to 5 foot depth in the year no manure was applied

Table 4. The effect of tillage, and source of nutrients and frequency of applications on soil cover in and between the row on 1 July 1985. In and between the row are defined as the 5 inch area centered over the row and the remainder, respectively.

Method and Frequency Fertilization	Broadcast K_2O	IN THE ROW		BETWEEN THE ROW	
		NO-TILL	CHISEL	NO-TILL	CHISEL
	lb/ac	(Percent Cover)			
CHECK	200	23.3 (20.53)[1]	6.0 (2.00)	62.0 (12.00)	15.3 (4.16)
FERTILIZER (ANNUAL)					
AMMONIUM NITRATE	200	54.7 (14.01)	9.7 (5.13)	62.7 (15.68)	22.0 (9.72)
AMMONIUM NITRATE	400	56.0 (17.30)	16.0 (8.94)	68.0 (10.81)	24.3 (14.05)
MANURE					
ANNUAL	0	18.0 (8.29)	19.3 (4.16)	23.7 (8.33)	18.7 (3.06)
ANNUAL	200	15.7 (12.86)	24.0 (11.14)	20.0 (11.31)	22.7 (2.31)
1982, 1984	0	48.0 (16.37)	16.8 (15.14)	74.0 (9.16)	13.3 (7.57)
1982, 1984	200	49.3 (18.90)	18.0 (16.37)	58.0 (32.19)	14.0 (7.21)
1983, 1985	0	33.3 (3.06)	17.3 (4.16)	24.7 (23.69)	22.0 (0)
1983, 1985	200	9.3 (6.11)	8.7 (2.31)	14.7 (13.32)	17.3 (9.24)

[1] Values in parenthesis represent the standard deviations, N=6.

Table 5. Significance levels of analysis of variance for soil cover in 1985.

	SIGNIFICANCE LEVELS	
MAIN EFFECTS	IN ROW	BETWEEN ROW
FERTILIZATION METHOD	.000	.000
TILLAGE	.000	.000
K-RATE	.780	.559
2-WAY INTERACTIONS		
F X T	.000	.000
F X K	.166	.391
T X K	.151	.389
3-WAY INTERACTIONS		
F X T X K	.598	.656

[1]Main effects are defined as follows: Frequency of manure applications (F) refers to annual and biennial manure applications, as well as the fertilizer treatment (300 lb N/ac), Tillage (T) refers to no-till and chisel plowing, K-rate is the rate of broadcast K used.

Table 6. Monthly climatalogical data for the 1983 to 1985 growing seasons[1].

		GDD (Base 50°/86°F)	
MONTH	TEMP °F	MONTHLY	CUMMULATIVE
		(1983)	
April	41.2	81	81
May	60.8	241	322
June	67.1	522	844
July	75.6	742	1626
August	74.1	715	2341
September	61.5	394	2735
		(1984)	
April	46.8	131	131
May	56.3	308	439
June	69.3	569	1008
July	71.1	646	1654
August	72.5	686	2340
September	58.1	328	2668
		(1985)	
April	52.8	248	248
May	62.2	427	675
June	64.6	448	1123
July	72.9	677	1800
August	65.5	481	2281
September	59.9	369	2650

[1]Data was obtained from Rosemount experiment station which is approximately 40 miles from the study site.

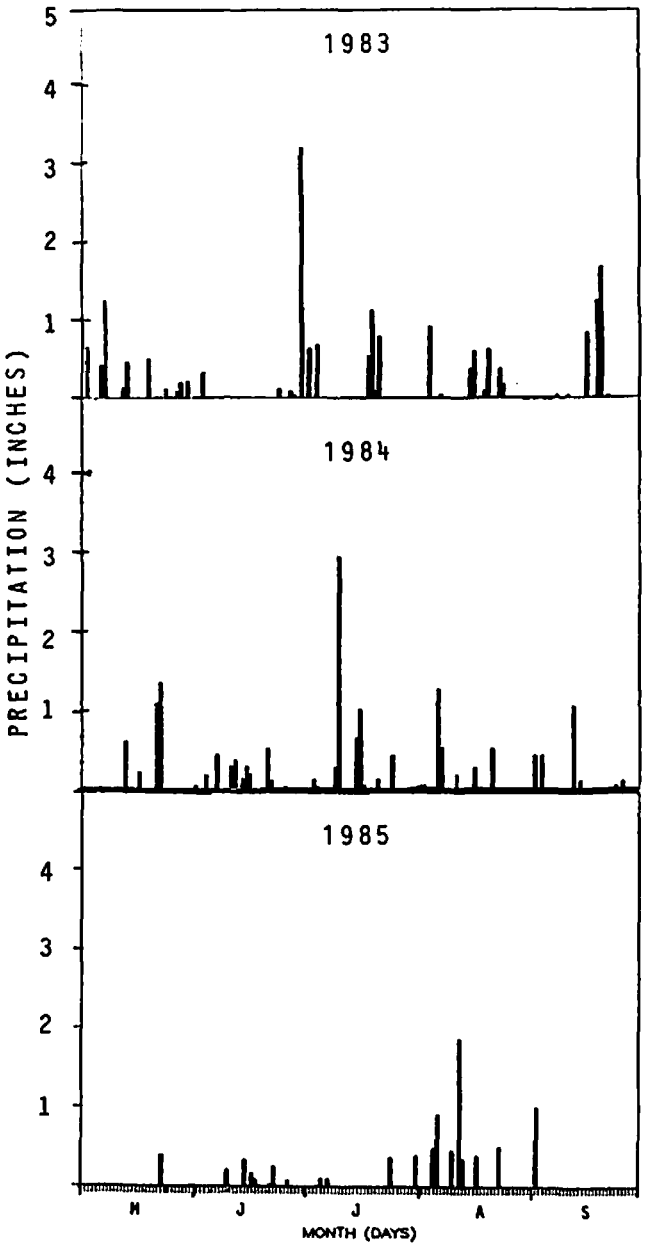

Figure 1. Distribution of precipitation at the study site.

Table 7. The effect of tillage and frequency of manure applications on soil nitrates taken on 16 April 1984.

Frequency of Manure Applications	Depth (feet)	No-till	Chisel
		-----(lb NO_3/ac)-----	
Check (None)	0-2	22.9 (10.23)[1]	25.5 (4.69)
	2-5	6.8 (5.31)	6.1 (2.24)
Annual	0-2	42.0 (13.79)	64.0 (18.59)
	2-5	33.2 (12.98)	24.8 (16.48)
1982, 1984	0-2	34.0 (6.15)	41.0 (18.01)
	2-5	19.4 (7.06)	12.2 (16.48
1983, 1985	0-2	35.0 (15.06)	38.2 (7.15)
	2-5	22.1 (2.29)	13.3 (5.53)

[1] Values in parenthesis represent the standard deviations, N=3.

Table 8. The effect of tillage and frequency of manure applications on soil nitrates on 25 April 1985.

Frequency of Manure Applications	Depth (feet)	No-till	Chisel
		------(lb NO_3/ac)------	
Check	0-2	46.7 (7.04)[1]	42.9 (8.02)
	2-5	24.6 (3.42)	24.9 (10.25)
Annually	0-2	64.5 (16.91)	80.7 (19.56)
	2-5	48.7 (16.59)	78.0 (15.76)
1982, 1984	0-2	53.2 (10.65)	59.3 (11.66)
	2-5	37.4 (3.78)	44.3 (9.39)
1983, 1985	0-2	54.7 (26.53)	48.0 (13.89)
	2-5	40.5 (27.16)	27.3 (6.27)

[1] Values in parenthesis represent the standard deviations, N=3.

Table 9. Significance levels of combined for 1984 and 1985 analysis of variance for soil nitrates.

	SIGNIFICANCE LEVELS
MAIN EFFECTS[1]	
FREQUENCY	.000
TILLAGE	.031
DEPTH	.000
YEAR	.000
2-WAY INTERACTIONS	
F X T	.002
F X D	.681
F X Y	.437
T X D	.226
T X Y	.290
D X Y	.406
3-WAY INTERACTIONS	
F X T X D	.829
F X T X Y	.222
F X D X Y	.967
T X D X Y	.076

[1]Main effects are defined as follows: Frequency (F) refers to annual and biennial manure applications, Tillage (T) refers to no-till and chisel plowing, Depth (D) refers to the two depth increments soil nitrates were measured (0 to 2 and 2 to 5 feet), and Year (Y) refers to 1984, and 1985. The check treatment was not included in this analysis.

Table 10. Significance levels of analysis of variance for soil nitrates in 1984 and 1985.

	SIGNIFICANCE LEVELS	
	1984	1985
MAIN EFFECTS[1]		
FREQUENCY	.000	.000
TILLAGE	.244	.113
DEPTH	.000	.001
2-WAY INTERACTIONS		
F X T	.062	.024
F X D	.825	.780
T X D	.004	.601

[1]Main effects are defined as follows: Frequency (F) refers to annual and biennial manure applications, Tillage (T) refers to no-till and chisel plowing, and Depth (D) refers to the two depth increments soil nitrates were measured (0 to 2 and 2 to 5 feet), The check treatment was not included in this analysis.

(biennial-1983). These greater nitrate levels in the 2 to 5 foot depth with no-till compared to chisel plowing may be the result of greater leaching of N with no-till than chisel plowing. In 1985 there were greater nitrate levels present with chisel plowing with annual manure applications at both depths, and a similar trend with biennial manure applications the year after application of manure (1984).

Soil moisture (Table 11) of the deep samples in 1985 was not significantly affected by manure application frequency, tillage, or depth of the sampling (Table 12). Since, these samples were taken in April, little difference would be expected between tillage or manure treatments.

Soil test K levels are given in Table 13 for 1983, 1984 and 1985, with analysis of variance results given in Tables 14, and 15 for individual years, and combined years, respectively. Tillage effects on the banded nature of manure injected K, resulted in variability in soil test K levels. With no-till the manure band was avoided when taking soil samples to prevent high K readings due to the concentrated K in these bands. With the chisel plow treatment the manure band was diffuse and undefineable, therefore, soil K levels were higher with this treatment. Potassium source, and K-rate were both significant in their effects on soil test K levels, and the levels of K in the soil are directly related to the amount of K supplied with the manure and with the broadcast K treatments. Soil K increased with all treatments over the three years. With the fertilizer treatment there was a trend for soil K levels to be greater with no-till than chisel plowing. With manure applications, the opposite trend was observed. This was due sampling effect mentioned previously.

The effects of tillage and manure treatment on grain yields from 1983 to 1985 are given in Table 16. The analysis of variance results for individual years are given in Table 17. Analysis of variance results for all years combined are given in Table 18. Source and frequency of nutrients, and tillage significantly affected grain yields in all three years. Generally, within a tillage treatment annual, biennial (in the year of manure application), and the fertilizer treatment resulted in similar grain yields. Generally, chisel plowing had greater yields than no-till. Differences between tillage treatments were lower in the year of manure application or when chemically fertilized. In 1984, chisel plowing resulted in greater grain yields than no-till when there was one year since manure application. There was a similar trend in 1983. The check treatment also had greater yields with chisel plowing than no-till, indicative of the greater mineralization of N occurring with soil conditions associated with chisel plowing. The rate of broadcast K applied did not affect grain yields significantly. Yields were significantly different between years with 1984 having the greatest yields.

The effects of tillage, and source and frequency of application of nutrients on stover yields are given in Table 18 for the three year period. Analysis of variance results are given in Tables 19, and 17 for individual and combined analysis of the three years, respectively. Tillage did not significantly affect the stover yields in 1983 or 1985. Yields in 1984 were generally greater when compared with the other two years. Stover yields were greater with chisel plowing than with no-till in 1984 with treatments other than the fertilizer treatment. Yields were greatest with fertilizer and annual manure applications when compared to the other treatments. Over all years tillage significantly affected stover yields. Chisel plowing resulted in greater yields in non manure application years than no-till.

SUMMARY

Soil cover was significantly greater with no-till than chisel plowing. Injection of dairy manure reduced the differences between tillage treatments for soil cover since, injection acted as a form of tillage.

Soil moisture was not affected by tillage, depth of measurement or frequency of manure applications when measured on 25 April 1985.

Potassium levels in the soil increased with all sources of K, and frequencies of application. Soil K levels were somewhat greater with no-till than chisel plowing with the fertilizer treatment. With manure applications, however, chisel plowing resulted in greater soil test K than with no-till because the manure was more evenly distributed in the soil after tillage, and was not defineable as in the no-till treatment where the injection band was avoided when taking soil samples.

Table 11. The effects of tillage and frequency of manure applications on soil moisture on 25 April 1985 in the 0 to 5 foot depth.

Frequency of Manure Application	Depth (feet)	No-till	Chisel
		-----(% by wt.)-----	
Check	0-2	22.5 (1.75)[1]	21.4 (1.60)
	2-5	22.1 (2.16)	20.8 (2.20)
Annual	0-2	23.7 (1.01)	22.8 (1.42)
	2-5	22.9 (3.28)	23.3 (1.59)
1982, 1984	0-2	23.2 (1.02)	22.8 (1.46)
	2-5	22.9 (2.98)	22.4 (2.90)
1983, 1985	0-2	22.4 (.91)	22.7 (1.08)
	2-5	22.8 (3.09)	22.8 (.68)

[1] Values in parenthesis represent the standard deviations, N=3.

Table 12. Significance levels of analysis of variance for soil moisture taken 1985.

	SIGNIFICANCE LEVELS
MAIN EFFECTS[1]	
FREQUENCY	.598
TILLAGE	.663
DEPTH	.655
2-WAY INTERACTIONS	
F X T	.893
F X D	.828
T X D	.678
3-WAY INTERACTIONS	
F X T X D	.741

[1]Main effects are defined as follows: Frequency (F) refers to annual and biennial manure applications, Tillage (T) refers to no-till and chisel plowing, Depth (D) refers to the two depth increments soil nitrates were measured (0 to 2 and 2 to 5 feet), and Year (Y) refers to 1984, and 1985. The check treatment was not included in this analysis.

Table 13. The effect of tillage, manure, and KCl application on soil test K levels in the 0 to 12 inch depth from 1983 to 1985.

Source and Frequency of Applications	Broadcast K_2O	16 June '83		2 July '84		11 July '85	
		SOIL TEST K					
	lb/ac	(PPM)[1]					
		No-till	Chisel	No-till	Chisel	No-till	Chisel
CHECK	200	95 (22.2)[2]	92 (40.7)	126 (21.9)	144 (35.9)	114 (22.9)	101 (14.6)
Fertilizer (annual)							
KCl[3]	200	115 (35.4)	112 (30.9)	128 (13.6)	132 (18.6)	158 (14.9)	143 (30.6)
KCl	400	176 (30.0)	153 (36.4)	174 (40.4)	175 (36.3)	266 (56.2)	204 (42.9)
Manure							
ANNUAL	0	100 (34.4)	143 (45.0)	128 (17.4)	162 (5.7)	121 (25.2)	148 (9.5)
ANNUAL	200	170 (41.8)	152 (30.3)	169 (32.6)	201 (17.8)	171 (31.6)	197 (23.6)
1982, 1984	0	73 (21.4)	98 (27.0)	106 (30.7)	130 (32.3)	90 (18.1)	100 (22.9)
1982, 1984	200	108 (18.6)	110 (41.1)	150 (29.5)	166 (41.7)	125 (21.2)	155 (43.6)
1983, 1985	0	74 (11.5)	105 (39.6)	98 (11.6)	106 (42.1)	97 (11.0)	87 (44.3)
1983, 1985	200	95 (38.1)	109 (19.0)	128 (27.6)	133 (26.6)	111 (17.4)	115 (23.1)

[1] PPM can be converted to lb/ac by multiplying by 2.
[2] Values in parenthesis represent the standard deviations, N=3.
[3] These rates of broadcast K were used with the fertilizer treatment because they corresponded closely with rates of K supplied with the annual manure application treatments in the manure.

Table 14. Significance levels of analysis of variance for soil test K levels from 1983 to 1985.

	SIGNIFICANCE LEVELS		
	1983	1984	1985
MAIN EFFECTS[1]			
SOURCE OF K	.000	.000	.000
TILLAGE	.380	.032	.449
K-RATE	.000	.000	.000
2-WAY INTERACTIONS			
S X T	.280	.251	.001
S X K	.221	.810	.007
T X K	.052	.628	.372
3-WAY INTERACTIONS			
S X T X K	.696	.949	.188

[1]Main effects are defined as follows: Source of K (S) refers to manure or KCl supplied K, Tillage (T) refers to no-till and chisel plowing, and K-rate (K) is the rate of broadcast K used. The check treatment was not used in this analysis.

Table 15. Significance levels of combined analysis of variance for soil test K, 1983, 1984, and 1985.

	SIGNIFICANCE LEVELS
MAIN EFFECTS[1]	
FREQUENCY AND SOURCE	.000
TILLAGE	.164
K-RATE	.000
YEAR	.000
2-WAY INTERACTIONS	
F X T	.000
F X K	.002
F X Y	.000
T X K	.032
T X Y	.155
K X Y	.071
3-WAY INTERACTIONS	
F X T X K	.672
F X T X Y	.322
F X K X Y	.445
T X K X Y	.343

[1]Main effects are defined as follows: Frequency and Source (F) refers to annual and biennial manure applications, as well as the fertilizer treatment (300 lb N/ac), Tillage (T) refers to no-till and chisel plowing, and K-rate is the rate of broadcast K used.
The check treatment was not included in this analysis.

Table 16. The effect of tillage, and source and frequency of application of nutrients on grain yields in 1983, 1984, and 1985.

Source and Frequency of Nutrients	Broadcast K_2O lb/ac	GRAIN YIELDS 1983 No-till	1983 Chisel	1984 No-till	1984 Chisel	1985 No-till	1985 Chisel
		(Bu/ac)					
CHECK	200	54.9 (12.11)[1]	90.8 (22.70)	66.2 (9.46)	85.1 (31.22)	62.4 (2.46)	77.6 (5.87)
Fertilizer (annual)							
AMMONIUM NITRATE	200	119.2 (6.24)	126.8 (13.05)	158.9 (9.08)	164.6 (14.19)	134.3 (9.27)	155.1 (9.46)
AMMONIUM NITRATE	400	123.0 (8.89)	134.3 (5.30)	153.3 (9.08)	157.0 (17.03)	136.2 (11.73)	145.7 (11.16)
Manure							
ANNUAL	0	126.8 (12.30)	134.3 (20.06)	143.8 (11.16)	162.7 (20.06)	147.6 (16.46)	149.5 (14.38)
ANNUAL	200	130.5 (6.43)	130.5 (8.51)	145.7 (12.11)	166.5 (17.60)	141.9 (8.51)	153.3 (20.43)
1982, 1984	0	104.1 (8.89)	124.9 (14.9)	155.1 (10.03)	153.3 (12.11)	115.4 (6.43)	121.1 (10.28)
1982, 1984	200	111.6 (7.95)	119.2 (7.19)	157.0 (6.43)	166.5 (39.16)	102.2 (14.19)	113.5 (16.84)
1983, 1985	0	124.9 (5.11)	113.5 (8.14)	98.4 (12.49)	138.1 (24.79)	132.4 (11.16)	145.7 (13.24)
1983, 1985	200	102.2 (20.24)	109.7 (9.46)	104.1 (31.79)	130.5 (23.46)	145.7 (6.24)	153.3 (13.05)

1 Values in parenthesis represent the standard deviations, N=3.

Table 17. Significance levels of analysis of variance for grain yields from 1983 to 1985.

	SIGNIFICANCE LEVELS 1983	1984	1985
MAIN EFFECTS1			
FREQUENCY AND SOURCE	.000	.000	.000
TILLAGE	.020	.000	.001
K-RATE	.583	.732	.462
2-WAY INTERACTIONS			
F X T	.204	.017	.647
F X K	.152	.415	.142
T X K	.913	.793	.708
3-WAY INTERACTIONS			
F X T X K	.140	.668	.489

[1]Main effects are defined as follows: Frequency and Source (F) refers to annual and biennial manure applications, as well as the fertilizer treatment (300 lb N/ac), Tillage (T) refers to no-till and chisel plowing, and K-rate (K) is the rate of broadcast K used. The check treatment was not included in this analysis.

Table 18. The effect of tillage and manure application on stover yields in 1983, 1984, and 1985.

Source and Frequency of Nutrients	Broadcast K_2O	STOVER YIELDS					
		1983		1984		1985	
	lb/ac	(T/ac)					
		No-till	Chisel	No-till	Chisel	No-till	Chisel
CHECK	200	1.8 (.14)1	2.2 (.46)	1.6 (.26)	2.1 (.17)	1.5 (.33)	1.7 (.16)
Fertilizer (annual)							
AMMONIUM NITRATE	200	2.9 (.22)	2.8 (.23)	3.6 (.17)	3.6 (.25)	2.5 (.27)	2.7 (.37)
AMMONIUM NITRATE	400	3.0 (.44)	3.2 (.49)	3.5 (.21)	3.4 (.17)	2.4 (.55)	2.6 (.33)
Manure							
ANNUAL	0	3.0 (.44)	3.6 (.58)	2.9 (.38)	3.5 (.50)	2.4 (.45)	2.3 (.45)
ANNUAL	200	3.3 (.21)	3.3 (.25)	3.0 (.42)	3.6 (.51)	2.4 (.39)	2.5 (.35)
1982, 1984	0	2.5 (.14)	2.7 (.34)	3.3 (.51)	3.1 (.17)	1.9 (.37)	2.0 (.52)
1982, 1984	200	2.6 (.28)	2.7 (.23)	3.1 (.21)	3.3 (.67)	1.9 (.43)	2.1 (.74)
1983, 1985	0	3.1 (.10)	2.8 (.12)	2.1 (.36)	2.6 (.41)	2.2 (.71)	2.1 (.43)
1983, 1985	200	2.7 (.48)	2.7 (.26)	2.4 (.81)	2.8 (.49)	2.4 (.34)	2.4 (.48)

parenthesis represent the standard deviations, N=3.

Table 19. Significance levels of analysis of variance for stover yields from 1983 to 1985.

	SIGNIFICANCE LEVELS		
	1983	1984	1985
MAIN EFFECTS[1]			
FREQUENCY AND SOURCE	.000	.000	.000
TILLAGE	.219	.001	.213
K-RATE	.212	.537	.636
2-WAY INTERACTIONS			
F X T	.206	.002	.643
F X K	.114	.399	.350
T X K	.825	.966	.533
3-WAY INTERACTIONS			
F X T X K	.084	.606	.957

[1]Main effects are defined as follows: Frequency and source (F) refers to annual and biennial manure applications, as well as the fertilizer treatment (300 lb N/ac), Tillage (T) refers to no-till and chisel plowing, and K-rate (K) is the rate of broadcast K used.
The check treatment was not included in this analysis.

Table 20. Significance levels of combined analysis of variance for 1983, 1984 and 1985 grain and stover yields.

	SIGNIFICANCE LEVELS	
	GRAIN	STOVER
MAIN EFFECTS[1]		
FREQUENCY AND SOURCE	.000	.000
TILLAGE	.000	.001
K-RATE	.502	.258
YEAR	.000	.000
2-WAY INTERACTIONS		
F X T	.057	.020
F X K	.730	.679
F X Y	.000	.000
T X K	.871	.948
T X Y	.104	.298
K X Y	.782	.738
3-WAY INTERACTIONS		
F X T X K	.405	.438
F X K X Y	.036	.088
T X K X Y	.894	.770

[1]Main effects are defined as follows: Frequency and source (F) refers to annual and biennial manure applications, as well as the fertilizer treatment (300 lb N/ac), Tillage (T) refers to no-till and chisel plowing, K-rate (K) is the rate of broadcast K used, and Year (Y) refers to 1983, 1984, and 1985.
The check treatment was not included in this analysis.

Grain yields were generally greater with chisel plowing than no-till. When in a manure injection year these differences were minimized, and in some instances yields were similar. Chisel plowing in some way increased the amount of N mineralized compared to no-till. This was indicated by the greater yields which occurred in 1984 with chisel plowing than no-till when manure was applied biennially (the year after application), and with the check treatment all three years. Stover yields had similar trends.

Broadcast K did not affect grain or stover yields, and was adequate without additional applications when manure was applied annually or biennially.

THE EFFECT OF TILLAGE, N RATE, AND NITRIFICATION INHIBITOR ON CORN RESPONSE

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In order to maintain yields, minimize production inputs, and reduce fertilizer N entry to groundwater, N management is of critical concern when tillage reductions are extreme. This is a summary of the third year of a study to investigate the effects of tillage in a continuous corn culture on N availability on a loamy sand soil under irrigation and a silt loam soil under dryland conditions.

This experiment is being conducted at two sites: the Sand Plains Experiment Station, Becker, MN and on a cooperators farm near Goodhue, MN. The Becker site is located in East Central (EC) Minnesota on a soil formed in deep glacial outwash. This soil is a Udorthentic Haploboroll (Hubbard, loamy sand). The other site is located in southeastern Minnesota (SE) on a soil formed in deep loess cap over limestone. The soil at this site is a Mollic Hapludalf (Mt. Carroll, silt loam) and Typic Hapludalf (Seaton, silt loam).

Methods

At the EC site a Buffalo planter equipped with clearing discs was used to plant the ridge till treatment. A White planter with 2" fluted coulters was used on all other tillage treatments. A Hiniker series 1 Econo till planter was used for all tillage treatments. The cleaning discs were raised for the no till and chisel treatments. Cultural practices utilized in this study are summarized in Table 1.

Anhydrous ammonia was used as the nitrogen source. A sidedressed treatment was used at the SE site in addition to the spring treatment at both sites. Nitrogen was applied at three rates with and without a nitrification inhibitor (N Serve) at both sites.

Results and Discussion

The soil cover after planting is shown in Table 2. There was more cover for a given tillage treatment at the SE site. The row area of the ridge till treatment had about 1/5 and 1/3 the soil cover of the row middles at the SE and EC sites respectively. The no till, chisel, and moldboard plow treatments had a similar cover in and between the row.

Yield and N uptake

Tillage has been shown to affect release of soil N. For this reason grain and stover yields and N uptake were measured on plots with no N applied with and without tillage by the anhydrous ammonia applicator (Table 3). There appears to be a trend favoring higher levels of yield and N uptake with the knifed plots but it is not statistically significant.

The grain and stover yields nd N uptake for the Bekcer site (EC) are shown in Table 4. At the highest rate of N the ridge till, chisel, and moldboard systems had similar grain yields. There was a significant tillage by N rate by inhibitor interaction. This is graphically shown in Figure 1. All tillage systems responded to the inhibitor but not at the same N rates. The ridge till treatment showed the classical inhibitor response diminishing with increasing N rate. There was little response with the moldboard system at any rate. The no till and chisel systems resulted in a large response at the 150 lb/A rate but little or none at the high and low rate. A similar trend occurred with N uptake.

The grain and stover yields and N uptake for the SE site are shown in Table 5. The N response was much less at this site. There was a significant tillage by time of application by inhibitor interaction at this site. This is illustrated in Figure 2. Spring or sidedress N resulted in similar yields with or without a nitrification inhibitor when corn was grown with ridge till tillage. When corn was grown with chisel plowing spring N had an advantage over sidedress and was independent of the inhibitor treatment. When sidedress N was used there was a dramatic drop in yield with the inhibitor treatment. This is the result of reduced nitrification due to the drought condition in 1985 which was less severe with the conserved moisture associated with the ridge till system.

Please refer to title page of this publication for information regarding application and use of this article.

Table 1. Management practices utilized at the Becker (EC) and Goodhue (SE) experimental locations.

Management Practice	EC (Becker)	Date	SE (Goodhue)	Date
Tillage	Moldboad plow & plowpacker	4/5		
	Chisel	4/29		5/7
	Ridge Till	6/24		6/29
	Culitivation	----		----
Planting Date[1]	No Till	5/7		5/7
Corn Variety	Pionner 3906		Pionner 3906	
Seeding Rates	29,580 seeds/A		28,000 seeds/A	
Row spacing	30 inches		38 inches	
Fertilizer treatments application		5/7		5/9
Starter Fertilizer	150 lbs/A 8-10-30		14gal/A 7-21-7	
Other Fertilizer	235 lbs/A 0-0-22	4/1		
	250 lbs/A 0-14-42	4/1		
Insecticide			Counter 15g 6#/A	
Herbicide[2]	Atrazine 2 lbs/A	5/3	Lasso 2.5 lbs/A	5/7
	Dual 8E 1.5 pint/A	5/3	Round Up 1 qt/A	5/7
	Round Up 1 qt./A	5/3	Atrazine 2 lbs/A	5/7
	Atrazine+oil 2 lbs/A	5/30	Buctril 1 pint/A	6/14
Irrigation	0.90 inches	June		
	5.90 inches	July		
	0.60 inches	August		

1 At the EC location the ridge till treatments were planted with a Buffalo till planter (disc trash cleaners) and a white (12 inch fluted coulter). At the SE location a Hiniker planter was used for all treatments (trash discs were raised for no till and chisel treatments).

2 Weed control was generally good at each location but giant foxtail was a problem on the no till plots at the SE location.

Table 2. The effect of tillage on soil cover by crop residue on 6/4/85.

	SE MN				EC MN			
	In Row		Between		In Row		Between	
Tillage	mean	sdev	mean	sdev	mean	sdev	mean	sdev
No till	71.7	21.2	76.0	9.8	53.8	20.1	53.8	12.7
Ridge till	11.7	8.6	53.7	6.3	10.5	6.0	28.3	11.5
Chisel	29.2	17.8	28.2	19.1	18.0	13.3	21.3	11.7
Moldboard					1.5	2.5	1.0	1.8

Table 3. The effect of the tillage associated with anhydrous application on yields and N uptake (No N applied).

	Yields				N uptake			
Location	Grain Bu/A		Stover T/A		Grain		Stover	
East Central	Knife	No Knife	Knife	No Knife	Knife	No Knife	Knife	No Knife
Moldboard	47	39	1.5	1.4	20	19	12	11
Chisel	41	49	1.6	1.4	22	19	15	13
Ridge Till	36	34	1.2	1.1	17	14	10	9
No Till	35	31	1.3	1.1	16	13	9	9
South East								
Spring ( )								
Chisel	59	85	1.8	1.8	30	44	17	20
Ridge Till	67	59	1.3	1.3	35	31	15	15
Sidedress ( )								
Chisel	86	85	1.8	1.8	45	44	18	20*
Ridge Till	73	59	1.4	1.3	38	31	15	15

*Significant as the result of a paired to test at - .10, n = 4.

Table 4. The effect of tillage, N rate, and nitrification inhibitor on corn yield and N uptake at Becker, MN, 1985.

Tillage	N Rate lbs/A	Inhibitor	Yield Grain Bu/A	Yield Stover T/A	N uptake lbs/A Grain	N uptake lbs/A Stover
No Till	75	-	106	2.22	47	22
"	"	+	104	2.45	37	26
"	150	-	107	2.40	62	29
"	"	+	143	2.84	88	41
"	300	-	141	3.00	87	56
"	"	+	151	3.09	104	64
Ridge Till	75	-	92	2.24	40	19
"	"	+	120	2.04	63	20
"	150	-	133	2.66	60	32
"	"	+	152	2.90	78	43
"	300	-	167	3.11	106	50
"	"	+	169	3.20	118	51
Chisel	75	-	121	2.68	57	27
"	"	+	115	2.40	50	27
"	150	-	148	3.14	87	42
"	"	+	171	3.41	108	48
"	300	-	169	3.54	122	55
"	"	+	168	3.49	104	61
Moldboard	75	-	75	2.13	29	18
"	"	+	92	2.48	39	23
"	150	-	157	3.22	76	38
"	"	+	163	3.37	98	43
"	300	-	186	3.78	103	65
"	"	+	187	3.73	115	64

Main Effects

	Yield Grain Bu/A	Yield Stover T/A	N uptake lbs/A Grain	N uptake lbs/A Stover
Tillage				
No Till	125	2.67	71	40
Ridge Till	139	2.69	78	36
Chisel	147	3.11	88	43
Moldboard	144	3.12	77	42
P Value	99	99	95	90
N rate lbs/A				
75	101	2.33	45	23
150	147	2.99	82	39
300	167	3.37	107	58
P value	99	99	99	99
Inhibitor				
-	134	2.84	73	38
+	144	2.95	83	43
P value	99	97	99	99
Interactions	----------P value %----------			
Till X Rate	93	68	88	21
Till X Inhibitor	90	95	94	89
Rate X Inhibitor	99	62	96	92
Till X Rate X Inhibitor	93	67	97	28

Table 5. The effect of tillage, N rate, time of application and nitrification inhibitor on corn yield and N uptake at Goodhue Co., MN, 1984.

Tillage	N Rate lbs/A	Time of Application	Inhibitor	Yield Grain Bu/A	Yield Stover T/A	N uptake lbs/A Grain	N uptake lbs/A Stover
Ridge Till	75	Spring	-	138	2.55	87	44
"	"	"	+	151	2.70	102	44
"	"	SD	-	149	2.35	99	37
"	"	"	+	137	2.33	80	37
"	150	Spring	-	150	2.82	103	45
"	"	"	+	140	2.44	95	50
"	"	SD	-	136	2.47	89	33
"	"	"	+	152	2.73	98	45
"	300	Spring	-	149	2.86	95	50
"	"	"	+	159	2.75	116	49
"	"	SD	-	152	2.64	93	40
"	"	"	+	146	2.54	101	40
Chisel	75	Spring	-	144	3.02	94	47
"	"	"	+	126	2.55	85	41
"	"	SD	-	160	2.78	106	42
"	"	"	+	152	2.65	109	36
"	150	Spring	-	141	3.05	93	53
"	"	"	+	120	2.89	83	56
"	"	SD	-	172	3.20	118	46
"	"	"	+	170	3.14	106	53
"	300	Spring	-	153	3.03	107	49
"	"	"	+	137	2.95	110	57
"	"	SD	-	162	2.91	122	52
"	"	"	+	168	3.15	127	51

Main Effects

	Yield Grain Bu/A	Yield Stover T/A	N uptake lbs/A Grain	N uptake lbs/A Stover
Tillage				
Ridge Till	147	2.60	97	42
Chisel	150	2.94	105	49
P Value	78	97	94	89
N Rate				
75	145	2.62	95	41
150	148	2.84	98	47
300	153	2.85	109	48
P Value	93	99	99	99
Time of Application				
Spring	142	2.80	97	48
Sidedress	155	2.74	104	43
P Value	99	77	99	99
Inhibitor				
-	150	2.81	101	45
+	147	2.74	101	46
P Value	89	83	16	61
Interactions	----------P Value %----------			
Till X Rate	18	72	73	87
Till X Time	99	98	99	76
Till X Inhibitor	99	56	87	34
Rate X Time	91	90	37	02
Rate X Inhibitor	26	31	95	88
Time X Inhibitor	83	96	45	26
Till X Rate X Time	82	01	14	19
Till X Rate X Inhibitor	26	91	32	54
Till X Time X Inhibitor	98	37	87	53
Rate X Time X Inhibitor	97	52	74	58
Till X Rate X Time X Inhibitor	90	92	96	21

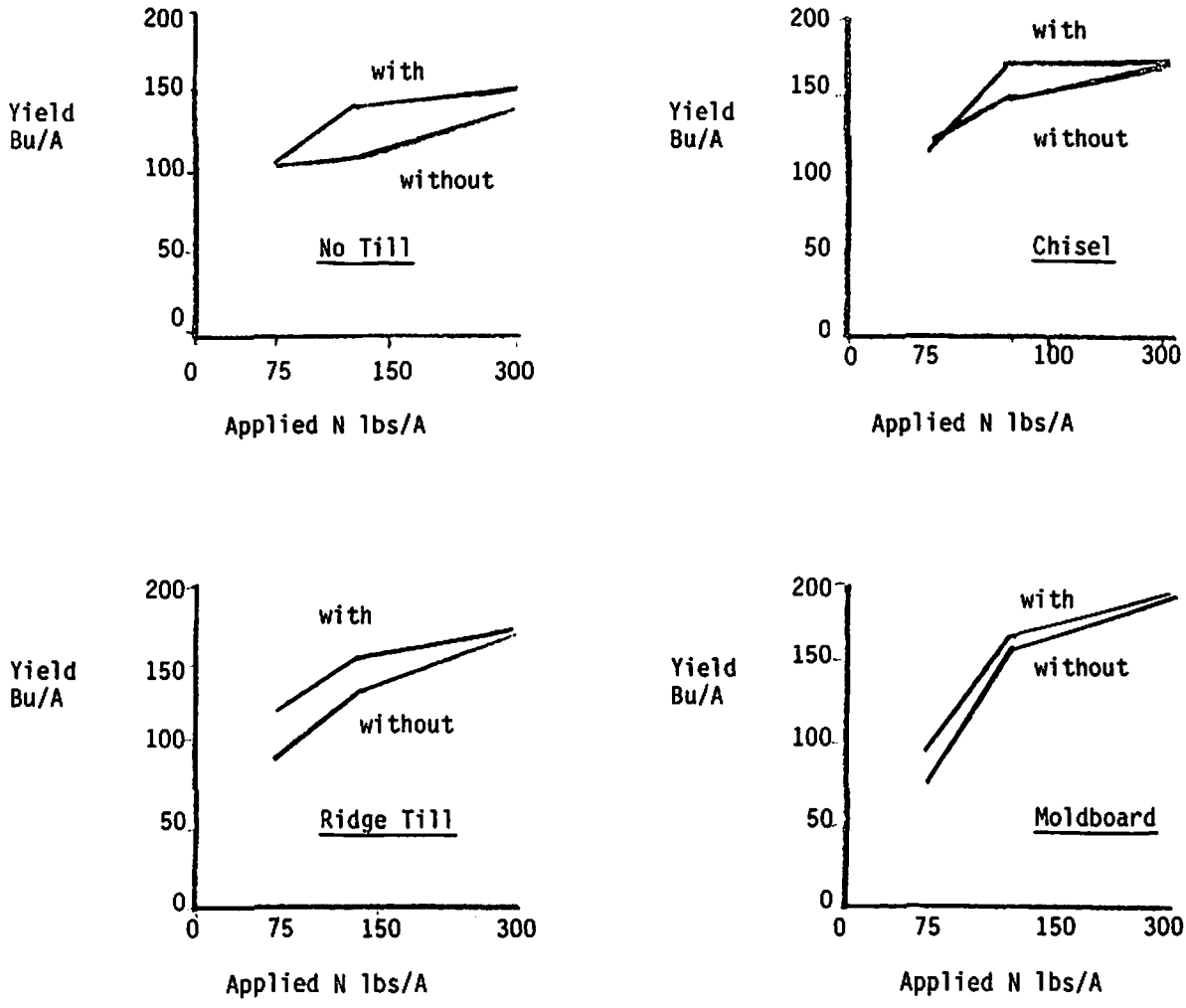

Figure 1. The effect of tillage, N rate, and nitrification inhibitor on grain yields at Becker, MN 1985.

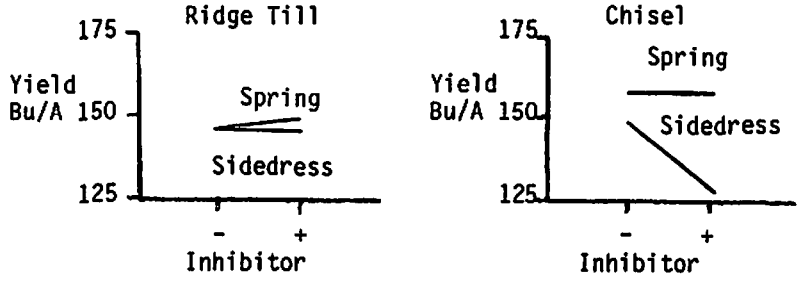

Figure 2. The effect of tillage, time of N application, and nitrification inhibitor over all rates of N at CE MN. 1985.