TILLAGE EFFECTS ON CORN AND SOYBEAN PRODUCTION, AND WATER QUALITY IN MEEKER COUNTY (KUECHLE FARM), MINNESOTA[1]

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Abstract

Experiments are being conducted for six years to demonstrate the effects of tillage and methods of fertilizer P placement in minimizing the P losses to water bodies. Results of the experiment conducted in 1991 show that the soil cover by soybean residue was adequate for erosion control with no tillage system but inadequate with other systems. The soil P content was maximum in the surface layer (0-2") and decreased steeply with the increase in depth for no tilled, ridge tilled and chisel plowed treatments. But with moldboard plowed treatment the difference between the soil P content at surface layer and sub-surface layers was absent. Corn grain moisture content analysis suggested that Corn with row applied P matured earlier to the broadcasted P. The maximum of tissue N was observed in no tillage system (3.04%) and the minimum of tissue N was observed in moldboard plowed treatment (2.63%).

A higher yield of 105.9 bu/ac was recorded for the row applied P when compared with broadcast which recorded 94.2 bu/ac. The increase in Corn yield was 12% in row applied P. In Soybean the maximum grain yield of 50.9 bu/ac was obtained in the treatment with moldboard plow.

Introduction

The water quality in the Clearwater River Chain of lakes is considered to be deteoriating due to the entry of phosphorus from various sources. It is suggested that agricultural activities in these areas have also contributed due to soil erosion. Erosion control in conjunction with better phosphorus management could prevent the contamination of surface water with phosphorus. A good management strategy would be to control erosion with crop residue and place phosphorus below the soil surface.

The present experiment is being conducted in Meeker County, MN, involving various tillage practices and methods of fertilizer P placement. This study is in its sixth year. The objective of this study is to demonstrate the effects of tillage and method of fertilizer P placement to minimize P losses to water bodies.

Materials and Methods

The experimental design is a randomized complete block split-plot design with tillage as the main plots and method of fertilizer application as sub-plots. The management practices are given in table 1. The initial soil tests are given in tables 2 and 3.

Crop residue was measured on 6/13/91 using a line transect technique. Crop residue was characterized in and between the rows. "In row" is defined as four inches centered over the row and "between row" the remainder.

Soil samples were collected on 6/11/91 from 0-2", 2-4" and 4-6" depths; in row and between row. The samples were analyzed for soil P content by Bray-1 method.

Corn ear leaf samples were taken at 50% silk emergence and were analyzed for N, P, and K.

Stand estimates were made on two ten-foot row samples from adjacent rows at two randomly selected monitoring sites in each tillage plot.

Results and Discussion

Soil Residue Cover. Soil cover by soybean residue in corn resulting from the tillage systems evaluated is shown in table 4 (Fig. 1A). There were significant differences of soybean residue between the tillage

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systems. The maximum residue cover was observed in the no tillage treatment followed by the chisel plow, ridge till and moldboard plow treatments respectively. The soil cover by soybean residue was adequate for erosion control with the no tillage system but inadequate with the other systems. As expected the soil cover was greater in 'between rows' than 'in rows',as the clearing disc on the planter clears residue from the row area.

The soil cover in the row by soybean residue should be less than 20% to minimize detrimental effects on the early development of corn. The chisel plowed treatment is adequate in this respect. Although the soybean residue in corn was greater in the no tillage treatment, it did not influence the corn stand .

The tillage effects on corn residue in soybeans also showed the same trend as the soybean residue in corn (table 5, Fig. 1B). There were significant differences between the treatments with maximum soil cover in no tillage treatment and the lowest soil cover in moldboard plowed treatment. The soil cover in the chisel plowed treatment is greater than that of ridge plowed treatment.

Soil P Distribution. The effect of tillage system, row position, and depth on soil P content is shown in table 6 (Fig. 2). There were no significant difference between no tillage, ridge tilled and chisel plowed treatments. The moldboard plowed treatment had the least soil P test and 40% less soil P than the ridge tilled treatment. However moldboard plowed treatment did not have any significant difference with other types of tillage.

There was a significant tillage and soil depth interaction on soil P content (table 7, Fig. 3). The soil P content was maximum in the surface layer (0-2") and decreased steeply with the increase in depth for no tilled, ridge tilled and chisel plowed treatments. But with the moldboard plowed treatment the difference between the soil P content at surface layer and sub-surface layers was absent. The ridge tillage system had the highest soil P content throughout the profile as compared to the other tillage systems.

The interaction of tillage, phosohorus application methods, and row position on soil profile P is shown in table 8 (Fig. 4). In no tillage system when P was broadcasted, the soil P content between the rows was greater at surface layer than in the rows. In case of row application, 'in row' soil P was greater at the surface layer. In both the cases, soil P either in the row or between the row was similar at the depths below 2". With ridge till system with broadcast phosphorus application the soil P content in between the rows were more than in the rows up to the 4" depth. The reason attributed for this fact is that when tillage is done in the ridge plots the soil from the ridge carrying the P fertilizer is removed in between the rows and thus shows up high P content upto 4" depth of the soil. In chisel plowed and moldboard plowed treatments, the P distribution was fairly uniform throughout the depth of sampling.

Earleaf Analysis. The effect of tillage and method of phosphorus application on tissue N, P, and K content is shown in table 9. Though tillage system had a significant effect on tissue N, it did not on tissue P and K. The maximum of tissue N was observed in no tillage system (3.04%), and the minimum of tissue N was observed in moldboard plowed treatment (2.63%). Method of fertilizer application did not have any significant effect on tissue N, P, and K composition.

Corn Population. The tillage and method of phosphorus application effects on corn stand at vegetative stage of the crop are shown in table 10. Neither treatments affected stands.The tillage and method of Phosphorus application interaction effects on corn stand at the harvest is shown in table 11.Though there no significant difference in stand due to main effects oftillage and method of P application,there were significant effects of tillage and method of Phosphorus application interaction on corn stand. There were no significant effects of tillage and soil types on the corn stand (table 12).

Soybean Population. There were no significant differences between the soybean stand in broadcast and row applied P treatments with ridge tillage system (table 13). There were significant differences due to other tillage systems on soybean stand (table 14). The maximum stand was observed in the moldboard plowed treatment. The method of fertilizer application did not influence the soybean stand. There were no significant differences between row applied and broadcast fertilizer treatments.

Corn grain yield . There was no significant interaction between effects of tillage and methods of phosphorus application on the grain yield of corn(table 15). The highest grain yield of 106.2 bu/ac was recorded for the moldboard plow and 91.6 bu/ac for the no tillage system. The method of phosphorus application had significant influence on the grain yield. A higher yield of 105.9 bu/ac was recorded for the row applied phosphorus when compared with broadcast which recorded 94.2 bu/ac. The increase in corn yield was approximately 12% in row applied phosphorus. There were no significant interaction of tillage systems and the soil types on the yield of the corn(table 16). However there were significant difference in corn yield for the different soil types. The highest corn yield (112.2 bu/ac) was obtained in Koronis fine sandyloam and the lowest was obtained in Delft clay loam. Though yield of corn in Marcellon loam type of soil was 106.7

bu/ac, it was on par with Koronis fine sandy loam.

Corn grain moisture content. There were no significant differences in grain moisture percent for the different tillage systems(table 17). However the method of phosphorus application had an influence over the grain moisture content. The grain moisture percent aws higher in the row applied phosphorus than broadcast suggesting early maturity of the crop when phosphorus was row applied. There were no significant tillage and method of application of phosphorus interaction effect on the grain moisture percent. There were no significant interaction effect of tillage and soil type on the corn grain moisture content (table 18).

Soybean grain yield . There were no significant interaction effect of tillage and method of phosphorus application on the soybean grain yield (table 19). However there were significant difference in yield for the tillage systems (excluding ridge tillage). Highest grain yield of 50.9 bu/ac was obtained in the treatment with moldboard plow. There were no significant differences in grain yield between the methods of phosphorus application for the ridge plow(table 19).

Soybean grain moisture.There were no significant differences in grain moisture for either of the treatments (table 20). The two methods of phosphorus application in the ridge plow treatment had no significant effect on the grain moisture.

Table 1. Cultural practices at Meeker County, MN, in 1991.

Tillage

No Till
Ridge Till
Fall Chisel Plowed-Field cultivated prior to planting
Fall Moldboard Plowed-Field cultivated prior to planting

Cropping History

Corn-soybean rotation since 1978.

1991 Crop

Corn- Northup King N 3624
Soybeans- Northrup King B 095

Planting and Harvest Dates

Corn - was planted with a two row Hiniker Series 1 EconoTill planter with 30 inch row spacing.

Soybeans - ridge till was planted with a two row Hiniker Series 1 EconoTill planter with 30 inch row spacing and all other tillage treatments were planted with a Tye no till drill with 7 inch row spacing equipped with 2 inch fluted coulter ahead of the double disc openers.

Crop	Planting Date	Planting Planter	Planting Rate	Harvested
Corn	May 16,1991	Row	32,000 seeds/A	October 9,1991
Soybeans	May 22, 1991	Drill	225,000 seeds/A	October 17,1991
Soybeans	May 16, 1991	Row	225,000 seeds/A	October 17,1991

Fertilizer History 1985-1990

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

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---- lb/A ----			
Corn:	7-21-7[4]	15 gal/A	12	35	12	May 10, 1989
	82- 0-0	183 lb/A	150	0	0	May 31, 1989
Soybeans	7-21-7[5]	15 gal/A	12	35	12	May 22, 1989
Corn :	7-21-7[4]	18 gal/A	14	42	14	May 10, 1990
	82-0-0	220 lb/ A	180	0	0	July 5, 1990
Soybean :	7-21-7[5]	18 gal/A	14	42	14	May 10, 1990

1. Planter placement 2" beside and 2" below row.
2. Drill soybeans were split with row fertilizer which was surface banded ahead of and incorporated by the fluted coulters.
3. Broadcast applied.
4. Planter placement 2" x 2" on 1/2 the plots.
5. Planter placement 2" x 2" on 1/2 the plots, Ridge Till only.

1991 Fertilizer

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied	Method of Application
			---- lb/A ----				
Corn:	10-34-0	5 gal/ac	6 -	20	- 0	5/16/91	Row placement 2"x2" below row.
	0-46-0	87lb/ac	0 -	40	- 0	5/13/91 5/15/91	Broadcast.
	83-0-0	260lb/ac	217	-	-	6/25/91	Injected
Soybeans :	10-34-0	5 gal/ac	6 -	20	- 0	5/16/91	Row placement 2"x2" below row.
	0-46-0	87lb/ac	0 -	40	- 0	5/13/91 5/15/91	Broadcast.

Soil

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

Weed Control

Corn

3.0 qt/A (3.0 lb/A) Lasso + 2.0 qts (4.0 l/A) Bladex 90 DF applied on May 23, 1991.

Soybeans

1.5 pt/A (0.188 lb/A) Fusilade 2000 + 1 pt/A (0.459 lb/a) Galaxy a premix of (0.375 lb/A Basagran + 0.084 lb/a Blazer) + 2 qt/A oil concentrate on June 14,1991. 11pt/A (0.5 lb/A) Basagran + 2 pt/A (0.375 lb/A) Poast + 1 qt/A Dash oil concentrate + 2 qt/A 28% UAN on June 26,1991.

Soil Test

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

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

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

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

Table 4. Effect of tillage and row position on soybean residue in corn at Meeker Co.(Kuechle farm) on 6/13/91.

Tillage	Residue(%)		
	In row	Between row	Means
No Tillage	10.7(9.9)	30.7(16.3)	20.7a
Ridge Tillage	4.0(4.6)	7.2(5.1)	5.6bc
Chisel Plow	12.0(12.8)	11.0(7.2)	11.5b
Moldboard Plow	2.0(2.1)	1.8(2.1)	1.8b
Mean	7.2 a	12.7 b	

1.The p value for tillage,row position and tillage by row position interaction are 0.002(n=32), 0.006(n=64)and 0.002(n=16) respectively. Means within same row or column with same letter are not significantly different (α=0.10).

Table 5. Effect of tillage on corn residue in soybeans at MeekerCo. (Kuechle farm) on 6/13/91.

Tillage	Residue(%)		
	In row	Between row	Means
No tillage	55.8(25.6)	46.0(27.8)	50.9a
Ridge Tillage	16.3(14.6)	17.0(17.9)	16.6b
Chisel Plow	24.8(16.0)	17.5(15.1)	21.1c
Moldboard Plow	10.5(8.9)	6.0(7.6)	8.3d
Mean	26.8	21.6	

1.The p value for tillage,row position and tillage by row position interaction are <0.001(n=32), 0.146 (n=64) and 0.718(n=16) respectively. Means within same column with same letter are not significantly different (α = 0.10).

Table 6. Effect of tillage and row positon on soil P content (ppm) in Meeker County, MN, on 6/11/91[1].

Tillage	In Row	Between Row	Mean
No Tillage	14.3 (8.7)	15.0 (9.0)	14.7 ab
Ridge Till	17.3(10.0)	23.7(14.6)	20.4 a
Chisel Plow	16.4 (8.7)	13.7 (7.0)	14.7 ab
Moldboard Plow	12.3 (3.9)	12.3 (2.6)	12.3 b
Mean	*15.2 a*	*15.9 a*	------

1.The P value for tillage, row position and tillage by row position interaction are 0.175 (n=24), 0.386 (n=48) and 0.025 (n=12) respectively. Means within same row and column with the same letter are not significant different (α = 0.10).

Table 7. Effects of Tillage and depth on soil P content (ppm) in Meeker Co., MN,on 6/11/91[1].

Depth	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean
0-2	22.5	31.2	23.3	13.2	22.5 a
2-4	11.9	20.1	12.9	12.8	14.4 b
4-6	9.6	10.1	8.3	11.0	9.8 c
Mean	*14.7 ab*	*20.4 a*	*14.7 ab*	*12.3 b*	----

1.The P value for tillage, depth and tillage by depth interactions are 0.175 (n=24),< 0.001(n=12) and 0.002 (n=08) respectively. Means within same row and column with the same letter are not significantly different (α = 0.10).

FIG. 1 EFFECT OF TILLAGE AND ROW POSITION ON SOIL COVER AT MEEKER CO . (KUECHLE FARM) 6/13/91

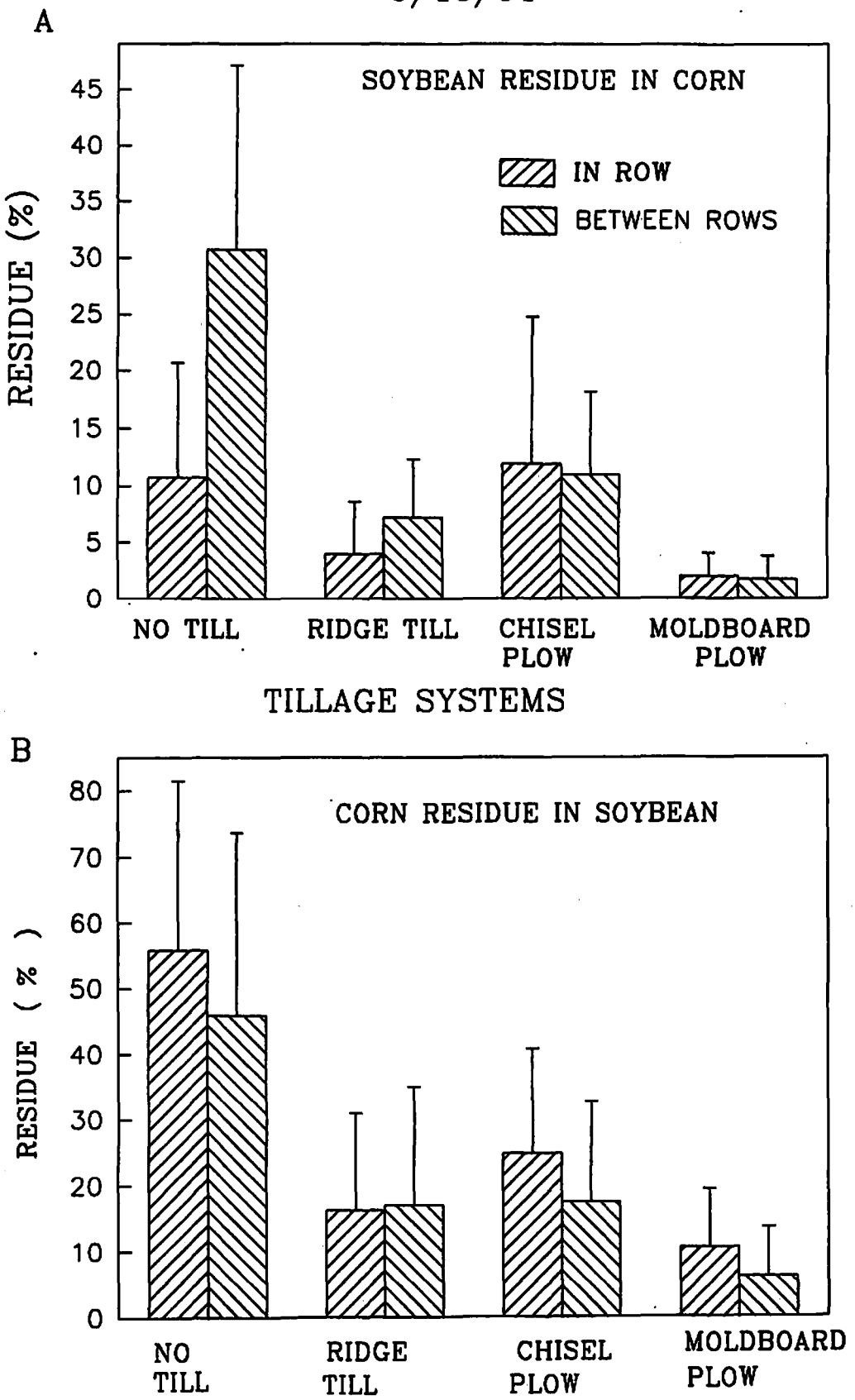

FIG .2 EFFECT OF TILLAGE AND ROW POSITION ON SOIL PHOSPHORUS AT MEEKER CO (KUECHLE FARM)
6/11/91

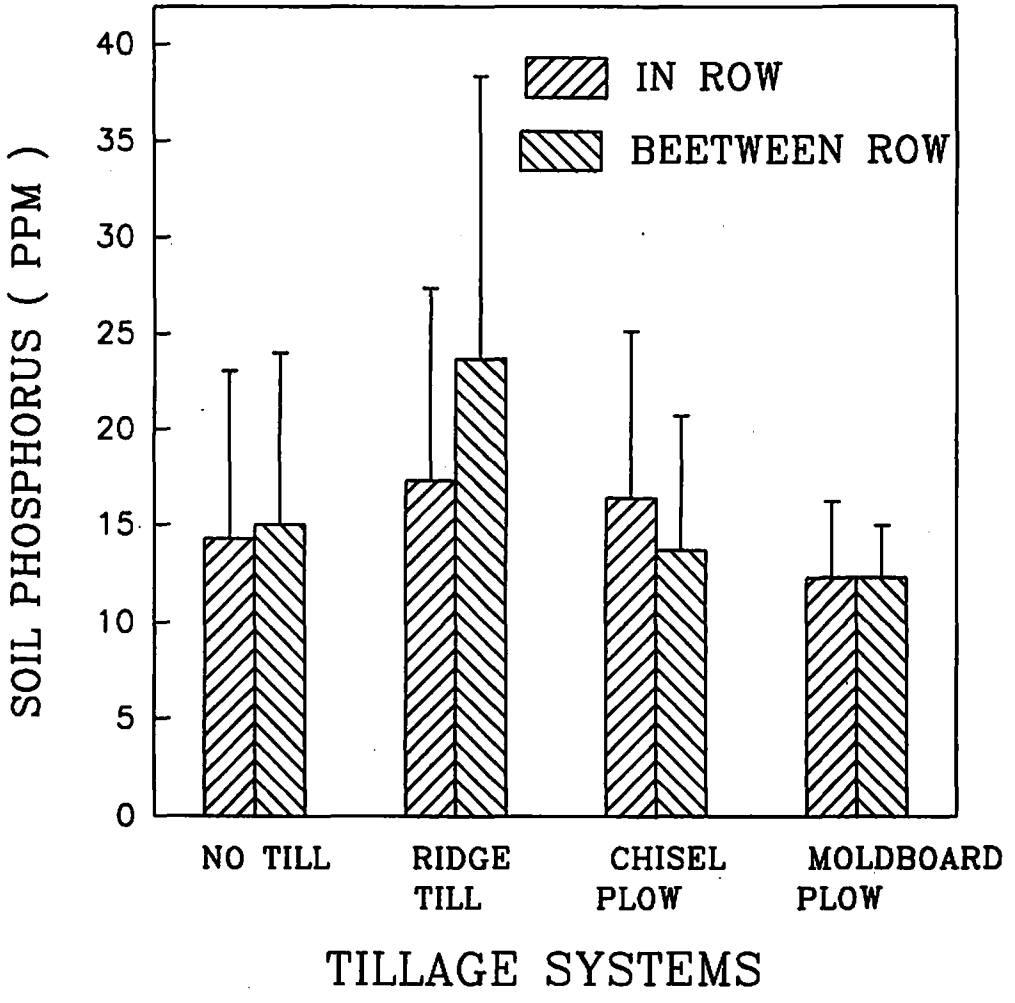

FIG. 3 EFFECT OF TILLAGE ON SOIL P IN SOIL PROFILE IN MEEKER (KUECHLE) CO.

6/11/91

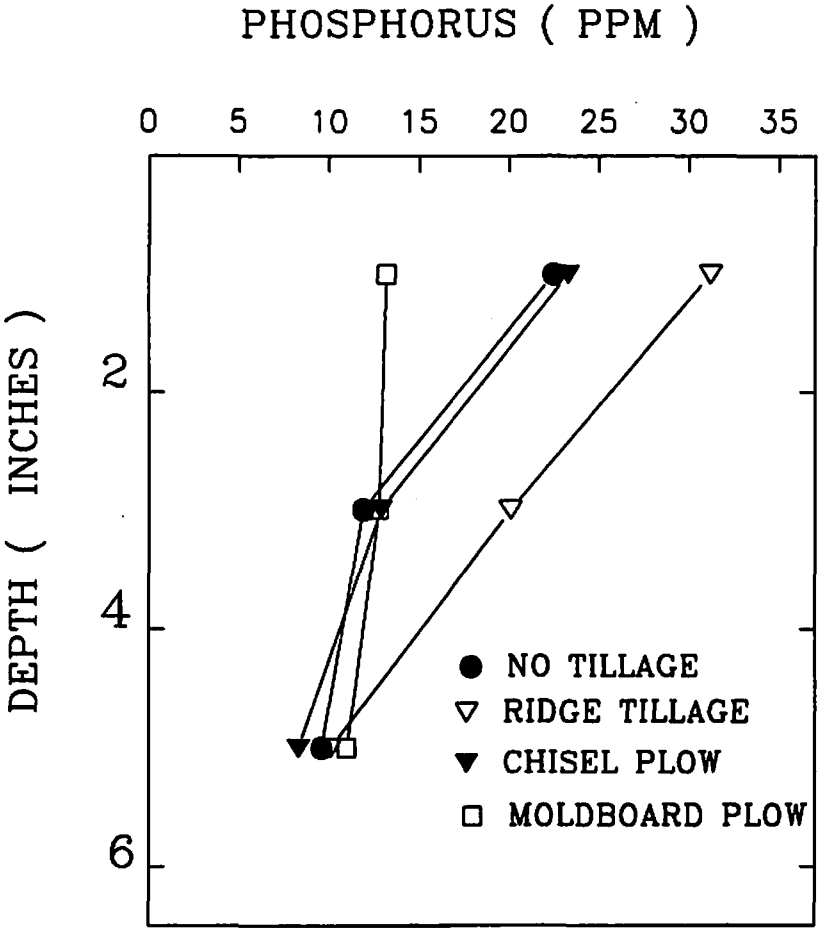

Table 8. Effect of tillage, method of phosphorus application, row postiton and soil depth on soil P content (ppm) in Meeker Co., MN, on 6/11/91[1].

Tillage	Fertilizer	Soil P (ppm)			
		Depth(in.)	In row	Between row	*Mean*
No Till	Broadcast	0-2	14.1	23.0	*18.5*
		2-4	8.3	9.2	*8.7*
		4-6	7.2	6.3	*6.8*
	Row application	0-2	31.8	21.3	*26.6*
		2-4	12.2	17.7	*14.9*
		4-6	12.0	12.8	*12.5*
Ridge Till	Broadcast	0-2	21.6	30.0	*25.8*
		2-4	11.0	20.4	*15.6*
		4-6	11.4	11.3	*11.3*
	Row application	0-2	24.3	48.8	*36.6*
		2-4	27.8	21.2	*24.5*
		4-6	7.4	10.4	*8.9*
Chisel Plow	Broadcast	0-2	22.1	17.9	*20.0*
		2-4	11.0	10.7	*10.8*
		4-6	8.6	7.5	*8.9*
	Row application	0-2	28.4	24.8	*26.6*
		2-4	20.6	10.5	*15.5*
		4-6	7.5	8.5	*8.3*
Moldboard	Broadcast	0-2	8.0	14.4	*12.8*
		2-4	14.3	10.5	*12.5*
		4-6	10.8	10.5	*10.7*
	Row application	0-2	12.0	15.2	*13.5*
		2-4	15.3	10.8	*13.1*
		4-6	11.0	11.6	*11.3*

1.The P value for tillage, fertilizer, depth and row position interaction is 0.068 (n=02) .

FIG. 4 EFFECTS OF TILLAGE, PHOSPHORUS APPLICATION METHODS AND ROW POSITION ON SOIL PROFILE P

6/11/91

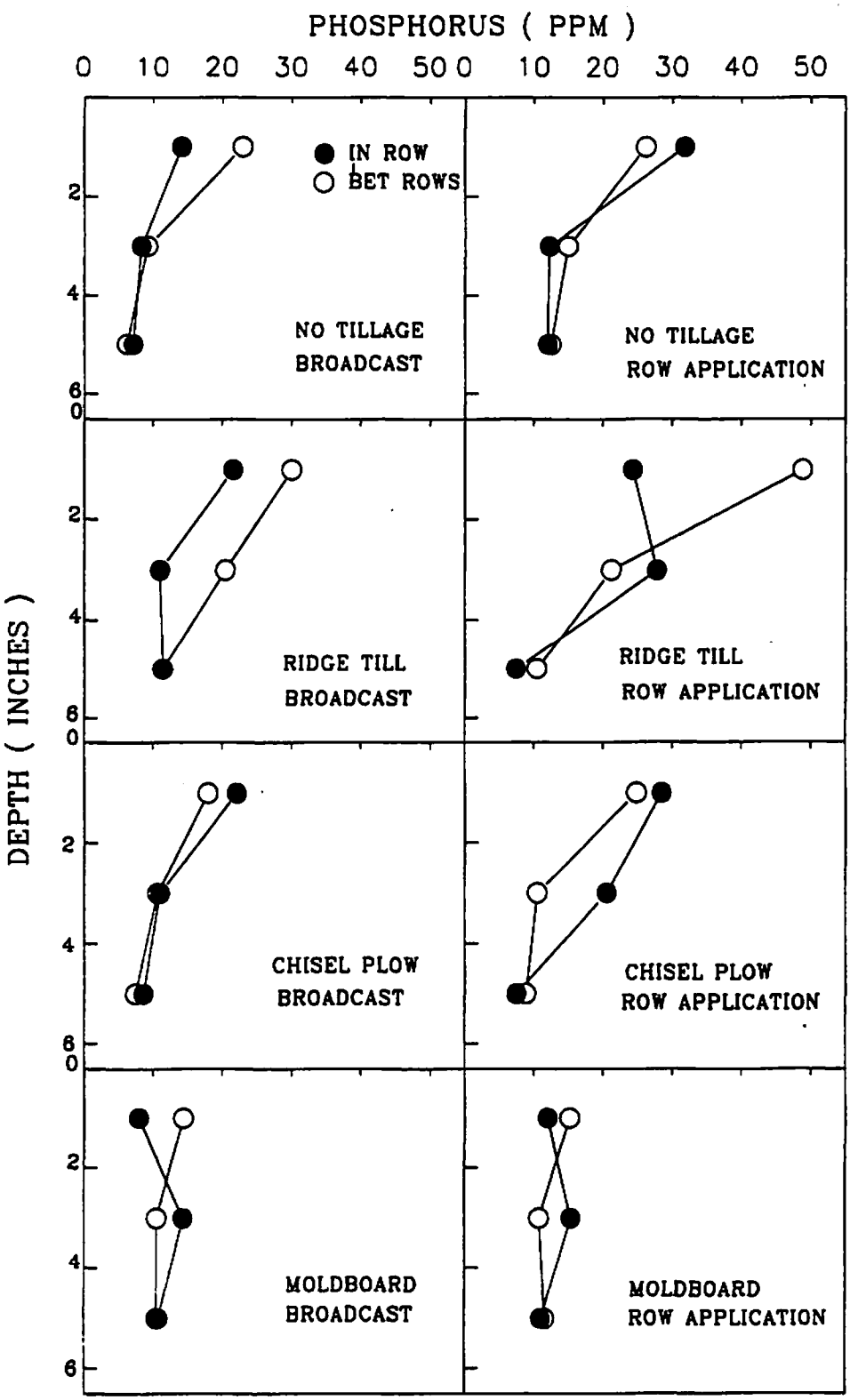

Table 9. Effect of tillage and method of phosphorus application on corn tissue N , P and K in Meeker Co. (Kuechle farm) on 7/26/91[1].

Fertilizer	TILLAGE SYSTEMS				
	No Tillage	Ridge Tillage	Chisel Plow	Moldboard Plow	Mean[2]
			N (%)		
Broadcast	3.10	2.96	2.86	2.56	2.87 a
Row applied	2.98	2.67	2.90	2.71	2.81 a
Mean	3.04 a	2.81 bc	2.88 ab	2.63 c	
			P (%)		
Broadcast	0.29	0.30	0.29	0.23	0.28 a
Row applied	0.28	0.26	0.27	0.26	0.26 a
Mean	0.29 a	0.28 a	0.28 a	0.24 b	
			K (%)		
Broadcast	1.18	1.29	1.46	1.42	1.34 a
Row applied	1.32	1.34	1.46	1.55	1.42 a
Mean[2]	1.25 a	1.31 a	1.46 a	1.48 a	

1. Pr > F value for main effects and interactions are

	N	P	K
Tillage	0.082 (n=8)	0.141 (n=8)	0.130 (n= 8)
Fertilizer	0.581 (n=16)	0.371 (n=16)	0.295 (n=16)
Tillage x Fertilizer	0.437 (n=4)	0.355 (n=4)	0.873 (n=4)

2. Means within same row or column with the same letter are not significantly different at $\alpha = 0.1$.

Table 10.Effect of tillage and method of Phosphorus application on corn stand (Plants/ac x 10^{-3}) in Meeker Co.(Kuechle Farm), MN , on 6/17/1991[1].

Method of P appln	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean
Broadcast	28.6	29.7	30.3	29.8	29.7 a
Row applied	29.9	30.9	30.7	30.6	30.5 a
Mean	29.2 a	30.3 a	30.6 a	30.2 a	

1 The p value for tillage,method of P application and tillage by method of P application for stand are 0.0.452 (n=32), 0.159 (n= 64), and 0.871 (n=16) respectively. Means within the same row or column with the same letters are not significantly different ($\alpha = 0.10$).

Table 11.Effect of tillage and method of Phosphorus application on corn stand (Plants/ac x 10^{-3}) at harvest(10/9/91) in Meeker Co. (Kuechle Farm), MN , 1991[1].

Method of P appln	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean
Broadcast	25.8	27.1	30.2	29.4	28.2 a
Row applied	28.9	28.8	28.2	28.7	28.7 a
Mean	27.5 a	28.0 a	29.2 a	29.1 a	

1. The p value for tillage,method of P application and tillage by method of P application for stand are 0.162, 0.674 and 0.050 respectively. Means within the same row or column with the same letters are not significantly different (α = 0.10).

Table 12. Effect of tillage and soil type on corn stand (Plants/acx10^{-3} per ac) in Meeker county (Kuechle Farm), MN 1991[1].

Soil	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean
Delft clayloam	26.4	27.5	28.7	29.2	27.9 a
Marcellon loam	30.2	27.8	29.6	28.3	29.2 a
Koronis fine sandyloam	27.5	32.6	29.9	29.4	28.8 a
Mean	27.5 a	28.1 a	29.2 a	29.1 a	

1.The p value for tillage, soil and tillage by soil type for corn stand are 0.205, 0.099 and 0.903 respectively. Mean with the same letters are not significantly different (α = 0.10).

Table 13. Effect of method of phosphorus application in ridge tillage on soybean population at MeekerCo. kuechle farm) on 6/17/91[1].

Method of fertilizer Application	Population(Plants/Ac x 10^{-3})
Broadcast	196.8 a (n= 14)
Row applied	226.7 a (n= 12)
Mean	211.8

1 The p value for method of phosphorus application in ridge till is 0.284. Means within same column with same letter are not sinificantly different (α = 0.10).

Table 14. Effect of tillage on soybean population in Meeker Co.(Kuechle farm) on 6/17/91[1].

Tillage	Population (Plants/Ac x 10^{-3})
No Tillage	80.5 a
Ridge tillage	211.8 b
Chisel Plow	87.4 a
Moldboard Plow	146.6 c

1.The p value for tillage on soybean population is 0.001 (n=16). Means within same column with same letter are not significantly different at α = 0.1.

Table 15. Effect of tillage and method of Phosphorus application on corn yield (bu/ac) in Meeker Co. (Kuechle Farm),MN, 1991[1].

Method of P application	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean
Broadcast	91.2	89.5	102.1	92.0	94.2 a
Row applied	91.9	105.9	107.2	120.4	105.9 b
Mean	91.6 a	98.4 a	104.7 a	106.2 a	

1.The p value for tillage,method of P application and tillage by method of P application for yield are 0.375, 0.119 and 0.414 respectively. Means within the same row or column with the same letters are not significantly different (α = 0.10).

Table16. Effect of tillage and soil types on corn yield (bu/ac) in Meeker Co.(Kuechle Farm), MN , 1991[1].

Soil	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean
Delft clayloam	85.4	90.3	88.8	102.6	91.9 a
Marcellon loam	111.1	99.3	122.4	90.4	106.7b
Koronis fine sandyloam	89.4	140.7	118.7	121.3	112.2 b
Mean	91.6 a	98.4 a	104.7 a	106.2 a	

1 The p value for tillage, soil and tillage by soil type for corn yield are 0.342, 0.022 and 0.612 respectively. Mean within the same row or column with the same letters are not significantly different (α = 0.10).

Table 17.Effect of tillage and method of Phosphorus application on corn grain moisture (per cent) in Meeker Co.(Kuechle Farm), MN , 1991[1].

Method of P appln	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean
Broadcast	21.1	20.0	20.4	21.5	20.8 a
Row applied	20.3	17.9	19.0	17.1	18.7 b
Mean	20.7 a	18.8 a	19.7 a	19.3 a	

1 The p value for tillage,method of P application and tillage by method of P application for grain moisture are 0.396, 0.017 and 0.347 respectively. Means within the same row or column with the same letters are not significantly different (α = 0.10).

Table 18. Effect of tillage and soil type on corn grain moisture (in percent) in Meeker Co.(Kuechle Farm), MN , 1991.

Soil	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean
Delft clayloam	20.5	20.3	21.3	20.5	20.7 a
Marcellon loam	18.4	17.6	17.7	16.6	17.6 a
Koronis fine sandy loam	22.8	17.6	18.6	18.3	19.7 a
Mean	20.7 a	18.8 a	19.7 a	19.3 a	

1 The p value for tillage, soil and tillage by soil type for grain moisture are 0.602, 0.102 and 0.891 respectively. Mean with the same letters are not significantly different (α = 0.10).

Table 19 Effect of tillage[1] and method of P application[2] on soybean yield (Bu/Ac) at Meeker Co.(kuechle farm) MN., 1991[3]

Method of P application	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean[4]
Broadcast	39.0	35.8 a	31.7	53.2	42.2 a
None	34.3	—	29.6	48.5	38.2 a
Row applied	—	39.9 a	—	—	
Mean[4]	36.7 a	37.9	30.7 a	50.9 b	

1 The statistical analysis for ridge tillage was carried out separately considering the main effect of only the methods of P application.
2 With no till,chisel plow and moldboard plow as main plot treatments the subplot treatments were broadcast and none.
3 The p value for tillage(except ridge till), method of P application and tillage by method of P application for grain yield are 0.003, 0.263 and 0.933 respectively. The p value for method of application of P application in ridge till is 0.386
4 Means within the row or column with the same letters are not significantly different (α = 0.10)

Table 20 Effect of tillage[1] and method of P fertilizer[2] application on soybean grain moisture (in percent) at Meeker Co.(Kuechle farm) MN., 1991[3]

Method of P application	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean[4]
Broadcast	6.6	6.3a	6.4	6.5	6.5 a
None	6.4	--	6.6	6.5	6.5 a
Row applied	—	6.3a	--	--	
Mean[4]	6.5 a	6.3	6.5 a	6.5 a	

1 The statistical analysis for ridge tillage was carried out separately considering the main effect of only the methods of P application.
2 With no till,chisel plow and moldboard plow as main plot treatments the subplot treatments were broadcast and none.
3 The p value for tillage(except ridge till), method of P application and tillage by method of P application for grain moisture content are 0.964, 0.977 and 0.415 respectively. The p value for method of application of P application in ridge till is 0.961

Table 18. Effect of tillage and soil type on corn grain moisture (in percent) in Meeker Co.(Kuechle Farm), MN , 1991.

Soil	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean
Delft clayloam	20.5	20.3	21.3	20.5	20.7 a
Marcellon loam	18.4	17.6	17.7	16.6	17.6 a
Koronis fine sandy loam	22.8	17.6	18.6	18.3	19.7 a
Mean	20.7 a	18.8 a	19.7 a	19.3 a	

1 The p value for tillage, soil and tillage by soil type for grain moisture are 0.602, 0.102 and 0.891 respectively. Mean with the same letters are not significantly different (α = 0.10).

Table 19 Effect of tillage[1] and method of P application[2] on soybean yield (Bu/Ac) at Meeker Co.(kuechle farm) MN., 1991[3]

Method of P application	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean[4]
Broadcast	39.0	35.8 a	31.7	53.2	42.2 a
None	34.3	—	29.6	48.5	38.2 a
Row applied	—	39.9 a	—	—	
Mean[4]	36.7 a	37.9	30.7 a	50.9 b	

1 The statistical analysis for ridge tillage was carried out separately considering the main effect of only the methods of P application.
2 With no till, chisel plow and moldboard plow as main plot treatments the subplot treatments were broadcast and none.
3 The p value for tillage(except ridge till), method of P application and tillage by method of P application for grain yield are 0.003, 0.263 and 0.933 respectively. The p value for method of application of P application in ridge till is 0.386
4 Means within the row or column with the same letters are not significantly different (α = 0.10)

Table 20 Effect of tillage[1] and method of P fertilizer[2] application on soybean grain moisture (in percent) at Meeker Co.(Kuechle farm) MN., 1991[3]

Method of P application	Tillage				
	No Till	Ridge Till	Chisel Plow	Moldboard Plow	Mean[4]
Broadcast	6.6	6.3a	6.4	6.5	6.5 a
None	6.4	--	6.6	6.5	6.5 a
Row applied	—	6.3a	--	--	
Mean[4]	6.5 a	6.3	6.5 a	6.5 a	

1 The statistical analysis for ridge tillage was carried out separately considering the main effect of only the methods of P application.
2 With no till, chisel plow and moldboard plow as main plot treatments the subplot treatments were broadcast and none.
3 The p value for tillage(except ridge till), method of P application and tillage by method of P application for grain moisture content are 0.964, 0.977 and 0.415 respectively. The p value for method of application of P application in ridge till is 0.961
4 Means within the row or column with the same letters are not significantly different (α = 0.10)

Tillage and Time of Manure Application Effects on Corn Response and Losses of Manure N and P at Meeker County, MN[1]

D. Ginting, J.F. Moncrief, S.C. Gupta, M.B. Kells, and B.J. Johnson[2]

Abstract

Two sources of manure applied fall and spring were compared to spring applied anhydrous ammonia. Nitrogen source comparisons were evaluated with two tillage systems (chisel and moldboard plowing). Application of dairy manure increased soil residue cover. The spring application provided more residue than the fall application due to fall primary tillage. Residue cover between plant rows was higher than residue in the rows. Chisel plowing resulted in higer residue cover. Corn stand was similar across the tillage and manure treatments. P concentration of the soil under chisel plowing is higher than P concentration under moldboard plowing. Spring application of manure increased soil P mainly on the top 3 inch depth.
Soil pH did not change with different tillage and manure treatment. Pig manure and dairy manure application resulted in similar earleaf N and K concentration. Spring application of dairy manure, resulted in higher P concentration of earleaf, however, grain yield was 15 bu/acre lower. Grain N and protein concentration is higher when soil is treated with manure. Soil type and tillage interacted significantly in influencing grain yield and number of corn ears. Poorly drained soil, Cordova soils, resulted in higher yield when moldboard plowed compared to chisel plowed.

Materials and Methods

Tillage ,source of nutrients (dairy manure, pig manure and anhydrous ammonia) and time of application of the manures (Fall and Spring) were compared to evaluate corn response and loss of N and P. This experiment was a continuation of the same experiment conducted in 1990. For both-year experiments, corn was grown.

Anhydrous ammonia was applied (5/13/91). At planting time (5/20/91), 150 lb/A starter (9-23-30) was applied. Time of application of manure in 1991 experiments were Fall (9/11/90) and Spring (5/10/91 or 5/15/91) prior to corn planting. Control plots were not treated with either anhydrous ammonia or manure.

The agronomic practices and composition of manures applied in 1990 and 1991 are shown in Table 1. In 1991, the rate of manure applied in fall and spring were similar. However, the rate of manure-N, P or K of dairy and pig manure sources are different due to the differences in nutrient concentration.

Measurements. Measurements taken were soil residue cover (6/11/91), corn stands (6/11/91), soil P and pH (6/11/91) and earleaf N, P and K concentration (7/19/91).

Residue cover was estimated by the line transect method and characterized in and between the rows within each plot. Soil cover measurements were made over 10 feet of row with a line consisting of 25 points. "In row" is defined as a four inch strip centered over the row and "between row" as the remainder.

Corns stands were estimated from the numbers of plants within the 10 foot row from each plot. Soil sample was taken in the row and between the rows at three depths (0-2, 2-4 and 4-6 inch). Soil P and pH, and corn earleaf N, P, and K concentration was determined using standard analysis.
Grain yield was harvest from rows of 40 feet long (Oct, 10, 1991).

Experimental Design. The experiment was arranged in split plot with tillage(chisel plowing and moldboard plowing) as main plots and nutrient sources (fall pig, fall dairy, spring pig, spring dairy, anhydrous ammonia, and none) as subplots. The design was extended to split-split-split plot to evaluate the influences of row position and soil depth in soil pH.

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Results and Discussions

Residue Cover. Tillage significantly influenced residue cover measured in spring 1991 (Table 2). The chisel plowing system resulted in higher soil cover than moldboard plowing. Soil inversion with moldboard plowing incorporated more residue. However, both chisel and moldboard plowing resulted in less than 30% soil residue cover, which is considered necessary for soil conservation. Lower than 30% residue cover was mainly due to excessive secondary tillage.

The application of pig manure, dairy manure and anhydrous ammonia resulted in higher soil residue cover compared to control plots. Dairy manure provide more residue cover than pig manure, because of the straw content in dairy manure. Spring application of dairy manure provide significantly more residue cover than fall dairy application. Loss of residue from the fall application is due to fall primary tillage. Residue from plots treated with anhydrous ammonia was higher than residue from fall pig or spring pig sources. Control plots resulted in the lowest residue cover.

Residue was significantly greater between the rows than in the rows, especially in the chisel plowed plots (Fig. 1). This indicated that straw from manure and corn residue was concentrated between the row. Row position interacted significantly with tillage or nitrogen source. Variability among samples (Fig. 1) within a treatment was high. Distribution of manure or plant residue is quite variable.

Corn Stands. Tillage or nitrogen source did not influence corn plant population. The time of application or manure source did not influence corn population (Table 3).

Soil Phosphorous. Tillage influenced soil phosphorus content significantly (Table 4). Chisel plowing consistently resulted in higher soil P levels on plots treated with anhydrous ammonia or spring pig manure (Figure 2).

Spring pig manure application increased soil phosphorous significantly. This was also shown by a higher P concentration of corn earleaves when treated with manure (Table 6). The increase of soil P concentration with manure application was consistent across the tillage treatments (Fig. 2). Manure P application increase soil P about 7.5 ppm in moldboard plowed treatment and or 19.6 ppm in the chisel plowed treatment.

The soil P concentration gradient was steep with depth especially on the plot treated with manure and chisel plowed (Fig. 2). The gradient decreased significantly from 3 inch deep. The gradient was negligible when no phosphorous was applied. The tillage, nutrient source, and soil depth interaction was significant at $P < 0.004$.

Soil pH. Soil pH was not influenced by tillage, nutrient source or soil depth (Table 5). However, tillage and soil depth, also tillage, nutrient source and soil depth interacted significantly at $P < 0.009$ and $P < 0.057$, respectively. At 0-2 inch deep, chisel plowing resulted in higher pH compared to moldboard plowing, especially when treated with anhydrous ammonia (Fig. 3). It may be that ammonium did not nitrify as rapidly with chisel plowing producing hydrogen ion, which reduce the pH.

Corn Earleaf N, P, K. Tillage did not influence N, P, or K of corn earleaf. Pig manure and dairy manure resulted in the same earleaf N concentration (Table 6). Control plots resulted in the lowest N concentration. Time of manure application did not affect corn earleaf N concentration.

Spring dairy manure application resulted in significantly higher corn earleaf P compared to other time and manure source applications. Corn earleaf K was not influenced by manure application.

Grain Yield. Yield was significantly influenced by manure treatment (table 8). The spring applied dairy manure resulted in 15 bu/a lower yield than the other manure and time of application combinations. No nitrogen application resulted in the lowest yield, 74 bu/a. Grain moistures are similar across tillage, nutrient sources (Table 7). Grain N and protein concentration is significantly influenced by manure treatments (Table 11 and 12).

A change in tillage system from moldboard plow to chisel plowing on Cordova soil, poory drained soil resulted in a decrease of yield and number of corn ears (Fig.4 and 5). Koronis sandy loam and Marcellon sandy loam resulted in similar yields and number of corn ears (Table 10). Corn population at harvest is significantly influenced by tillage. On Cordova soil, moldboard plowing resulted in higher plant population (Table 9) compared to chisel plowing, however on Koronis and Marcellon corn population at harvest are similar (Table 8).Precipitation data is presented in Fig. 6.

Table 1. Cultural practices at Meeker County, MN. 1991.

Tillage

Fall Chisel Plowed, spring field cultivated
Fall Moldboard Plowed, spring field cultivated

Crop

1990 Corn-Pioneer 3751
1991 Corn-Northrop King

Planting and Harvest Dates

Plots were planted with a four row John Deere Maximerge planter equipped with spring tine row cleaners at a 38 inch row spacing.

Crop	Planting Date	Planting Rate	Harvested
Corn	May 20,1991	30,000 seeds/A	

1990 Fertilizer and Manure Analysis

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---- lb/A ----			
Corn	9-23-30[1]	150 lb/A	14	35	45	May 8, 1990
	82-0-0[2]	85 lb/A	70	0	0	April 24, 1990

1. Planter placement 2" beside and 2" below row.
2. Anhydrous ammonia was applied on selected plots.

Chemical composition of dairy and pig manure from barn gutters and an anaerobic pit from farrowing house at Meeker County, Fall-1989.

Manure Type and Rate of Application		Nitrogen					Phosphorus		Potassium	
		Mineral	Organic	Total	$	Available	P_2O_5	$	K_2O	$
Source	Rate	------- lb/A --------				- lb/A -	lb/A		lb/A	
Dairy	13.2 t/A	62	97	159	15.90	86	107	21.40	134	13.40
Pig	4,100 g/A	120	75	195	19.50	146	212	46.68	100	10.00

1. It is assumed that fertilizer cost .10, .20, and .10 per pound of N, P_2O_5, and K_2O respectively. All mineral N and 25% of organic N are available.

Chemical composition of dairy and pig manure from barn gutters and an anaerobic pit from farrowing house at Meeker County, Spring-1990 (4/5/90 for liquid and 5/18/90 for dairy).

Manure Type and Rate of Application		Nitrogen					Phosphorus		Potassium	
		Mineral	Organic	Total	$	Available	P_2O_5	$	K_2O	$
Source	Rate	------- lb/A --------				- lb/A --	lb/A		lb/A	
Dairy	11.6 t/A	149	61	210	21.00	164	89	17.80	217	21.70
Pig	4,100 g/A	93	43	136	13.60	108	127	25.40	82	8.20

1. It is assumed that fertilizer cost .10, .20, and .10 per pound of N, P_2O_5, and K_2O respectively. All mineral N and 25% of organic N are available.

1991 Fertilizer and Manure Analysis

Crop	Material Analysis	Rate	Actual N	Actual P_2O_5	Actual K_2O	Date Applied
			---- lb/A ----			
Corn	8-23-30[1]	150 lb/A	12	35	45	May 20, 1991
	82-0-0[2]	100 lb/A	82	0	0	May 13, 1991

1. Planter placement 2" beside and 2" below row.
2. Anhydrous ammonia was applied on selected plots.

Chemical composition of dairy and pig manure from barn gutters and an anaerobic pit from farrowing house at Meeker County, Fall-1990 and Spring-1991.

Manure Type and Rate of Application		Nitrogen					Phosphorus		Potassium		Date
		mineral	Organic	Total	$	Available	P_2O_5	$	K_2O	$	Applied
Source	Rate	------- lb/A --------				- lb/A --	lb/A		lb/A		
Fall Pig	3250 g/A	65	60	125	12.5	80	65	13.0	75	7.5	11/9/90
Fall Dairy	13.9 t/A	4	155	159	15.9	43	12	2.4	11	1.1	11/9/90
Spring Pig	3700 g/A	74	68	142	14.2	91	75	15.0	85	8.5	5/10/91
Spring Dairy	13.9 t/A	6	134	140	14.0	40	41	9.2	25	2.5	5/15/91

1. It is assumed that fertilizer cost .10, .20, and .10 per pound of N, P_2O_5, and K_2O respectively. All mineral N and 25% of organic N are available.

Soil

The soils present at this site are as follows: 60% is Koronis fine sandy loam (Mollic Haplaudalfs, fine-loamy, mixed, mesic) with good internal drainage; 20% Cordova loam (Typic Argiaquolls, fine-loamy, mixed, mesic) with poor internal drainage; and the remaining 20% is Marcellon loam (Aquic Argiudolls, fine-loamy, mixed, mesic) with somewhat poor internal drainage.

Weed Control: - 0.25 lb a.i./A Buctril + 0.5 lb a.i./A Atrazine as postemergence herbicide.
- 1.5 lb a.i./A Lasso as preemergence herbicide.

Insect Control: - 8.0 oz/A Lorsban 15G.

Table 2. Effects of tillage, nutrient source and row position on residue cover (%) at Meeker County, (Ecker Farm), MN (June 11, 1991).

N Source	Tillage						Overall Mean
	MOLDBOARD			CHISEL			
	In Row	Between Row	Mean	In Row	Between Row	Mean	
	%						
Fall Hog	2.5 (4.8)	2.3 (2.9)	2.4 (3.9)	12.3 (10.3)	21.0 (9.5)	16.7 (10.7)	**9.5 bc** **(10.7)**
Spr Hog	2.8 (3.2)	4.8 (5.3)	3.8 (4.4)	14.8 (11.8)	18.0 (11.1)	16.4 (11.4)	**10.1 bc** **(10.7)**
Fall Dairy	2.5 (2.5)	5.3 (5.0)	3.9 (4.1)	15.1 (11.2)	23.8 (10.0)	19.4 (11.4)	**11.6 bc** **(11.5)**
Spr Dairy	14.0 (10.8)	29.5 (22.1)	21.8 (18.8)	19.5 (20.7)	32.5 (9.6)	26.0 (17.6)	**23.9 a** **(18.0)**
Anhydrous	4.0 (4.6)	6.0 (4.4)	5.0 (4.5)	17.0 (15.6)	26.3 (11.0)	21.6 (14.1)	**13.3 b** **(13.3)**
None	2.8 (4.3)	2.0 (4.1)	2.4 (4.2)	9.5 (10.4)	18.8 (10.6)	14.1 (11.3)	**8.3 c** **(10.3)**
Mean	*4.8* *(7.0)*	*8.3* *(13.6)*	*6.5 b* *(11.0)*	*14.7* *(13.9)*	*23.4* *(11.2)*	*19.0 a* *(13.3)*	-----

- Numbers in parenthesis are Standard deviations.
- P>F value for main effects and significant extractions are:
- tillage = 0.001 (n=192)
- nutrient source = 0.001 (n=064)
- row position = 0.001 (n=192)
- tillage x row position= 0.007 (n=96)
- nutrient source x row position= 0.009 (n=32)
- tillage x nutrient source x row position=0.379 (n=16)
* Means at the same row or column with the same letters are not significantly different at $\alpha = 0.1$.

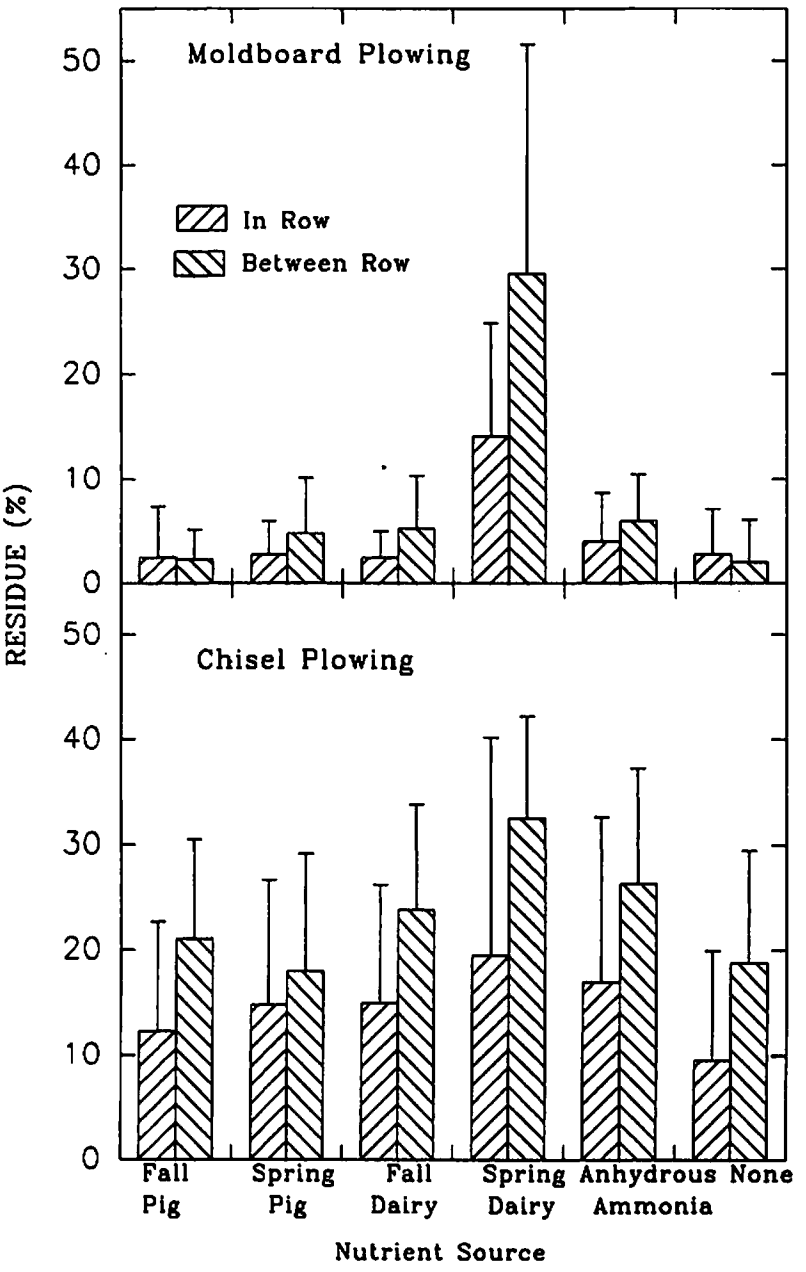

Fig. 1. Effects of tillage, nutrient source, and row position on soil cover by residue in Meeker Co., MN, 1991.

Table 3. The effects of tillage and nutrient source on corn population at Meeker County (Ecker Farm), MN (June 11,1991).

Nitrogen Source	Tillage		
	Moldboard	Chisel	Mean
	----------1000 plants/a----------		
Fall Pig	31.6 (1.8)	31.8 (2.9)	31.7 a (2.2)
Spring Pig	30.7 (2.3)	31.6 (2.9)	31.1 a (2.6)
Fall Dairy	30.3 (2.3)	31.9 (2.8)	31.1 a (2.6)
Spring Dairy	30.6 (2.2)	31.1 (2.6)	30.9 a (2.3)
Anhydrous	31.0 (3.1)	31.0 (2.1)	31.0 a (2.6)
None	30.7 (2.9)	31.6 (2.7)	31.1 a (2.8)
Mean	*30.8 a* *(2.4)*	*31.5 a* *(2.6)*	----

Number in parenthesis are Standard Deviations.
Means at the same row followed the same letters are not significantly different.
at $\alpha = 0.1$.

Table 4. Effects of tillage, nutrient source and soil depth on soil P concentration (ppm) at Meeker County (Ecker Farm), MN (June 11, 1991).

Soil depth (inches)	Tillage						Overall Mean
	MOLDBOARD			CHISEL			
	Spring Pig	Anhydrous	Mean	Spring Pig	Anhydrous	Mean	
	ppm						
0-2	36.6 (9.6)	24.2 (2.3)	30.5 (9.3)	70.8 (24.3)	30.6 (12.5)	50.7 (27.9)	**40.5 (22.7)a**
2-4	27.3 (8.9)	21.0 (3.5)	24.8 (6.8)	42.5 (13.4)	29.6 (8.6)	36.0 (12.5)	**30.3 (11.3)b**
4-6	28.5 (9.6)	23.1 (3.3)	25.8 (7.2)	37.2 (9.3)	31.2 (17.0)	33.0 (13.1)	**30.0 (11.1)b**
Mean	*30.8 (9.5)*	*23.3 (3.0)*	----	*50.1 (21.8)*	*30.5 (11.9)*	----	
Overall Mean	----	----	**27.0 (7.8)b**	----	----	**39.5 (19.8)a**	

- Numbers in parenthesis are Standard deviations.
- P value of main effect and significant interactions.
- tillage = 0.017 (n=24) - nsource x depth = 0.005 (n=08)
- nutrient source = 0.063 (n=24) - tillage x nutrient source x soil depth = 0.084 (n=04)
- soil depth = 0.003 (n=16)

Means at the same row or column with the same letters are not significantly different.

Table 5. Effects of tillage, nutrient source and soil depth on soil pH at Meeker County (Ecker Farm), MN, (6/11/91).

Soil depth (inches)	Tillage						Overall Mean
	MOLDBOARD			CHISEL			
	Spring Pig	Anhydrous	Mean	Spring Pig	Anhydrous	Mean	
0-2	5.9 (0.3)	5.8 (0.2)	5.9 (0.2)	6.1 (0.3)	6.5 (0.6)	6.3 (0.5)	**6.1 a (0.4)**
2-4	6.0 (0.1)	5.9 (0.1)	6.0 (0.1)	6.1 (0.3)	6.2 (0.7)	6.1 (0.5)	**6.0 a (11.3)**
4-6	6.0 (0.1)	6.3 (0.5)	6.2 (0.4)	6.0 (0.4)	6.1 (0.6)	6.1 (0.5)	**6.1 a (0.4)**
Mean	*6.0 (0.2)*	*6.0 (0.4)*	----	*6.0 (0.3)*	*6.3 (0.6)*	----	
Overall Mean	----	----	**6.0 a (0.3)**	----	----	**6.2 a (0.5)**	

- Numbers in parenthesis are Standard deviations.
- P value of main effect and significant interactions.
- tillage = 0.428 (n=24) - tillage x soil depth = 0.009 (n=08)
- nutrient source = 0.566 (n=24) - tillage x nutrient source x soil depth = 0.057 (n=04)
- soil depth = 0.653 (n=16)

* Means at the same row or column with the same letters are not significantly different at $\alpha = 0.1$.

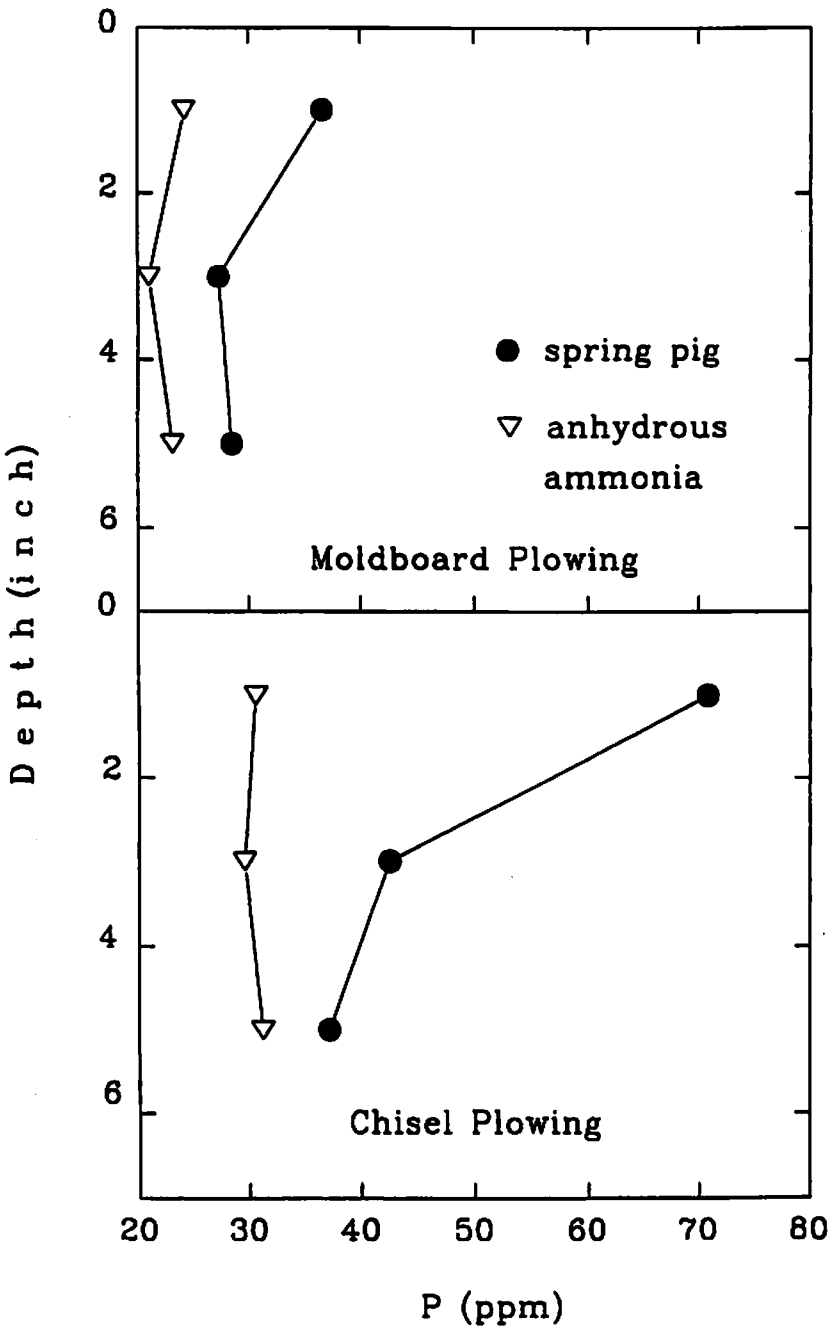

Fig. 2. Effects of tillage, N source and soil depth on soil P concentration

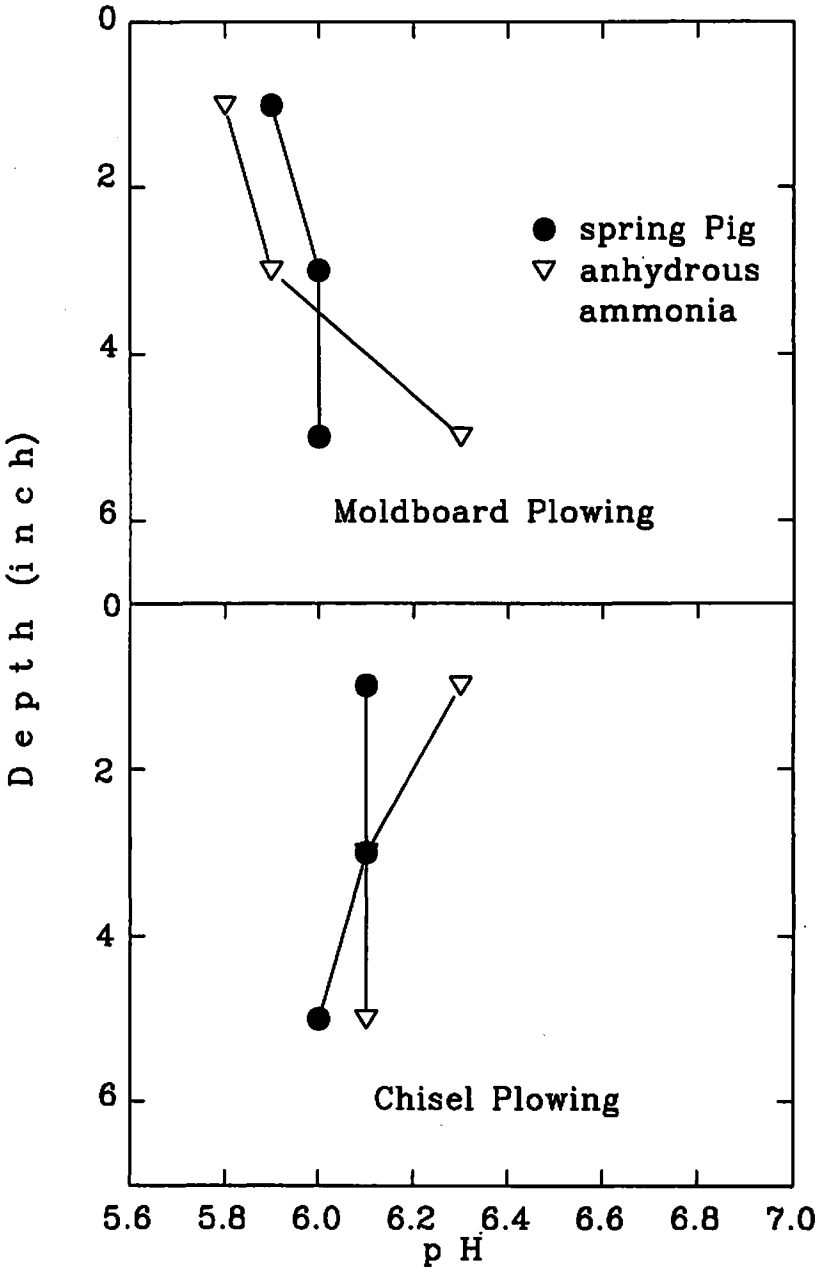

Fig. 3. Effects of tillage, N source and soil depth on soil pH at Meeker County, MN, in 1991

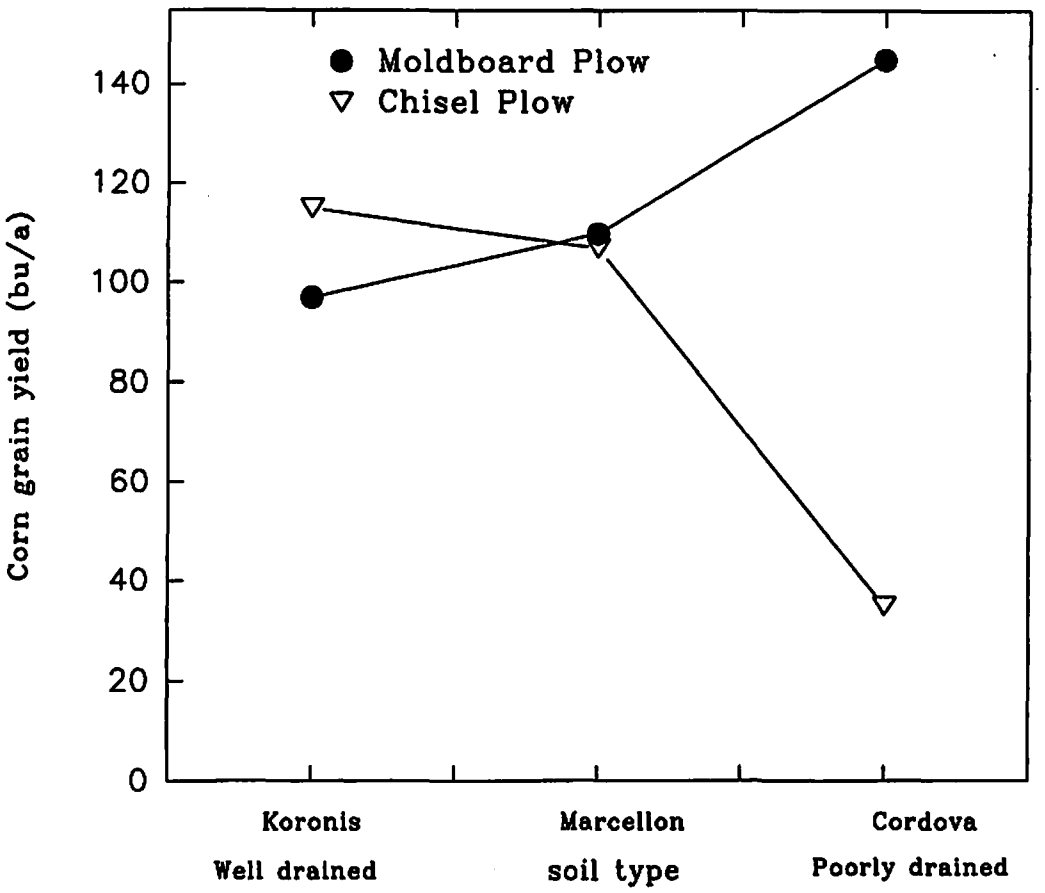

Fig. 4. Tillage system and soil type interaction on corn grain yield at Meeker Co. (Ecker farm), Oct. 10. 1991.

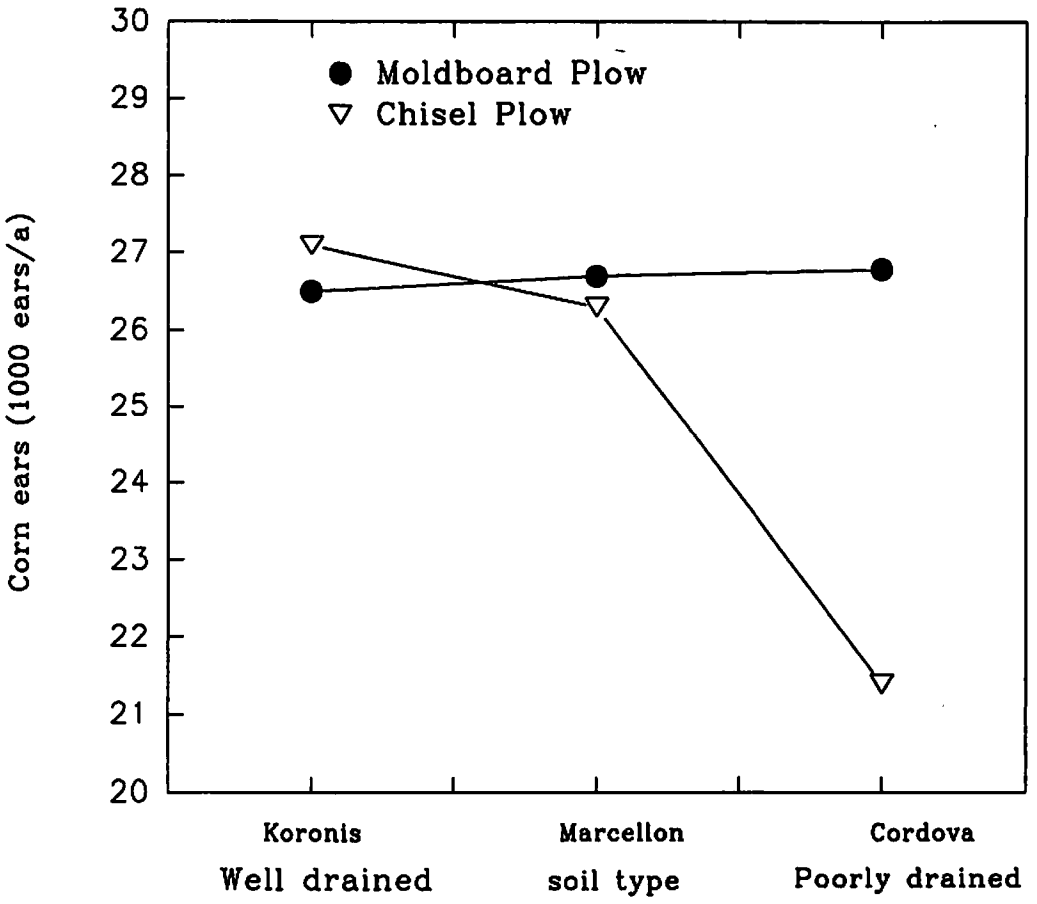

Fig. 5. Tillage system and soil type interaction on number of corn ears at Meeker Co. (Ecker farm), Oct. 10. 1991.

Table 6. The effects of nutrient source on corn earleaf N, P & K at Meeker Ecker County (Ecker Farm), MN (July 19, 1991).

Nitrogen Source	Plant Tissue		
	N (%)	P (%)	K (%)
Fall Pig	1.9 b (0.2)	0.18 b (0.03)	2.5 a (0.4)
Spring Pig	2.1 ab (0.3)	0.19 b (0.02)	2.4 a (0.2)
Fall Dairy	2.0 ab (0.3)	0.20 b (0.03)	2.5 a (0.3)
Spring Dairy	1.9 ab (0.5)	0.22 a (0.02)	2.3 a (0.2)
Anhydrous	2.2 a (0.3)	0.18 b (0.03)	2.3 a (0.2)
None	1.4 c (0.2)	0.18 b (0.03)	2.3 a (0.2)
P > F	*0.0009*	*0.001*	*0.142*

- Number in parenthesis are Standard Deviations.

* Means at the same row followed the same letters are significantly different.

Table 7. Effect of tillage systems, soil type and nutrient sources on corn grain moisture at Meeker County (Ecker farm), MN (Oct. 10, 1991).

Nutrient Source	Tillage System		Mean
	Moldboard Plow	Chisel Plow	
	%		
Fall Hog	13.6(1.2)	17.0(12.7)	15.3(8.9)a
Spring Hog	14.1(2.1)	15.8(4.1)	15.0(3.3)a
Fall Dairy	12.5(1.2)	13.3(4.1)	12.9(2.9)a
Spring Dairy	13.5(1.7)	13.7(1.6)	13.6(1.6)a
Anhydrous Ammonia	14.0(3.6)	17.4(10.5)	15.7(7.7)a
None	18.6(12.0)	13.8(3.22)	16.2(8.8)a
Mean	14.4(5.3)a	15.2(7.0)a	

The p value of Tillage (n=42-43) : 0.329
Nutrient Source (n=14-15) : 0.681
Tillage x Nutrient Source interactions (n=7-8) : 0.497

Nutrient Source	Soil			Mean
	Koronis	Marcellon	Cordova	
	%			
Fall Hog	13.1(1.7)	12.9(1.4)	29.1(23.6)	15.3(8.0)a
Spring Hog	14.9(3.7)	14.0(3.1)	17.9(0.4)	15.0(3.3)a
Fall Dairy	12.2(0.9)	12.0(1.4)	17.5(7.1)	12.9(2.9)a
Spring Dairy	13.6(1.8)	13.1(1.4)	14.7(0.2)	13.6(1.6)a
Anhydrous Ammonia	17.4(9.9)	12.6(0.8)	15.0(4.6)	15.7(7.7)a
None	17.6(11.5)	12.8(1.3)	17.4(3.7)	16.2(8.8)a
Mean	14.8(6.5)a	12.9(1.7)a	18.6(9.2)a	

The p value of Nutrient Source (14-15) : 0.745
soil (n=12-48) : 0.413
Nutrient source x soil interactions (n=2-8) : 0.214

Tillage System	Soil			Mean
	Koronis	Marcellon	Cordova	
	%			
Moldboard Plow	15.2(6.8)	12.9(1.4)	14.1(2.4)	14.4(5.3)b
Chisel Plow	14.4(6.2)	12.9(2.1)	23.1(11.4)	15.2(7.0)a
Mean	14.8(6.5)a	12.9(1.7)a	18.6(9.2)a	

The p value of Tillage (n=42-43) : 0.001
soil (n=12-48) : 0.751
Tillage systems x soil interactions (n=6-24) : 0.004

Table 8. Effect of tillage systems, soil type and nutrient sources on corn grain yield at Meeker County, (Ecker Farm), Oct. 10, 1991.

Nutrient Source	Tillage System		Mean
	Moldboard Plow	Chisel Plow	
	bu/a		
Fall Hog	114(33)	101(40)	108(36)a
Spring Hog	133(34)	100(40)	116(40)a
Fall Dairy	118(34)	119(46)	119(39)a
Spring Dairy	101(35)	97(18)	99(27)a
Anhydrous Ammonia	122(29)	106(47)	114(38)a
None	58(19)	85(42)	72(34)b
Mean	108(38)a	101(39)a	

The p value of Tillage (n=42-43) : 0.455
Nutrient Source (n=14-15) : 0.005
Tillage x Nutrient Source interactions (n=7-8) : 0.304

Nutrient Source	Soil			Mean
	Koronis	Marcellon	Cordova	
	bu/a			
Fall Hog	108(24)	115(23)	92(102)	108(36)a
Spring Hog	122(35)	120(34)	79(78)	116(40)a
Fall Dairy	122(29)	117(41)	108(94)	119(39)a
Spring Dairy	92(19)	103(34)	116(50)	99(27)b
Anhydrous Ammonia	111(25)	132(28)	89(99)	114(38)a
None	81(37)	62(27)	57(46)	72(34)c
Mean	106(31)a	109(36)a	90(63)b	

The p value of Nutrient Source (14-15) : 0.001
soil (n=12-48) : 0.047
Nutrient source x soil interactions (n=2-8) : 0.963

Tillage System	Soil			Mean
	Koronis	Marcellon	Cordova	
	bu/a			
Moldboard Plow	97(35)	110((38)	145(31)	108(38)a
Chisel Plow	115(25)	107(36)	35(24)	101(39)b
Mean	106(31)a	108(36)a	90(63)a	

The p value of Tillage (n=42-43) : 0.046
soil (n=12-48) : 0.127
Tillage Systems x soil interactions (n=6-24) : 0.001

Table 9. Effect of tillage systems, soil type and nutrient sources on corn population at harvest at Meeker County (Ecker Farm) Oct. 10, 1991.

Nutrient Source	Tillage System		Mean
	Moldboard Plow	Chisel Plow	
	---------- 1000 plants/a ----------		
Fall Hog	29.2(3.1)	28.1(3.0)	28.6(7.6)a
Spring Hog	29.8(1.7)	27.7(3.5)	28.7(2.9)a
Fall Dairy	29.5(1.8)	27.5(1.3)	28.5(1.8)a
Spring Dairy	27.2(2.6)	27.3(1.3)	27.2(6.6)a
Anhydrous Ammonia	28.0(1.2)	27.5(3.2)	27.8(2.4)a
None	28.1(2.1)	28.3(1.5)	28.2(1.7)a
Mean	28.7(1.4)a	27.7(7.8)b	

The p value of Tillage (n=42-43) : 0.039
Nutrient Source (n=14-15) : 0.499
Tillage x Nutrient Source interactions (n=7-8) : 0.660

Nutrient Source	Soil			Mean
	Koronis	Marcellon	Cordova	
	---------- 1000 plants/a ----------			
Fall Hog	28.0(3.5)	29.5(2.7)	29.4(0.7)	28.6(3.0)a
Spring Hog	29.4(3.0)	28.3(3.1)	26.8(1.9)	28.7(2.9)a
Fall Dairy	28.4(2.2)	29.1(1.3)	27.5(1.5)	28.5(1.8)a
Spring Dairy	27.8(1.6)	25.7(2.5)	28.2(0.5)	27.2(2.0)a
Anhydrous Ammonia	28.2(1.3)	28.3(1.1)	25.1(6.3)	27.8(2.4)a
None	28.6(1.6)	27.4(1.8)	28.2(2.9)	28.2(1.7)a
Mean	28.4(2.3)a	28.1(2.4)a	27.5(2.6)a	

The p value of Nutrient Source (14-15) : 0.473
soil (n=12-48) : 0.392
Nutrient source x soil interactions (n=2-8) : 0.572

Tillage System	Soil			Mean
	Koronis	Marcellon	Cordova	
	---------- 1000 plants/a ----------			
Moldboard Plow	28.7(2.3)	28.4(2.6)	29.1(0.9)	28.7(2.2)a
Chisel Plow	28.1(2.2)	27.8(2.2)	25.9(2.9)	27.7(2.4)b
Mean	28.4(2.3)a	28.1(2.4)a	27.5(2.6)a	

The p value of Tillage (n=42-43) : 0.030
soil (n=12-48) : 0.466
Tillage Systems x soil interactions (n=6-24) : 0.716

Table 10. Effect of tillage systems, soil type and nutrient sources on number of corn ears at harvest at Meeker County (Ecker Farm) ,Oct. 10, 1991.

Nutrient Source	Tillage System		Mean
	Moldboard Plow	Chisel Plow	
	---------- 1000 ears/a ----------		
Fall Hog	26.1(4.4)	25.9(3.0)	26.0(3.6)bc
Spring Hog	27.8(2.0)	27.0(2.7)	27.4(2.3)ab
Fall Dairy	28.8(2.2)	27.4(1.4)	28.1(1.9)a
Spring Dairy	25.5(2.9)	25.1(1.6)	25.3(2.3)c
Anhydrous Ammonia	26.3(1.7)	25.7(4.8)	26.0(3.5)bc
None	25.0(3.2)	25.2(3.0)	25.1(3.0)c
Mean	26.6(3.0)a	26.0(2.9)a	

The p value of Tillage (n=42-43) : 0.446
Nutrient Source (n=14-15) : 0.039
Tillage x Nutrient Source interactions (n=7-8) : 0.979

Nutrient Source	Soil			Mean
	Koronis	Marcellon	Cordova	
	----------1000 ears/a----------			
Fall Hog	25.5(3.9)	28.0(2.1)	24.1(4.9)	26.0(3.6)a
Spring Hog	28.2(1.9)	27.0(2.9)	24.9(1.2)	27.4(2.3)a
Fall Dairy	28.3(2.0)	28.4(2.1)	26.8(1.5)	28.1(1.9)a
Spring Dairy	26.1(2.2	24.2(2.4)	23.9(1.2)	25.3(2.3)a
Anhydrous Ammonia	26.6(1.9)	27.1(1.1)	21.5(9.0)	26.0(3.5)a
None	26.0(3.0)	23.9(1.5)	23.6(5.1)	25.1(3.0)a
Mean	26.8(2.7)a	26.5(2.6)a	24.1(3.9)b	

The p value of Nutrient Source (14-15) : 0.126
soil (n=12-48) : 0.015
Nutrient source x soil interactions (n=2-8) : 0.544

Tillage System	Soil			Mean
	Koronis	Marcellon	Cordova	
	----------1000 ears/a ----------			
Moldboard Plow	26.5(3.4)	26.7(2.9)	26.8(1.3)	26.6(3.0)a
Chisel Plow	27.1(2.2)	26.3(2.3)	21.4(3.8)	26.0(2.9)b
Mean	26.8(2.7)a	26.5(2.6)a	24.1(3.9)b	

The p value of Tillage (n=42-43) : 0.019
soil (n=12-48) : 0.056
Tillage System x soil interactions (n=6-24) : 0.059

Table 11. Effect of tillage systems, soil type and nutrient sources on corn grain N concentration at Meeker County (Ecker Farm) ,Oct. 10, 1991.

Nutrient Source	Tillage System		Mean
	Moldboard Plow	Chisel Plow	
	----------%----------		
Fall Hog	0.95(0.09)	0.98(0.06)	0.96(0.08)a
Spring Hog	1.02(0.08)	1.04(0.13)	1.02(0.10)a
Fall Dairy	0.99(0.13)	0.99(0.09)	0.99(0.11)a
Spring Dairy	1.02(0.14)	0.97(0.04)	0.99(0.10)a
Anhydrous Ammonia	1.00(0.12)	0.9790.09)	0.98(0.10)a
None	0.95(0.13)	0.91(0.06)	0.93(0.09)a
Mean	0.99(0.11)a	0.98(0.09)a	

The p value of Tillage (n=42-43) : 0.975
Nutrient Source (n=14-15) : 0.184
Tillage x Nutrient Source interactions (n=7-8) : 0.871

Nutrient Source	Soil			Mean
	Koronis	Marcellon	Cordova	
	----------%----------			
Fall Hog	0.96(0.08)	1.01(0.06)	0.89(0.00)	0.97(0.08)ab
Spring Hog	1.02(0.09)	1.05(0.12)	0.99(0.19)	1.02(0.10)a
Fall Dairy	0.97(0.07)	1.00(0.11)	1.08(0.21)	0.99(0.11)ab
Spring Dairy	0.96(0.07)	0.99(0.08)	1.14(0.14)	0.99(0.10)ab
Anhydrous Ammonia	0.95(0.08)	1.00(0.09)	1.07(0.18)	0.98(0.10)ab
None	0.95(0.11)	0.90(0.03)	0.88(0.04)	0.93(0.09)b
Mean	0.96(0.08)a	1.00(0.09)a	1.01(0.15)a	

The p value of Nutrient Source (14-15) : 0.088
soil (n=12-48) : 0.359
Nutrient source x soil interactions (n=2-8) : 0.298

Tillage System	Soil			Mean
	Koronis	Marcellon	Cordova	
	----------%----------			
Moldboard Plow	0.95(0.09)	1.00(0.07)	1.10(0.16)	0.99(0.11)a
Chisel Plow	0.98(0.08)	1.00(0.11)	0.91(0.07)	0.98(0.09)b
Mean	0.96(0.08)a	1.00(0.09)a	1.01(0.15)a	

The p value of Tillage (n=42-43) : 0.072
soil (n=12-48) : 0.419
Tillage System x soil interactions (n=6-24) : 0.001

Table 12. Effect of tillage systems, soil type and nutrient sources on grain protein concentration at Meeker County (Ecker Farm) ,Oct. 10, 1991.

Nutrient Source	Tillage System		Mean
	Moldboard Plow	Chisel Plow	
	----------%----------		
Fall Hog	5.91(0.61)	6.10(0.38)	6.00(0.50)a
Spring Hog	6.30(0.52)	6.45(0.80)	6.38(0.66)a
Fall Dairy	6.18(0.78)	6.19(0.58)	6.18(0.66)a
Spring Dairy	6.29(0.89)	6.06(0.27)	6.18(0.62)a
Anhydrous Ammonia	6.20(0.72)	6.01(0.60)	6.10(0.64)a
None	5.86(0.80)	5.65(0.39)	5.75(0.60)a
Mean	6.13(0.69)a	6.08(0.56)a	

The p value of Tillage (n=42-43) : 0.975
Nutrient Source (n=14-15) : 0.184
Tillage x Nutrient Source interactions (n=7-8) : 0.871

Nutrient Source	Soil			Mean
	Koronis	Marcellon	Cordova	
	----------%----------			
Fall Hog	5.97(0.53)	6.30(0.37)	5.51(0.00)	6.00(0.50)ab
Spring Hog	6.34(0.55)	6.53(0.75)	6.13(1.22)	6.38(0.66)a
Fall Dairy	6.03(0.47)	6.23(0.71)	6.72(1.35)	6.18(0.66)ab
Spring Dairy	5.94(0.42)	6.18(0.51)	7.09(0.93)	6.18(0.62)ab
Anhydrous Ammonia	5.89(0.54)	6.24(0.58)	6.63(1.13)	6.10(0.64)ab
None	5.87(0.73)	5.62(0.20)	5.46(0.26)	5.75(0.60)b
Mean	6.01(0.54)a	6.82(0.57)a	6.26(0.96)a	

The p value of Nutrient Source (14-15) : 0.088
soil (n=12-48) : 0.359
Nutrient source x soil interactions (n=2-8) : 0.298

Tillage System	Soil			Mean
	Koronis	Marcellon	Cordova	
	----------%----------			
Moldboard Plow	5.92(0.59)	6.20(0.46)	6.84(1.01)	6.13(0.69)a
Chisel Plow	6.09(0.49)	6.24(0.68)	5.68(0.44)	6.08(0.56)b
Mean	6.01(0.54)a	6.22(0.58)a	6.26(0.96)a	

The p value of Tillage (n=42-43) : 0.072
soil (n=12-48) : 0.419
Tillage System x soil interactions (n=6-24) : 0.001

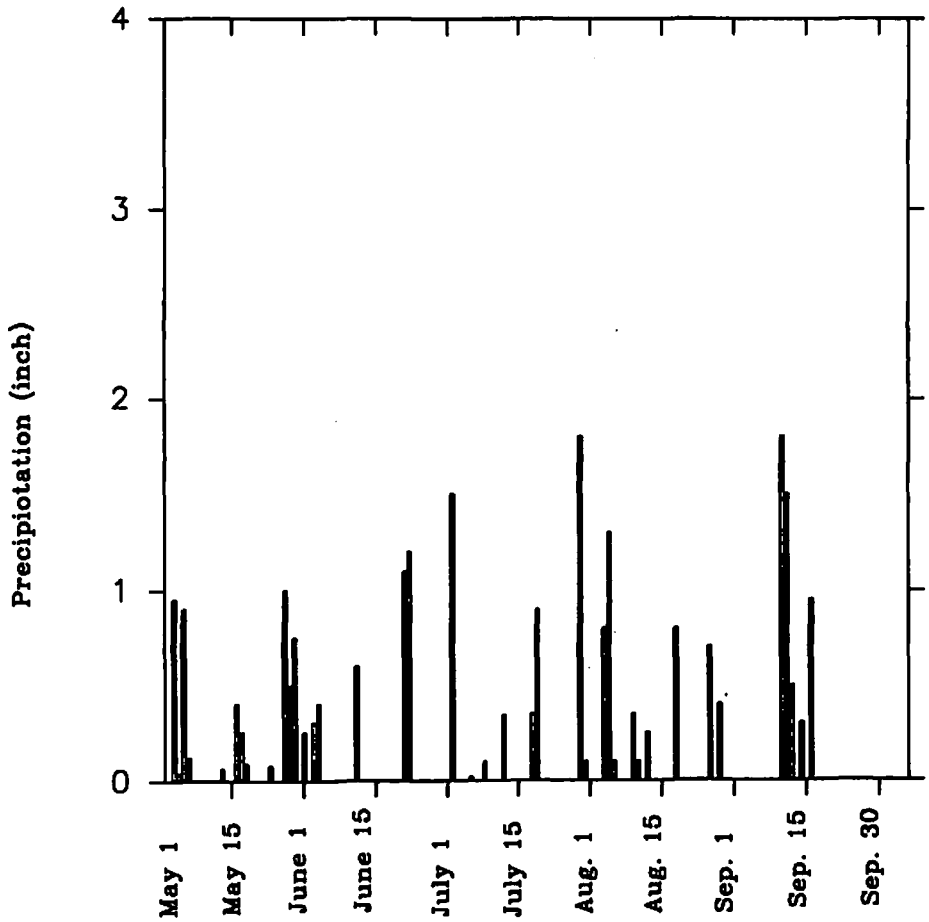

Fig. 6. Daily growing season precipitation at Kimball, Meeker County, MN. 1991 (Source:Minnesota Climatological Network).

TILLAGE EFFECTS ON CORN RESPONSE TO MANURE AT STEARNS COUNTY, MN[1]

D. Ginting, J.F. Moncrief, S.C. Gupta, M.B. Kells, and B.J. Johnson[2]

Abstract

Tillage, effects on two sources of plant nutrients (manure and anhydrous ammonia) on soil residue cover, plant responses and soil P, K distribution were evaluated. Soil type influences on grain yield components were also evaluated. Tillage significantly influenced surface residue. Amount of residue varied in or between rows. Lower plant population under field cultivating resulted from slippage of planter drive units. Differences in nutrient sources did not influence plant population, however soil phosphorus was increased significantly. Soil phosphorus varied significantly with row position and soil depth. Soil potassium was significantly influenced by barnyard manure application, row position and soil depth. Soil PH was not different among treatments. Ear leaf N and K were higher in moldboard plowing and field cultivating system compared to ridge tillage. Barnyard manure application significantly influence earleaf N and K. Earleaf P concentration was not influenced by manure application or tillage.

Tillage significantly influenced corn grain yield. The yield was the lowest under No-Till system which was mainly due to increased Russian Thistle. Yield were significantly effected by soil types which are different mainly in soil water holding capacity. Grain N and protein concentration of Hawick soil is significantly lower compared to deeper soil (Fairhaven and Esterville). Tillage and soil type did not influence corn population, number of ears or broken stalks above the ear. Difference in nutrient sources had no influences on grain yield. Broken corn stalks from corn borer damage was lower with barnyard manure application.

Materials and Methods

Treatments. At this site spring applied solid dairy manure from a manure pack around a pole barn and side dress anhydrous ammonia were evaluated as nitrogen sources within moldboard, chisel, and ridge till tillage systems. This experiment is a continuation of the experiments in 1989 and 1990. In 1989 two dairy manure sources (barngutter and barnyard) were evaluated in terms of ability to provide nutrients for corn. The residual effects of manure application were evaluated for soybean in 1990. No nutrient were applied in 1990. In 1991, the experimental area was treated with fresh barnyard manure. Manure was applied in the last two week of April in 1989, whereas in 1991 manure was applied on May 15.

In addition to the barnyard manure, starter (9-18-9) was applied at planting time (5/23/91). Commercial N (75 lb/A) as anhydrous ammonia was applied in each tillage treatment (6/4/91). This resulted in tillage main plots split with manure and anhydrous ammonia. Agricultural activities conducted in the experimental area are shown in Table 1.

Tillage treatments evaluated were spring moldboard plowing or field cultivation followed by a light discing, ridge till and no till systems. Within every tillage system (except no-till) there were manure and anhydrous ammonia treatments.

Measurements. Soil cover was estimated by a line transect method at two sites in each plot. Soil cover was characterized relative to row position i.e. in row and between row. In row is defined as a 10 inch strip centered over the row and between row is the remainder.The residue measurements were made on two adjacent corn rows. Soil cover measurements were made over 10 foot of row with 25 points (6/6/91).

Corn stands were estimated by tallying the number of plants in 10-feet row from each treatment where four subsamples were measured for cover (6/6/91).

Soil sample were taken from each treatment. Individual soil samples were taken both in the row and between rows at 3 depth intervals (0-2, 2-4, and 4-6 inches). Soil P, K and pH were determined.

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Corn earleaf samples at 50% silk emergence were taken on July 26, 1991 for determination of N, P, K concentration.

Grain yield and moisture, corn stand, number of ears and number of broken stalks were measured at harvest (10/2/91). Corn grain yields were estimated for each of the three soil types found at this site. The soils vary in thickness and are underlain by coarse sand and gravel. The Fairhaven loam is the deepest with 22 to 48 inches of loam textured material, the Esterville sandy loam has 11 to 22 inches of sandy loam material, the Hawick sandy loam is the thinnest with less than 10 inches of sandy loam material.

Statistical Analysis . The experimental design is a split plot with tillage main plots and nutrient source (manure/fertilizer) subplots. The design was extended to split-split-split plot to adapt the analysis of the influence of row position and soil depth on soil measurements.

Results and Discussion

Residue Cover. Soil cover by soybean residue are shown in Table 2. There was not adequate soil cover effect for soil erosion control with all conservation tillage system in 1991. Average residue cover ranged from 0.75% with moldboard plowing to 14.5% under no-till conditions.

Tillage significantly affected surface residue. Moldboard plowing consistently resulted in less residue, either in the row or between row. Field cultivating and no-tillage, provide higher surface residue. In the ridge till system, soil residue cover was low in the row. This was mainly due to the removal of residue from the row to between row with mounted sweep.

Residue cover between the row was significantly higher than residue in the row. Although the residue amount is not adequate for soil erosion control, concentrating residue cover between the row is advantageous because runoff would likely occur on this area.

Corn Population. Corn stands are shown in Table 3. Tillage significantly influence stands. Corn stands were the lowest in plots field-cultivated. Corn was planted with different planter according to tillage treatments. No-till and ridge till were planted with a buffalo till planter. The molboard and chisel treatments were planted with conventional International Harvester planter. The application of barnyard manure in 1991 as a nutrient source did not influence corn stand establishment.

Soil Phosphorus . Soil P concentration is shown in Table 4. Average soil test phosphorus are not different with tillage systems evaluated. Barnyard manure application in the spring 1991 (Table 1) significantly increase soil phosphorus about 15 ppm compared to no application.

Row position influenced soil phosphorus significantly. Soil phosphorus was significantly higher between the row than in the row (Fig. 1).

The tillage and row position interaction was significant, especially with the ridge till system. Ridge tillage resulted in higher soil concentration at 0-2 inch deep located between the row. High soil phosphorus at the soil surface may be subject to soil erosion.

The tillage and soil depth interaction was significant. Ridge till resulted in a significantly higher soil P concentration gradient than other tillage methods in 4 inches deep (Fig. 1). Tillage, manure, and soil depth or tillage, soil depth, and row position interactions were also significant at P=0.1 in soil P concentration.

Soil Potassium . Soil K are shown in table 5. As in phosphorus, average soil K concentrations was similar among tillage methods.

The nutrient source influence soil K significantly. The application of 22.7 ton/a barnyard manure (Table 1) increase soil K concentration significantly, about 52 ppm compared to no application.

Row position influence soil K significantly. Soil K between the rows is higher than soil K in the row. This was mainly due tillage.

Soil depth influenced soil K significantly, which suggested that soil K decreased with depth. The soil K gradient was steep in the top 0-4 inch deep.

Tillage interacted significantly with row position, especially with ridge till. Soil K in ridge till between the row was higher than in the row where as there was not much difference in other tillage methods. Tillage, row position, and soil depth or nutrient source, row position, and soil depth interacted significantly at $P<0.10$ (Fig. 2).

Soil pH . Soil pH was shown in Table 6. Soil pH ranged from 6.3 to 6.9. Soil pH was similar over tillage methods, nutrient source and soil depth.

Earleaf N, P, K. Corn earleaf N, P, K as influenced by barnyard manure application and tillage are in Table 7. Corn earleaf N and K concentration was significantly influenced by tillage methods. Moldboard plowing and field cultivating provided significantly higher N concentration than ridge tillage. Earleaf P was not influenced by tillage.

Corn earleaf P was not influenced by nutrient source either. Barnyard manure application influenced corn earleaf N and K concentration significantly. Visual symptoms of what appeared to be K stress in unmanured plots in July was supported by the lower K concentration. Tillage and nutrient source did not interact in earleaf N, P or K.

Tillage influenced earleaf N concentration of plots treated with anhydrous ammonia. Compared to no-till or ridge till, moldboard plowing showed significantly higher earleaf N concentration (Table 8).

Grain yield. Tillage influenced corn grain yields (table 13). Ridge tillage, chisel and moldboard plowing statistically resulted in similar corn yields. Corn grown with a no-till system resulted in about a 20 bu/a lower yield then the other tillage methods. The lower yield with the no tillage system was due in part to a Russian Thistle problem. Tillage methods did not influence grain moisture, corn population, ear numbers and broken stalks at harvest (Table 12, 14, 15, and 16).

Yields, grain N (Table 17) and protein (Table 18) concentration were also affected by soil type. Hawick, shallow soils, resulted in lower N and protein concentration. Even in the wet year (Fig. 4), soil depth was correlated to yield (Fairhaven and Esterville soils produced a higher yield than the Hawick soil). Yield performance of soils is shown in Table 13 and Fig. 3. Soil types influenced grain moisture (Table 12). Soil types did not influence corn population, numbers of ears or broken corn stalks at harvest (Table 14,25 and 16).

Although on average there was no difference in nitrogen source (manure and anhydrous ammonia) effects were not consistent for all soil types found at the Stearns County site. The two deeper soils with more water holding capacity resulted in a 13 bu/a higher yield with the manure N source. There was an 8 bu/a advantage with the anhydrous ammonia N source on the Hawick soil (Fig. 3). Anhydrous ammonia has been a consistent performing nitrogen source on sandy, shallow soils. Difference in nutrient sources did not influence, corn population and numbers of ears. Barnyard manure, however resulted in significantly lower number of broken stalks at harvest compared to anhydrous ammonia (Table 16).

STEARNS COUNTY

Table 1. Cultural practices at Stearns County, MN. 1991.

Tillage

No Till
Ridge Till
Spring Field cultivation + discing
Spring Moldboard Plowing + discing

Cropping History

1981-red clover and oats, 1982-corn, 1983-soybeans, 1984-corn, 1985-corn, 1986-soybeans, 1987-corn, 1988-Soybeans 1989-corn, 1990-soybean
1991 Crop Corn-Johnson 882

Planting and Harvest Dates

Ridge till and notill plots were planted with a four row Buffalo Till planter equipped with 12" sweeps at a 36 inch row spacing. Moldboard and field cultivator plots were planted with a conventional International 55 harvester.

Crop	Planting Date	Planting Rate	Harvested
Corn	May 23, 1991	23,000 seeds/A	Oct. 2 1991

Fertilization History 1981-1987

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

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

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

1989 Fertilizer and Manure Analysis

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

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

Analysis and rate of application of manure in 1989.

Manure Source	Date Applied	NH_4	NO_3	Mineral	Organic	Total N	Total P	Total K	Manure Density	Manure Rate	Solids Total	Solids Volatile	Solids Fixed
		%							lb/ft³	T/A	%		
Barn Gutter[1]	4/13/89	.260	.012	.272	.264	.536	.109	.424	64.8	16.4	27.66	45.96	54.04
Barnyard[2]	4/25/89	.050	.003	.053	.639	.692	.204	.377	33.8	15.0	16.50	64.62	35.38

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

Rate of applied, available and value[1] of nitrogen[2], phosphorus, and potassium.

Source	Mineral	Organic	Total Nitrogen	$	Nitrogen Available 1989	1990	1991	P_2O_5	$	K_2O	$
	-- Applied N lb/acre ---				-- lb/A -			lb/A		lb/A	
Barn Gutter	89	87	176	17.60	111	11	6	82	16.40	167	16.70
Barnyard	16	192	208	20.80	64	24	12	140	28.00	136	13.60

1. It is assumed that fertilizer cost .10, .20, and .10 per pound of N, P_2O_5, and K_2O respectively.
2. It is assumed that all of the mineral N and 25% of the organic N will be available during the year of application.

1990 Treatment

No manure or anhydrous ammonia was applied.

1991 Fertilizer and Manure Analysis

Crop	Material Analysis	Rate	Actual N	P_2O_5	K_2O	Date Applied
			---- lb/A ----			
Corn	9-18-9	5 gal/A	5	10	5	May 23, 1991
	82-0-0	75 lb/A	62	0	0	June 4, 1991

1. Planter placement 1" below the seed.

Analysis and rate of application of manure on May 1991.

Manure Source	Date Applied	NH_4	NO_3	Mineral	Organic	Total N	Total P	Total K	Manure Density	Manure Rate	Solids Total	Solids Volatile	Solids Fixed
		----------			%	----------			lb/ft^3	T/A	--------	%	---------
Barnyard[2]	5/15/91	0.017	TR	0.017	0.559	0.576	0.02	0.08	33.8	22.7	21.03	71.54	28.46

2. A manure pack collected in and around a pole shed.
TR. Trace.

Rate of applied, available and value[1] of nitrogen[2], phosphorus, and potassium.

Source	Mineral	Organic	Total Nitrogen	$	Nitrogen Available 1989	1991	P_2O_5 1989	1991	K_2O 1989	1991
	-- Applied N lb/A ---				--lb/A--		-- lb/A--		---lb/A---	
Barnyard	8	254	262	26.20	64	72	140	21	136	44

1. It is assumed that fertilizer cost .10 $ per lb of N
2. It is assumed that all of the mineral N and 25% of the organic N will be available during the year of application.

Soil

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

Weed Control

0.75 lb a.i./A Prowl + 1.2 lb a.i./A Bladex 90 DF (June 4, 1991).

Table 2. Effect of tillage and row position on soybean residue (%) in corn at Stearns Co. MN (June 6, 1991).

Residue Location	Tillage				Mean
	No Till	Ridge Till	Field Cultivator	Moldboard Plow	
Between Row	14.5	11.0	14.0	1.0	10.1 a
In Row	5.0	1.5	13.0	0.8	5.1 b
Weighted Mean	13.5 ab	10.0 b	13.9 a	1.0 c	

The The p value for residue location, tillage and the tillage by location interaction are 0.013 (n=16), 0.004 (n=8) and 0.141 (n=4), respectively. Mean within the same row or column with the same letter are not significantly different (α=0.10).

Table 3. Effect of tillage and barnyard manure applied on corn population at Stearns Co. MN (June 6, 1991).

Manure Treatment	Tillage			Mean
	Ridge Till	Field Cultivator	Moldboard Plow	
	Plants/A x 10^{-3}			
Manure	20.5	16.0	19.2	18.6 a
Anhydrous ammonia	22.1	16.7	17.8	18.9 a
Mean	21.3 a	16.4 c	18.5 b	

The p value of manure, tillage and the manure x tillage interaction for corn population are 0.76 (n=24), 0.019 (n=16) and 0.474 (n=8) respectively.

Means within the same row and column with the same letter are not significantly different (α=0.10).

Table 4. Effects of tillage, manure application, row position, and soil depth on soil P (ppm) at Stearns Co. (June 1991).

Depth (inches)	Tillage			
	Ridge Till	Field Cultivator	Moldboard	Mean
		Manure		
0-2	65.7(52.5)	55.2 (8.1)	34.2 (9.3)	52.1(31.1)
2-4	17.0 (7.3)	31.7 (7.1)	55.7(11.9)	34.8(18.6)
4-6	12.3 (3.6)	19.8 (3.5)	42.5 (6.9)	37.1(24.5)
Mean	*31.7(37.4)*	*35.6(16.5)*	*44.1(12.6)*	*37.1(24.5)a*
		No Manure		
0-2	33.0(11.9)	32.6(6.2)	20.1 (3.8)	28.6(9.6)
2-4	20.6 (6.5)	20.3(5.4)	20.3 (7.5)	20.4(5.9)
4-6	14.3 (6.6)	15.2(4.4)	18.2 (6.5)	15.8(5.4)
Mean	*22.7(11.3)*	*22.7(9.0)*	*19.5 (5.6)*	*21.6(8.8)b*
Overall Mean	**27.2(27.3)a**	**29.1(14.6)a**	**31.8(15.8)a**	----

Depth (inches)	Tillage			
	Ridge Till	Field Cultivator	Moldboard	Mean
		In Row		
0-2	25.8 (7.7)	45.5(13.2)	28.1 (9.8)	33.1(13.2)
2-4	14.3 (5.9)	29.4 (9.2)	39.5(21.0)	27.7(16.4)
4-6	12.8 (5.3)	17.4 (4.7)	27.9(11.7)	19.4 (9.7)
Mean	*17.6 (8.4)*	*30.8(14.9)*	*31.8(14.7)*	*26.7(14.2)b*
		Between Row		
0-2	72.9(44.0)	42.2(16.2)	26.3(11.1)	47.1(32.7)
2-4	39.0 (3.8)	22.7(7.1)	36.5(24.3)	27.5(14.9)
4-6	13.8 (3.2)	17.7(4.8)	32.0(18.3)	21.3(13.2)
Mean	*36.6(36.0)*	*27.5(14.7)*	*31.8(17.6)*	*32.0(24.2)a*

- Numbers in parenthesis are standard deviations
- P>F value for main effect and significant interactions are:

- tillage	: 0.681 (n=24)	tillage x nutrient source	: 0.080 (n=12)
- nutrient source	: 0.003 (n=36)	tillage x row position	: 0.006 (n=06)
- row position	: 0.032 (n=36)	nutrient source x row position	: 0.070 (n=18)
- soil depth	:<0.001(n=24)	tillage x soil depth	: <0.001 (n=8)
- row position x soil depth	: 0.066 (n=18)	nutrient source x soil depth	: 0.092 (n=12)

- tillage x nutrient source x soil depth:0.010 (n=04) tillage x soil depth x row position : 0.010 (n=04)

* Means in the same row or column followed by the same letter are not significantly different.

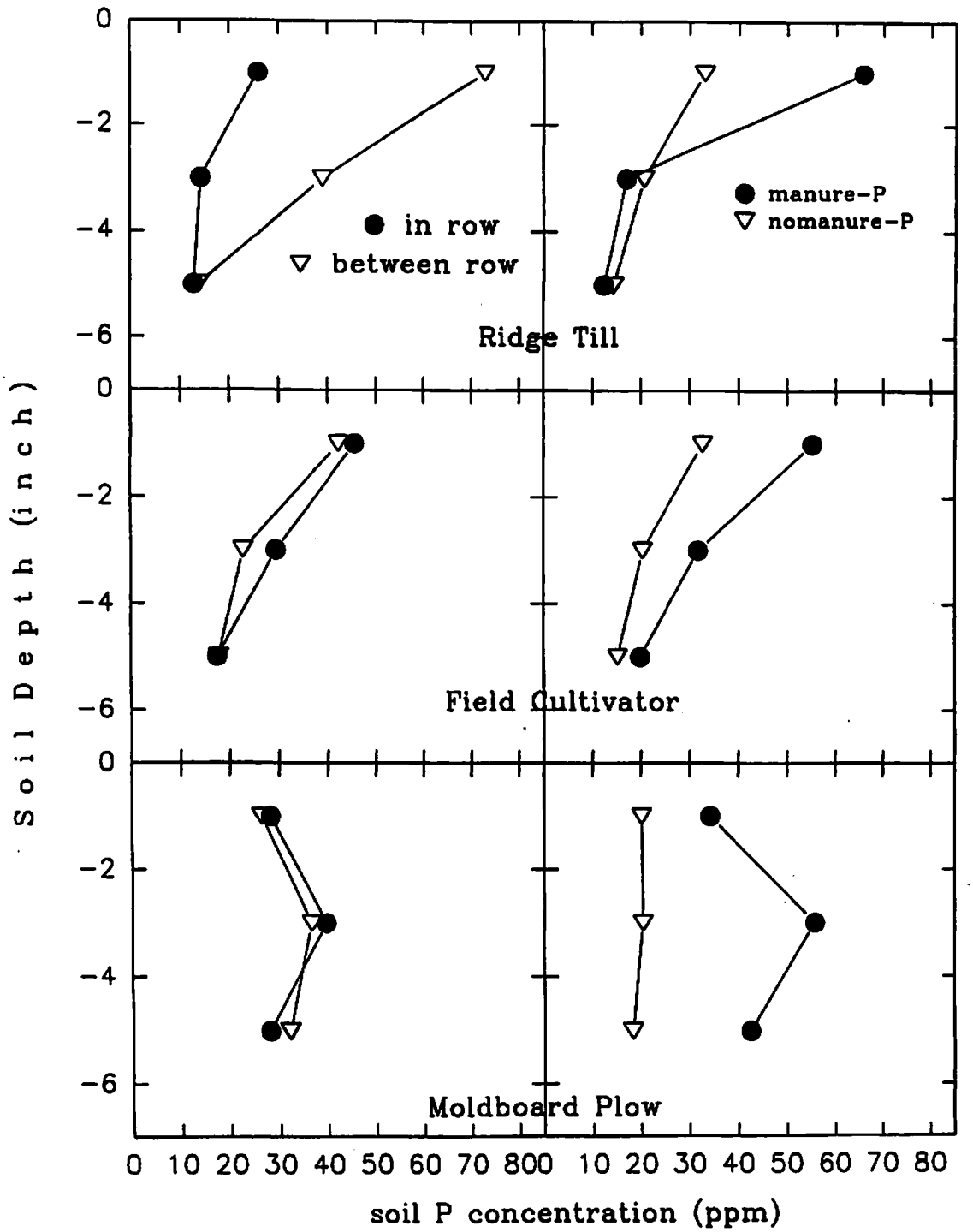

Fig. 1. The effects of (a) tillage methods*row position*soil depth interaction and (b) tillage methods*nutrient source* soil depth interaction on soil P at Stearns Co, MN (June 5, 1991).

Table 5. Effects of tillage, row position, manure application, and soil depth on soil K at Stearns Co. MN (June 6, 1991).

Depth (inches)	Tillage		
	Ridge Till	Field Cultivator	Moldboard
	ppm		
		IN ROW	
0-2	84.2(13.8)	125.3(82.2)	109.5(35.7)
2-4	42.8 (6.5)	91.7(28.7)	164.7(110.7)
4-6	40.7 (8.9)	70.5(17.3)	108.5 (43.5)
MEAN	*55.8(22.8)*	*95.9(51.9)*	*127.7 (70.5)*
		BETWEEN ROW	
0-2	292.4(164.0)	164.1(75.6)	98.7(31.2)
2-4	96.6 (45.8)	73.1(31.5)	125.4(38.7)
4-6	55.2 (07.4)	58.7(10.4)	111.3(41.7)
MEAN	*148.1(140.0)*	*98.6(65.0)*	*111.8(35.9)*
OVERALL MEAN	**102.0(108.8)a**	**97.2(57.6)a**	**119.7(55.2)a**

Depth (inches)	Nsource		
	Manure 1991	Anhydrous	Mean
	ppm		
		IN ROW	
0-2	102.5 (68.7)	92.1(20.6)	106.4(50.6)
2-4	131.0(104.6)	68.6(25.4)	99.8(79.5)
4-6	85.4 (45.5)	61.1(28.2)	73.2(38.1)
MEAN	*112.2 (75.0)*	*74.3(27.0)*	*93.0(58.8)* b
		BETWEEN ROW	
0-2	249.6(148.8)	120.5(59.4)	185.1(123.4)
2-4	122.3 (46.4)	74.6(18.3)	98.4 (41.9)
4-6	85.5(47.1)	64.7(15.8)	75.9 (35.3)
MEAN	*152.4(114.2)*	*86.6(42.8)*	*119.6 (91.4)*a
OVERALL MEAN	**132.3(97.4)a**	**80.3(39.9)a**	——

P value for main effects and significant interactions:
tillage : 0.3630 (n=24) tillage x row position: 0.0090 (n=12)
nutrient source : 0.0100 (n=36) till x soil depth : 0.0002 (n=08)
row position : 0.0370 (n=36) row position x soil depth : 0.0060 (n=12)
soil depth : 0.0001 (n=24) nutrient source x soil depth: 0.1000 (n=12)
tillage x row position x soil depth = 0.039 (n=4)
nutrient source x row position x soil depth = 0.067 (n=4)

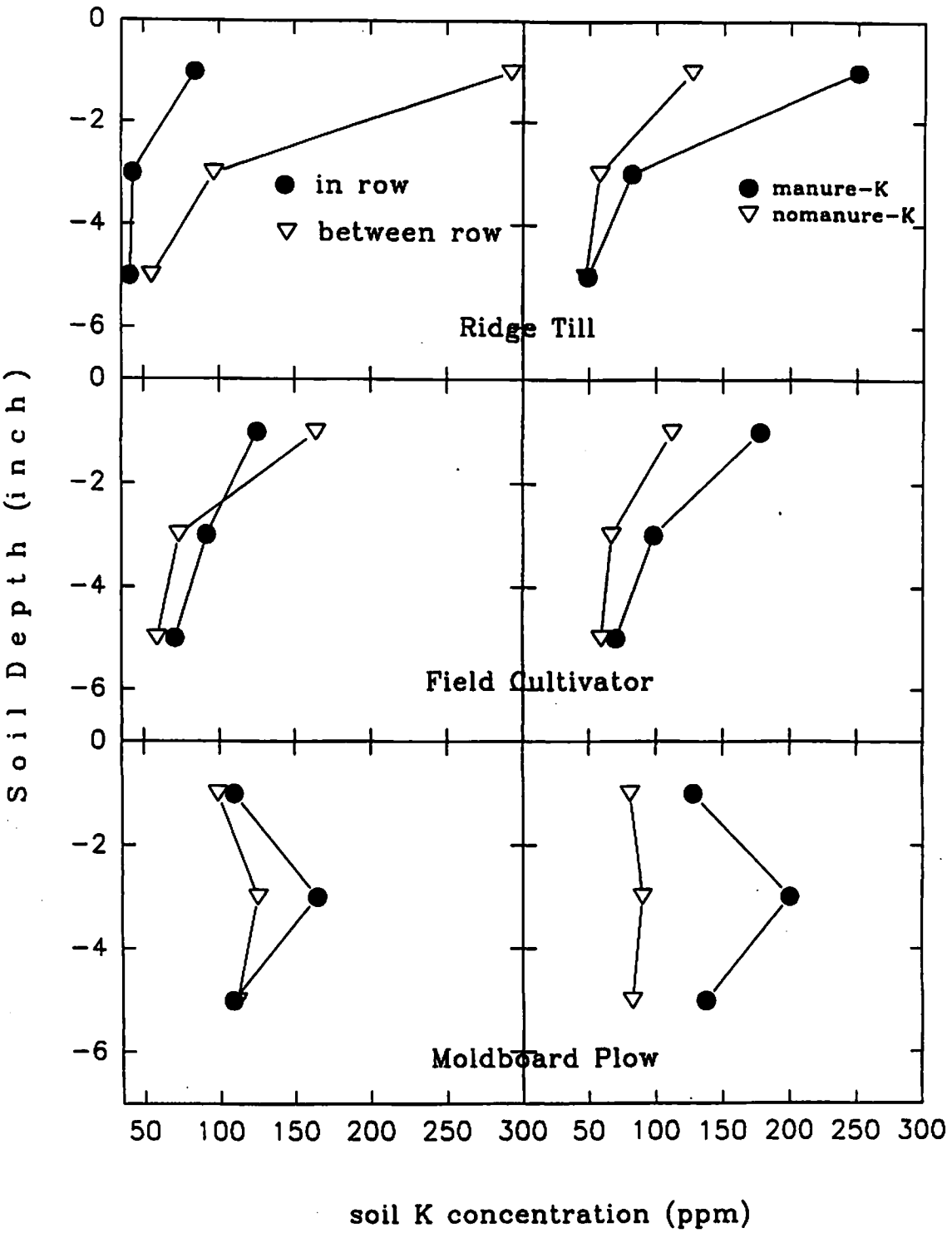

Fig. 2. The effects of (a) tillage methods*row position*soil depth interaction and (b) tillage methods*nutrient source* soil depth interaction on soil K at Stearns Co, MN (June 5, 1991).

Table 6. Effects of tillage, row position, nutrient source, and soil depth on soil pH at Stearns Co. MN (June 6, 1991).

Depth (inches)	Tillage			
	Ridge Till	Field Cultivator	Moldboard	Mean
		In Row		
0-2	6.5(0.2)	6.4(0.1)	6.4(0.2)	6.4(0.2)
2-4	6.5(0.1)	6.4(0.1)	6.4(0.2)	6.4(0.2)
4-6	6.6(0.2)	6.5(0.1)	6.5(0.2)	6.5(0.1)
Mean	*6.5(0.1)*	*6.4(0.1)*	*6.4(0.2)*	6.4(0.1)
		Between Row		
0-2	7.0(0.4)	6.4(0.1)	6.9(0.1)	6.6(0.3)
2-4	6.7(0.1)	6.4(0 .2)	6.5(0.2)	6.5(0.2)
4-6	6.6(0.1)	6.9(0.2)	6.4(0.1)	6.5(0.2)
Mean	*6.8(0.3)*	*6.4(0.2)*	*6.4(0.2)*	6.5(0.3)
Overall Mean	**6.6a(0.2)**	**6.4a(0.1)**	**6.4a(0.2)**	

Depth (inches)	Tillage			
	Ridge Till	Field Cultivator	Moldboard	Mean
		Manure		
0-2	6.9(0.5)	6.4(0.1)	6.5(0.2)	6.6(0.4)
2-4	6.6(0.2)	6.3(0.1)	6.6(0.2)	6.5(0.2)
4-6	6.7(0.3)	6.4(0.1)	6.5(0.1)	6.5(0.1)
Mean	*6.7(0.3)*	*6.4(0.1)*	*6.5(0.2)*	6.5(0.3)
		Anhydrous Ammonia		
0-2	6.6(0.2)	6.5(0.1)	6.4(0.1)	6.5(0.1)
2-4	6.6(0.1)	6.5(0.2)	6.3(0.2)	6.5(0.2)
4-6	6.6(0.1)	6.5(0.1)	6.3(0.2)	6.5(0.2)
Mean	*6.6(0.1)*	*6.5(0.1)*	*6.4(0.1)*	6.5(0.2)

- Numbers in parenthesis are standard deviations
- P>F value for main effect and significant interactions are:
- tillage : 0.301 (n=24)
- nutrient source : 0.309 (n=36)
- soil depth : 0.102 (n=24)
- row position x soil depth: 0.083 (n=12)
- nutrient source x soil depth: 0.089 (n=12)
- tillage x nutrient source x soil depth:0.045(n=6)
- tillage x nutrient source : 0.060 (n=18)
- tillage x row position x soil depth : 0.092(n=04)

Table 7. Effect of tillage and barnyard manure applied in 1991 on corn earleaf N , P and K concentration at Stearns Co. MN (July 26, 1991).

Manure Treatment	Tillage			Mean
	Ridge Till	Field Cultivator	Moldboard Plow	
		N (%)		
Manure	2.9	3.3	3.4	3.2 b
Anhydrous ammonia	3.1	3.4	3.4	3.3 a
mean	3.0 b	3.3 a	3.4 a	
		P (%)		
Manure	0.35	0.36	0.32	0.34 a
Anhydrous ammonia	0.42	0.36	0.35	0.38 a
mean	0.38 a	0.36 a	0.33 a	
		K (%)		
Manure	1.0	1.5	2.0	1.5 a
Anhydrous ammonia	0.6	0.9	1.3	0.9 b
mean	0.8 b	1.2 ab	1.6 a	

The p value of manure , tillage and manure x tillage interactions

1. for N are 0.062 (n=12) , 0.009 (n=8) and 0.855 (n=4) respectively .
2. for P are 0.119 (n=12) , 0.270 (n=8) and 0.262 (n=4) respectively .
3. for K are 0.005 (n=12) , 0.004 (n=8) and 0.927 (n=4) respectively .

Means within the row or column with the same letter are not significantly different.

Table 8. Effect of tillage on corn earleaf N , P and K concentration at Stearns Co. MN (July 26, 1991).

N Source	Tillage			
Anhydrous Ammonia	No-Till	Ridge Till	Field Cultivator	Moldboard Plow
		N (%)		
	3.1bc	3.1c	3.4ab	3.4a
		P (%)		
	0.39a	0.42a	0.35a	0.35a
		K (%)		
	1.0a	0.6a	0.9 a	1.3 a

The p value of tillage

1. for N is 0.100 (n=4)
2. for P is 0.173 (n=4)
3. for K is 0.110 (n=4)

Means within the row with the same letter are not significantly different

Table 9. Effect of tillage and barnyard or barngutter manure applied in 1989 on blooming-soybean trifolia N , P and K concentration at Stearns Co. MN (July 25, 1990).

Manure (1989)	Tillage			Mean
	Ridge Till	Chisel Plow	Moldboard Plow	
		P (%)		
Barnyard	0.54	0.48	0.53	0.51 a
No Barnyard	0.51	0.49	0.50	0.50 a
mean	0.52 a	0.48 b	0.51 a	
		K (%)		
Barnyard	1.8	1.9	2.3	2.0 a
No Barnyard	1.4	1.5	2.3	1.8 b
mean	1.6 b	1.7 b	2.3 a	
		P (%)		
Barngutter	0.53	0.59	0.91	0.66 a
No Barngutter	0.54	0.45	0.77	0.58 a
mean	0.53 b	0.52 b	0.84 a	
		K (%)		
Barngutter	1.7	1.9	2.3	1.9 a
No Barngutter	1.4	1.5	1.6	1.5 b
mean	1.5 a	1.7 a	2.0 a	

The p value of barnyard manure, tillage and barnyard manure x tillage interactions

1. for P are 0.672 (n=6) , 0.084 (n=4) and 0.881 (n=2) respectively .
2. for K are 0.057 (n=6) , 0.052 (n=4) and 0.141 (n=2) respectively .

The p value of barngutter manure, tillage and barngutter manure x tillage interactions

1. for P are 0.703 (n=6) , 0.100 (n=4) and 0.952 (n=2) respectively .
2. for K are 0.029 (n=6) , 0.196 (n=4) and 0.472 (n=2) respectively .

Means within the row or column with the same letter are not significantly different.

Table 10. Effect of tillage and barnyard or barngutter manure applied in 1989 on soybean seed P and K concentration at Stearns Co. MN (October 11, 1990).

Manure (1989)	Tillage			Mean
	Ridge Till	Chisel Plow	Moldboard Plow	
		P (%)		
Barnyard	1.20	1.17	1.05	1.14 a
No Barnyard	1.17	1.16	1.22	1.18 a
mean	1.18 a	1.17 a	1.13 a	
		K (%)		
Barnyard	2.0	2.2	2.2	2.1 a
No Barnyard	2.0	2.1	2.4	2.2 a
mean	2.0 a	2.2 a	2.3 a	
		P (%)		
Barngutter	1.13	1.20	1.26	1.20 a
No Barngutter	1.24	1.08	1.17	1.16 a
mean	1.18 a	1.14 a	1.21 a	
		K (%)		
Barngutter	1.9	2.1	2.1	2.0 a
No Barngutter	1.9	2.0	1.9	1.9 b
mean	1.9 a	2.0 a	2.0 a	

The p value of barnyard manure, tillage and barnyard manure x tillage interactions

1. for P are 0.314 (n=6) , 0.169 (n=4) and 0.201 (n=2) respectively .
2. for K are 0.625 (n=6) , 0.324 (n=4) and 0.436 (n=2) respectively .

The p value of barngutter manure, tillage and barngutter manure x tillage interactions

1. for P are 0.649 (n=6) , 0.437 (n=4) and 0.456 (n=2) respectively .
2. for K are 0.091 (n=6) , 0.571 (n=4) and 0.420 (n=2) respectively .

Means within the row or column with the same letter are not significantly different.

Table 11. The influence of tillage on blooming-soybean trifolia and soybean seed P, K concentration as influenced on tillage of plots not treated with either barnyard or barngutter manure (July 25, 1990).

Material	Tillage			
	No-Till	Ridge Till	Chisel Plow	Moldboard Plow
Soybean Trifolia		P (%)		
	0.49a	0.52a	0.47a	0.63a
		K (%)		
	1.8ab	1.4b	1.5b	2.0a
Soybean Seed		P (%)		
	1.1a	1.2a	1.1a	1.2a
		K (%)		
	2.0a	2.0a	2.1a	2.1a

The p value of tillage for soybean trifolia

1. P is 0.424 (n=4)
2. K is 0.082 (n=4)

The p value of tillage for soybean seed

1. P is 0.318 (n=4)
2. K is 0.455 (n=4)

Means within the row with the same letter are not significantly different.

Table 12. Effect of tillage, soil and residual effect of manure applied in 1989 on corn grain moisture at Stearns Co., Oct. 2, 1991.

Nutrient Source	Tillage			Mean
	Ridge Till	Field Cultivator	Moldboard Plow	
	%			
Barnyard	21.8(1.5)	21.1(1.2)	21.9(1.4)	21.6(1.4)a
Anhydrous ammonia	21.1(1.9)	20.6(2.4)	23.1(5.8)	21.6(3.8)a
Mean	21.4(1.7)a	20.8(1.8)a	22.5(4.0)a	

The p value of manure (n=27-29) : 0.907
tillage (n=16-19) : 0.307
manure x tillage interactions (n=8-11) : 0.551

Nutrient Source	Soil			Mean
	Fair Haven	Esterville	Hawick	
	%			
Barnyard	22.1(1.0)	22.2(1.3)	20.8(1.6)	21.6(1.4)a
Anhydrous ammonia	21.7(1.9)	23.5(6.1)	19.9(1.2)	21.6(3.8)a
Mean	21.9(1.5)a	23.0(4.7)ab	20.4(1.4)b	

The p value of manure (n=27-29) : 0.970
soil (n=15-21) : 0.038
manure x soil interactions (n=6-11) : 0.436

Tillage System	Soil			Mean
	Fair Haven	Estherville	Hawick	
	%			
No Till	21.9(0.7)	20.9(0.8)	21.5(0.0)	21.4(0.9)a
Ridge Till	22.2(1.6)	21.7(1.7)	19.6(1.5)	21.1(1.9)a
Field Cultivator	21.2(2.9)	19.9(3.2)	20.0(1.4)	20.6(2.4)a
Moldboard	21.7(0.7)	28.4(9.2)	20.2(1.0)	23.1(5.8)a
Mean	21.7(1.6)a	22.7(5.2)a	20.1(1.2)a	

The p value of Tillage (n=8-11) : 0.294
soil (n=11-14) : 0.340
tillage x soil interactions (n=1-4) : 0.310

Means within the same row or column with the same letter are not significantly different .

Table 13. Effect of tillage, soil and residual effect of manure applied in 1989 on corn grain yield at Stearns Co.,Oct 2, 1991.

Nutrient Source	Tillage			Mean
	Ridge Till	Field Cultivator	Moldboard Plow	
	---------- bu/a ----------			
Barnyard	107(25)	109(22)	115(17)	111(21)a
Anhydrous ammonia	97(22)	105(9)	114(8)	105(16)a
Mean	101(23)b	107(16)ab	114(14)a	

The p value of manure (n=27-29) : 0.229
tillage (n=16-19) : 0.053
manure x tillage interactions (n=8-11) : 0.443

Nutrient Source	Soil			Mean
	Fair Haven	Estherville	Hawick	
	---------- bu/a ----------			
Barnyard	122(9)	118(8)	94(25)	111(21)a
Anhydrous ammonia	109(18)	105(21)	102(11)	105(17)a
Mean	116(16)a	110(17.6)a	98(19)b	

The p value of manure (n=27-29) : 0.330
soil (n=15-21) : 0.003
manure x soil interactions (n=6-11) : 0.052

Tillage System	Soil			Mean
	Fair Haven	Estherville	Hawick	
	----------bu/a ----------			
No Till	85(20)	71(4)	73(0)	77(15)b
Ridge Till	98(28)	99(31)	94(9)	97(22)a
Field Cultivator	107(12)	109(4)	98(4)	105(9)a
Moldboard	122(9)	110(8)	112(7)	114.3(9)a
Mean	102(21)a	94(23)b	99(14)a	

The p value of Tillage (n=8-11) : 0.024
soil (n=11-14) : 0.066
tillage x soil interactions (n=1-4) : 0.868

Means within the same row or column with the same letter are not significantly different .

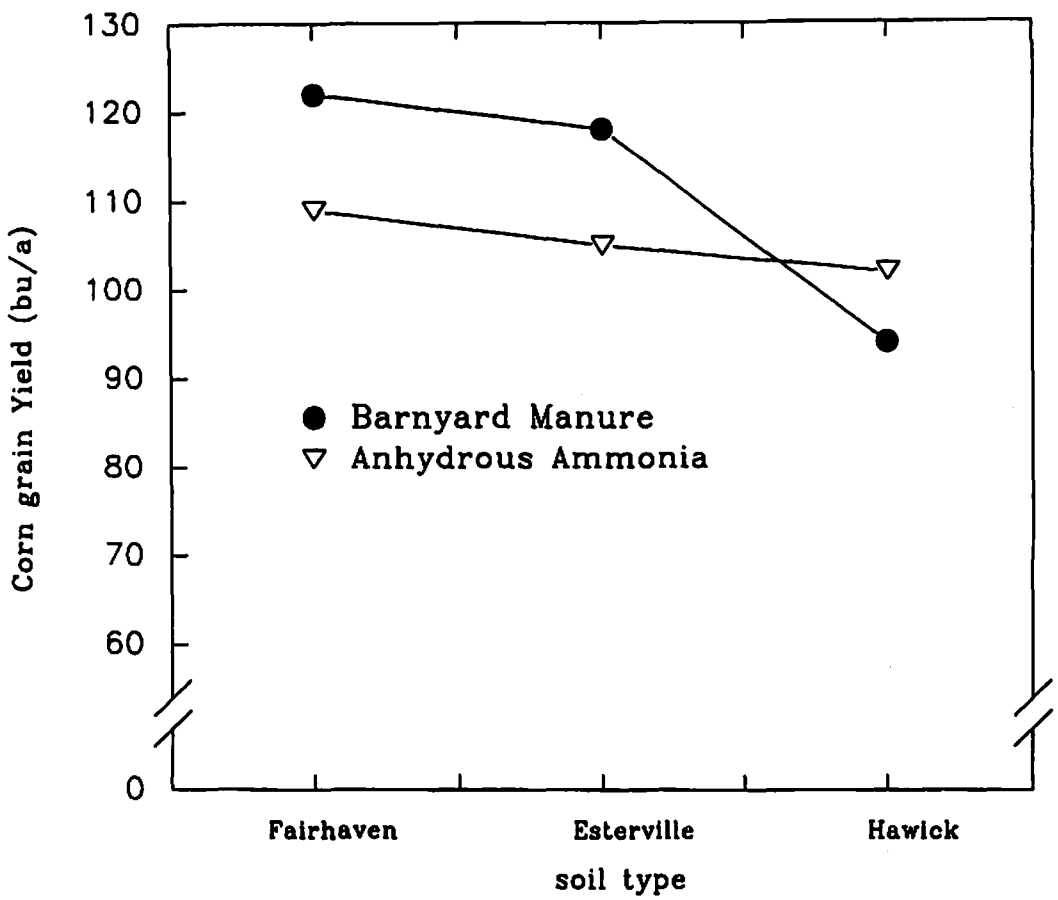

Fig. 3.. Nutrient source and soil type interaction on corn grain yield at Stearns Co., Oct. 2. 1991.

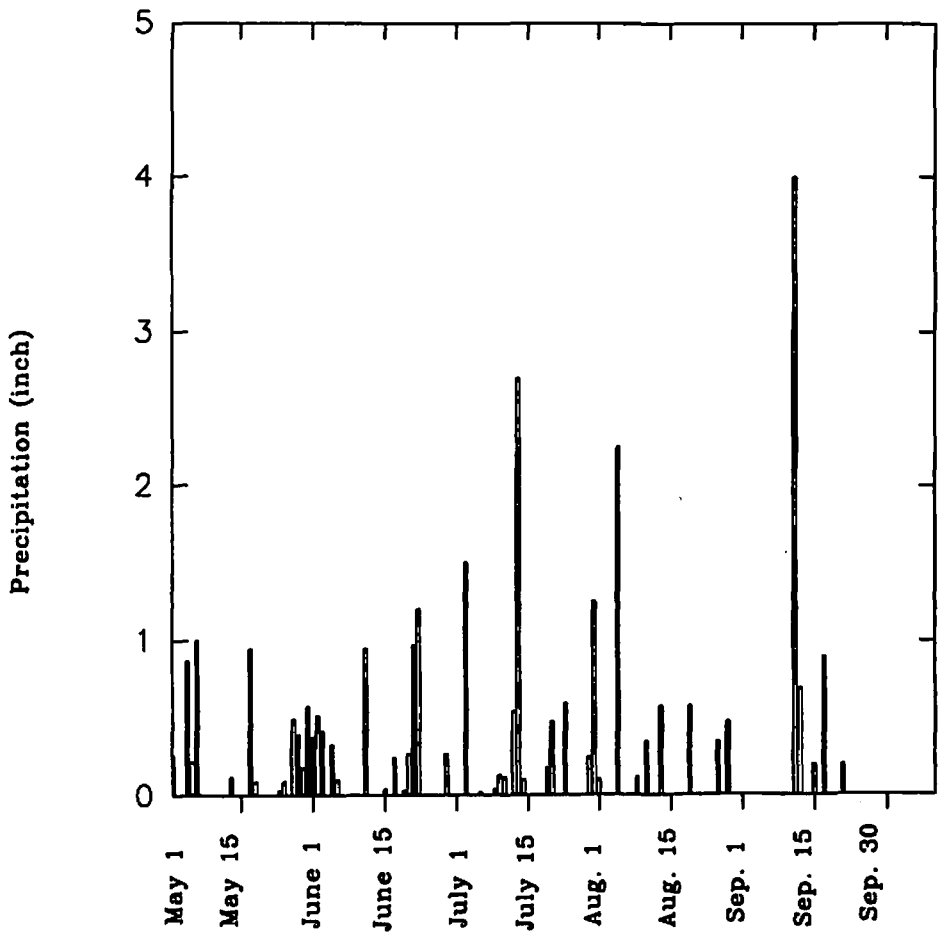

Fig. 4. Daily growing season precipitation at Kimball, Stearns County MN 1991 (Source: Minnesota Clomatological Network).

Table 14. Effect of tillage, soil and residual effect of manure applied in 1989 on corn population at harvest at Stearns Co., Oct 2, 1991.

Nutrient Source	Tillage			Mean
	Ridge Till	Field Cultivator	Moldboard Plow	
	1000 plants/a			
Barnyard	20.6(1.3)	17.5(0.9)	18.4(1.9)	18.8(1.9)a
Anhydrous ammonia	20.3(2.3)	17.7(1.2)	18.4(1.5)	18.9(2.1)a
Mean	20.4(1.9)a	17.6(1.1)b	18.4(1.7)b	

The p value of manure (n=27-29) : 0.684
tillage (n=16-19) : 0.009
manure x tillage interactions (n=8-11) : 0.955

Nutrient Source	Soil			Mean
	Fair Haven	Estherville	Hawick	
	1000 plants/a			
Barnyard	18.6(1.9)	19.2(1.7)	18.7(2.2)	18.8(1.9)a
Anhydrous ammonia	18.0(2.4)	18.8(1.4)	19.9(1.9)	18.9(2.0)a
Mean	18.3(2.1)a	19.0(1.5)a	19.3(2.1)a	

The p value of manure (n=27-29) : 0.857
soil (n=15-21) : 0.370
manure x soil interactions (n=6-11) : 0.382

Tillage System	Soil			Mean
	Fair Haven	Estherville	Hawick	
	1000 plants/a			
No Till	20.1(3.1)	20.1(2.8)	18.5(0.0)	19.9(2.6)a
Ridge Till	19.6(2.3)	19.7(1.6)	21.3(2.1)	20.2(2.3)a
Field Cultivator	17.2(1.6)	18.3(0.3)	18.0(0.8)	17.7(1.2)a
Moldboard	17.4(1.9)	18.0(1.4)	19.5(0.9)	18.4(1.5)a
Mean	18.6(2.7)a	19.2(1.9)a	19.8(1.8)a	

The p value of Tillage (n=8-11) : 0.373
soil (n=11-14) : 0.953
tillage x soil interactions (n=1-4) : 0.616

Means within the same row or column with the same letter are not significantly different .

Table 15. Effect of tillage, soil and residual effect of manure applied in 1989 on number of corn ears at Stearns Co., Oct 2,1991.

Nutrient Source	Tillage			Mean
	Ridge Till	Field Cultivator	Moldboard Plow	
	1000 ears/a			
Barnyard	19.6(0.9)	17.2(1.3)	17.9(1.5)	18.2(1.6)a
Anhydrous ammonia	19.6(2.3)	17.4(1.0)	18.1(1.7)	18.4(2.0)a
Mean	19.6(1.8)a	17.3(1.1)b	18.0(1.6)b	

The p value of manure (n=27-29) : 0.986
tillage (n=16-19) : 0.034
manure x tillage interactions (n=8-11) : 0.881

Nutrient Source	Soil			Mean
	Fair Haven	Estherville	Hawick	
	1000 ears/a			
Barnyard	18.5(1.5)	18.3(1.4)	17.8(1.7)	18.2(1.6)a
Anhydrous ammonia	17.8(2.5)	18.6(1.9)	19.1(1.4)	18.5(2.0)a
Mean	18.2(2.0)a	18.5(1.6)a	19.4(1.7)a	

The p value of manure (n=27-29) : 0.822
soil (n=15-21) : 0.925
manure x soil interactions (n=6-11) : 0.299

Tillage System	Soil			Mean
	Fair Haven	Estherville	Hawick	
	1000 ears/a			
No Till	18.9(3.1)	18.2(2.4)	18.2(0.0)	18.5(2.5)a
Ridge Till	19.5(3.9)	19.4(2.3)	19.8(1.3)	19.6(2.3)a
Field Cultivator	17.1(1.2)	18.0(0.8)	17.4(0.5)	17.4(1.0)a
Moldboard	16.9(1.9)	18.0(1.7)	19.1(1.3)	18.2(1.7)a
Mean	18.1(2.6)a	18.5(2.0)a	18.9(1.4)a	

The p value of Tillage (n=8-11) : 0.674
soil (n=11-14) : 0.899
tillage x soil interactions (n=1-4) : 0.606

Means within the same row or column with the same letter are not significantly different .

Table 16. Effect of tillage, soil and residual effect of manure applied in 1989 on broken corn stalks at Stearns Co., Oct 2,1991.

Nutrient Source	Tillage			Mean
	Ridge Till	Field Cultivator	Moldboard Plow	
	1000 stems/a			
Barnyard	9.6(5.1)	8.3(4.0)	10.6(4.6)	9.6(4.5)b
Anhydrous ammonia	15.1(6.3)	12.3(4.6)	8.8(4.7)	12.2(6.0)a
Mean	12.8(6.6)a	10.3(4.7)ab	9.7(4.6)a	

The p value of manure (n=27-29) : 0.072
tillage (n=16-19) : 0.044
manure x tillage interactions (n=8-11) : 0.343

Nutrient Source	Soil			Mean
	Fair Haven	Estherville	Hawick	
	1000 stems/a			
Barnyard	8.8(3.5)	10.8(6.5)	9.7(4.5)	9.6(4.5)b
Anhydrous ammonia	10.2(6.2)	11.2(6.2)	15.1(4.9)	12.2(6.0)a
Mean	9.5(4.9)a	11.0(6.1)a	12.4(5.3)a	

The p value of manure (n=27-29) : 0.063
soil (n=15-21) : 0.284
manure x soil interactions (n=6-11) : 0.458

Tillage System	Soil			Mean
	Fair Haven	Estherville	Hawick	
	1000 stems/a			
No Till	16.2(4.2)	14.7(7.4)	17.1(0.0)	15.6(5.3)a
Ridge Till	14.5(8.2)	12.4(7.5)	18.4(4.6)	15.2(6.6)a
Field Cultivator	10.6(5.0)	12.5(6.4)	15.2(1.5)	12.3(4.6)a
Moldboard	5.3(1.1)	8.7(5.9)	11.6(4.3)	8.8(4.7)a
Mean	11.9(6.2)a	12.3(6.5)a	15.2(4.7)a	

The p value of Tillage (n=8-11) : 0.131
soil (n=11-14) : 0.594
tillage x soil interactions (n=1-4) : 0.825

Means within the same row or column with the same letter are not significantly different .

Table 17. Effect of tillage, soil and residual effect of manure applied in 1989 on corn grain N concentration at Stearns County (Eckman Farm), Oct 2,1991.

Nutrient Source	Tillage			Mean
	Ridge Till	Field Cultivator	Moldboard Plow	
	%			
Barnyard	1.25(0.12)	1.37(0.14)	1.35(0.12)	1.33(0.14)b
Anhydrous ammonia	1.38(0.07)	1.40(0.050	1.39(0.08)	1.39(0.07)a
Mean	1.33(0.12)b	1.38(0.11)a	1.37(0.11)a	

The p value of manure (n=27-29) : 0.020
tillage (n=16-19) : 0.034
manure x tillage interactions (n=8-11) : 0.412

Nutrient Source	Soil			Mean
	Fair Haven	Estherville	Hawick	
	%			
Barnyard	1.38(0.01)	1.37(0.11)	1.23(0.16)	1.32(0.14)a
Anhydrous ammonia	1.43(0.05)	1.41(0.06)	1.33(0.05)	1.39(0.07)a
Mean	1.41(0.07)a	1.39(0.08)a	1.28(0.13)b	

The p value of manure (n=27-29) : 0.195
soil (n=15-21) : 0.001
manure x soil interactions (n=6-11) : 0.458

Tillage System	Soil			Mean
	Fair Haven	Estherville	Hawick	
	%			
No Till	1.34(0.15)	1.43(0.01)	1.40(0.00)	1.38(0.10)a
Ridge Till	1.38(0.05)	1.43(0.07)	1.33(0.05)	1.38(0.07)a
Field Cultivator	1.44(0.01)	1.37(0.01)	1.34(0.02)	1.40(0.05)a
Moldboard	1.48(0.01)	1.40(0.03)	1.32(0.06)	1.39(0.08)a
Mean	1.41(0.09)a	1.42(0.04)a	1.34(0.05)a	

The p value of Tillage (n=8-11) : 0.802
soil (n=11-14) : 0.651
tillage x soil interactions (n=1-4) : 0.080

Means within the same row or column with the same letter are not significantly different .

Table 18. Effect of tillage, soil and residual effect of manure applied in 1989 on corn grain protein concentration at Stearns County (Eckman Farm), Oct 2,1991.

Nutrient Source	Tillage			Mean
	Ridge Till	Field Cultivator	Moldboard Plow	
	%			
Barnyard	7.74(0.75)	8.46(0.88)	8.40(0.81)	8.22(0.89)b
Anhydrous ammonia	8.58(0.45)	8.70(0.31)	8.65(0.49)	8.63(0.43)a
Mean	8.23(0.71)b	8.58(0.65)a	8.52(0.67)a	

The p value of manure (n=27-29) : 0.020
tillage (n=16-19) : 0.034
manure x tillage interactions (n=8-11) : 0.412

Nutrient Source	Soil			Mean
	Fair Haven	Estherville	Hawick	
	%			
Barnyard	8.57(0.47)	8.51(0.70)	7.67(1.0))	8.22(0.85)a
Anhydrous ammonia	8.92(0.32)	8.75(0.35)	8.26(0.30)	8.64(0.42)a
Mean	8.74(0.42)a	8.66(0.51)a	7.97(0.78)b	

The p value of manure (n=27-29) : 0.195
soil (n=15-21) : 0.001
manure x soil interactions (n=6-11) : 0.458

Tillage System	Soil			Mean
	Fair Haven	Estherville	Hawick	
	%			
No Till	8.34(0.94)	8.87(0.10)	8.68(0.00)	8.61(0.63)a
Ridge Till	8.56(0.34)	8.90(0.48)	8.27(0.35)	8.58(0.45)a
Field Cultivator	8.97(0.09)	8.52(0.04)	8.34(0.14)	8.70(0.31)a
Moldboard	9.19(0.08)	8.69(0.18)	8.20(0.36)	8.70(0.31)a
Mean	8.75(0.59)a	8.78(0.29)b	8.29(0.31)b	

The p value of Tillage (n=8-11) : 0.802
soil (n=11-14) : 0.651
tillage x soil interactions (n=1-4) : 0.080

Means within the same row or column with the same letter are not significantly different .