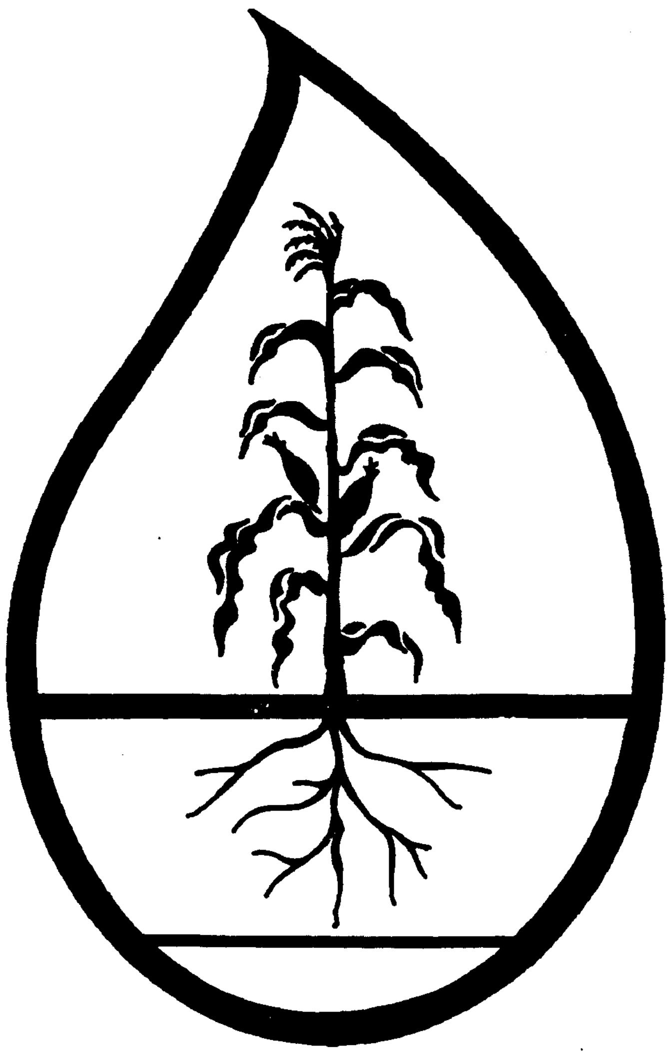
Soil Science Research Report - 1992

SOIL SCIENCE

RESEARCH REPORT 1992

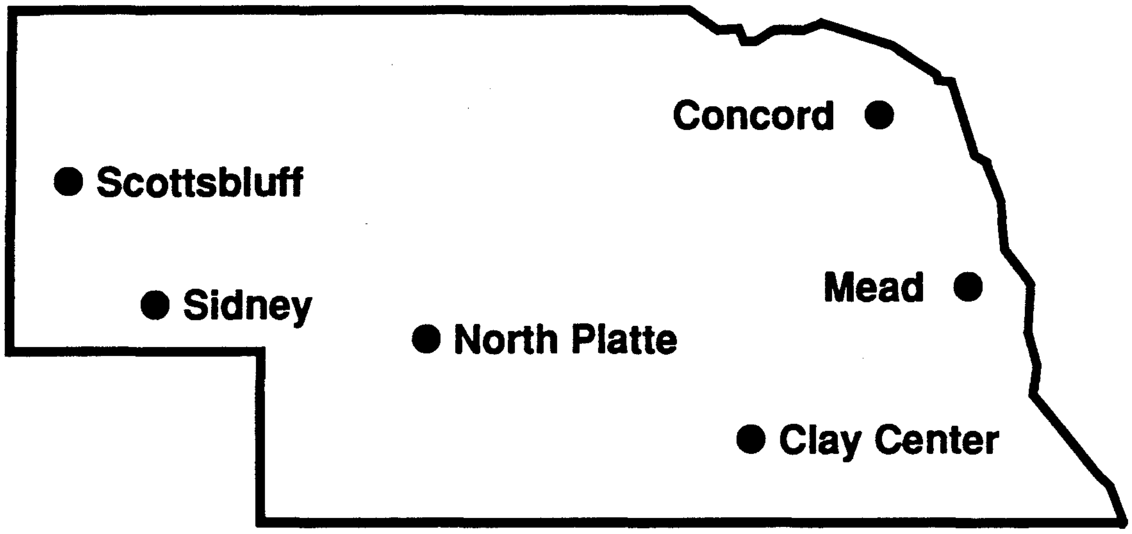


DEPARTMENT OF AGRONOMY

Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln
Lincoln, Nebraska

Table of Contents

Climate Weather Data Collection Points



Panhandle Research & Extension Center - Scottsbluff
High Plains Agricultural Lab - Sidney
West Central Research & Extension Center - North Platte
Northeast Research & Extension Center - Concord
Agricultural Research & Development Center - Mead
South Central Research & Extension Center - Clay Center

West Central Research and Extension Center
North Platte, NE Weather Data, 1992

		Precipitation		Avg Air Temp.		GGD	
Month	Period	1992	Normal[1]	1992	Normal[1]	1992	Normal
January	1-31	0.74	0.41	29.7	21.3	-	-
February	1-28	1.35	0.55	36.5	27.3	-	-
March	1-31	3.21	1.12	41.2	34.7	-	-
April	1-30	0.08	1.85	48.5	47.6	-	-
May	1-10	0.05		62.8		123	
	11-20	0.92		62.1		121	
	21-31	0.98		51.6		49	
	Total	1.85	3.36	58.5	58.2	293	354
June	1-10	0.57		59.5		95	
	11-20	1.54		66.4		165	
	20-30	1.50		67.2		172	
	Total	3.61	3.72	64.4	68.3	432	576
July	1-10	0.23		68.5		177	
	11-20	1.72		68.9		187	
	21-31	2.44		66.9		170	
	Total	4.39	2.98	68.0	74.2	534	751
August	1-10	1.78		71.6		205	
	11-20	0.77		65.5		155	
	21-31	3.58		62.4		136	
	Total	6.13	1.92	66.4	72.4	496	668
September	1-30	0.02	1.67	62.4	61.9	368	444
October	1-31	1.16	0.91	51.0	50.2	104	
November	1-30	0.35	0.56	31.4	35.0		
December	1-31	0.24	0.43	21.7	25.9		
Year		23.13	19.47	48.3	48.1		
Growing Season May/Sept		16.00	13.65	63.9	67.0	2227[2]	2793

[1]30 year average 1951 to 1980: NOAA - LBF North Platte, NE.
[2]50° to 86°F base May 1 to first fall frost 10/14

NOTES:
a) Highest temperature on Aug 10 -- 97°
b) Highest 24-hour precipitation on June 14 -- 1.51"
c) Highest 2-day precipitation on August 25-26 -- 3.46"
d) Last spring frost -- May 26 = 31°
e) First fall frost -- Oct 14

Weather Data - 1992

Northeast Research and Extension Center
Concord, NE 68728 Weather Data - 1992

Month	Period	Precipitation 1992[1] (inches)	Precipitation Normal (inches)	Avg. Air Temp 1992[2] (°F)	Avg. Air Temp Normal (°F)	Growing Degree Days* 1992	Growing Degree Days* Normal
January	1-31	0.68	0.48	29.5	18.2		0
February	1-29	1.00	0.52	33.5	21.5		0
March	1-31	3.37	1.99	39.2	34.6	14.5	
April	1-30	1.97	2.67	43.9	48.2	54.5	24
May	1-10	0.0		62.5		127.5	
	11-20	2.64		69.0		98.5	
	21-31	0.16		55.8		76.0	
	Total	2.80	3.90	59.6	59.5	302.0	293
June	1-10	1.29		63.9		138.5	
	11-20	2.44		70.0		199.5	
	20-30	3.29		65.0		150.0	
	Total	7.02	3.79	66.3	69.5	488.0	604
July	1-10	0.98		68.4		184.0	
	11-20	2.56		67.4		174.0	
	21-31	3.50		65.4		179.0	
	Total	7.04	2.18	67.0	74.3	537.0	754
August	1-10	2.35		68.5		185.0	
	10-20	0.34		64.1		141.0	
	21-31	2.20		63.8		152.0	
	Total	4.89	2.55	65.4	71.2	478.0	623
September	1-30	4.35	2.29	60.2	62.1	312.5	363
October	1-31	4.08	1.79	49.8	48.9	141.5	14
November	1-30	1.79	1.49	31.4	34.6	0	0
December	1-31	0.79	0.71	22.9	20.9	0	0
Year	Jan-Dec	39.78	24.36	47.1		2328	2675
Growing Season	May-Sept	26.10	14.71	63.7		2118	2637

* 50 Base from Average of Hi & Low Temps
[1] Highest 24-hr precip June 29, 2.90 inches
[2] Highest temperature May 1, 93°F
Last Spring Frost, May 26
First Fall Frost, Sept. 18 - 31.7°F
1992 data from Automated Weather Station
19 yr average (normals) from NOAA data

High Plains Agricultural Laboratory
Sidney, NE, Weather Data 1992

Month	Period	Precipitation 1992	Precipitation Normal	Avg Air Temp 1992	Avg Air Temp Normal	GDD (50°F) 1992	GDD (50°F) Normal
		---inches---		----°F---			
January	1-31	0.16	0.41	30.5	25.4	26.4	0
February	1-29	0.51	0.37	38.1	30.4	65.1	0
March	1-31	2.21	1.12	40.8	35.6	117.4	13.2
April	1-30	0.76	1.79	49.4	46.0	235.8	163.4
May	1-10	0.08	1.00	60.7	52.8	140.8	86.3
	11-20	0.08	1.00	61.9	56.1	156.3	102.4
	21-31	1.22	1.17	49.6	59.6	68.4	133.2
	Total	1.38	3.17	57.2	56.3	365.4	322.0
June	1-10	0.63	1.10	58.6	63.4	110.6	142.1
	11-20	1.06	1.06	64.7	66.7	148.3	167.4
	21-30	2.52	1.00	68.6	69.4	183.2	193.8
	Total	4.21	3.16	64.0	66.5	442.1	503.3
July	1-10	0.44	0.90	67.0	72.1	169.3	212.5
	11-20	0.83	0.90	66.9	73.8	166.8	219.9
	21-31	1.50	0.89	69.1	73.7	205.0	241.0
	Total	2.77	2.69	67.7	73.2	541.1	673.3
August	1-10	0.20	0.60	72.0	73.0	205.6	215.6
	11-20	0.24	0.60	66.6	71.7	162.7	209.0
	21-31	2.16	0.59	62.1	68.9	143.1	207.4
	Total	2.60	1.79	66.8	71.1	511.4	632.0
September	1-30	0.67	1.23	63.0	61.5	454.8	422.3
October	1-31	0.62	0.94	49.6	49.9	247.2	256.9
November	1-30	0.00	0.50	32.0	36.0	30.5	27.1
December	1-31	0.04	0.42	22.9	28.6	9.5	0
Year	Jan-Dec	15.93	17.59	48.5	48.5	3046.8	3013.4
Season	May-Sept	12.39	13.83	61.4	62.5	2550.6	2716.2

NOTES:

1. Highest temperature on August 7 -- 95.9°F
2. Highest 24 hour precipitation on June 26 -- 1.26"
3. Last spring frost, May 29 -- 32.0°F
4. First fall frost, September 28 -- 31.4°F
5. 1992 data and normals from Automated Weather Station

Panhandle Research and Extension Center
Scottsbluff, NE, Weather Data 1992

		Precipitation		Avg Air Temp		GDD (50°F)	
		1992	Normal	1992	Normal		
Month	Period	---inches---		----°F----		1992	Normal
January	1-31	0.48	0.43	31.6	24.4	31.8	0
February	1-29	0.48	0.36	37.6	30.1	76.5	0
March	1-31	1.33	0.97	41.1	36.0	131.6	10.3
April	1-30	0.20	1.43	50.3	46.4	260.2	153.9
May	1-10	0.31	0.80	62.0	53.6	149.7	86.0
	11-20	0.00	0.87	64.1	57.1	162.1	103.0
	21-31	1.30	0.99	53.4	60.6	84.0	133.8
	Total	1.61	2.66	59.6	57.2	395.9	322.8
June	1-10	0.24	1.00	61.0	64.4	129.0	145.2
	11-20	0.48	1.00	67.2	67.7	174.0	177.1
	21-30	1.53	0.93	70.4	70.3	197.4	203.4
	Total	2.25	2.93	66.2	67.5	500.5	525.7
July	1-10	1.46	0.70	68.0	73.1	172.9	221.5
	11-20	1.06	0.60	66.9	74.7	166.3	228.3
	21-31	0.28	0.66	69.3	74.5	202.4	249.5
	Total	2.80	1.96	68.1	74.1	541.6	699.3
August	1-10	0.08	0.34	71.2	73.5	195.8	222.6
	11-20	0.12	0.30	67.5	72.1	168.0	215.4
	21-31	1.15	0.33	60.6	69.2	136.5	210.9
	Total	1.35	0.97	66.2	71.5	500.2	648.9
September	1-30	0.16	1.08	61.8	61.6	452.5	414.0
October	1-31	0.99	0.75	49.4	50.1	264.5	246.5
November	1-30	0.12	0.52	31.2	36.0	30.6	24.1
December	1-31	0.16	0.51	19.3	27.8	0.1	0
Year	Jan-Dec	11.93	14.57	48.6	48.6	3186.0	3045.4
Season	May-Sept	8.37	11.03	62.1	63.1	2650.9	2764.6

NOTES:

1. Highest temperature on July 6 -- 97.3°F
2. Highest 24 hour precipitation on May 21 -- 1.10"
3. Last spring frost, April 26 -- 23.7°F
4. First fall frost, September 28 -- 31.3°F
5. 1992 data and normals from Automated Weather Station

South Central Research and Extension Center
Clay Center 1992 Weather Data

		Precipitation		Avg. Air Temp		GDD	
Month	Period	1992	Normal	1992	Normal	1992	Normal
Jan	1-31	0.79	0.65	34.07	22.85	32.33	0.00
Feb	1-28	0.61	0.89	37.52	29.32	67.14	0.00
Mar	1-31	2.46	1.76	42.64	37.83	114.42	21.74
Apr	1-30	0.59	2.71	50.29	51.60	236.35	216.98
May	1-10	0.47	1.22	62.17	58.86	153.39	107.73
	11-20	0.51	1.30	65.37	62.24	160.25	125.51
	21-31	1.11	1.43	55.36	65.70	102.85	172.74
	Total	2.09	3.95	60.79	62.38	416.49	405.98
June	1-10	3.70	1.40	62.84	69.42	131.01	194.22
	11-20	0.40	1.40	68.59	72.47	182.58	224.62
	21-30	0.20	1.33	70.25	74.55	198.59	239.37
	Total	4.30	4.13	67.23	72.15	512.18	658.21
July	1-10	0.99	1.10	70.71	76.40	205.29	248.08
	11-20	2.29	1.07	71.40	77.55	213.97	253.59
	21-31	4.83	1.10	69.15	77.38	207.68	278.04
	Total	8.11	3.27	70.38	77.12	626.94	779.71
August	1-10	2.87	1.10	72.81	76.84	221.45	250.49
	11-20	0.95	1.10	66.96	75.68	169.92	244.66
	21-31	0.91	1.21	66.50	72.97	169.04	250.70
	Total	4.73	3.41	68.68	75.09	560.90	745.85
September	1-30	0.55	3.03	64.22	65.85	497.60	480.87
October	1-31	2.81	1.67	51.95	54.75	263.04	280.81
November	1-30	NA	0.92	33.83	39.45	22.18	37.08
December	1-31	NA	0.66	24.77	28.66	0.00	0.00
Growing Season	May-Sept	19.78	17.79	66.27	70.52	*2614.11	3070.62

* 50 to 86 F base, May 1 until first frost (defined as 32 F or less)
1) Highest temperature on April 30, -- 92.61
2) Highest 24-hour precipitation on July 24 -- 3.11
3) Last spring frost -- May 6
4) First fall frost -- October 9

University of Nebraska Agricultural Research Center
Mead, Nebraska 1992 Weather Data

Month	Period	Total Precipitation, in Actual	Total Precipitation, in Normal[1]	Average Temperature °F 1992	Average Temperature °F Normal[1]	Total GDD[2] 1992	Total GDD[2] Normal[1]
Jan	1-31	1.05	0.75	33	20	28	0
Feb	1-28	1.15	0.95	37	27	54	0
Mar	1-31	3.21	2.00	43	36	118	11
Apr	1-30	1.12	2.82	50	51	211	200
May	1-10	.04		63		165	
	11-20	.51		64		162	
	21-31	1.34		57		116	
	Total	1.89	4.06	50	62	443	401
June	1-10	0.36		65		150	
	11-20	1.32		71		201	
	21-30	0.12		70		199	
	Total	1.80	4.25	69	72	550	656
July	1-10	2.28		73		223	
	11-20	3.46		71		211	
	21-31	1.54		69		205	
	Total	7.28	3.22	71	77	639	793
Aug	1-10	0.79		72		207	
	11-20	0.20		66		167	
	21-31	0.71		66		185	
	Total	1.70	4.02	68	74	559	747
Sept	1-10	0.99		65		167	
	11-20	0.91		68		193	
	21-30	0.28		58		126	
	Total	2.18	3.16	64	65	486	462
Oct	1-31	2.20	1.98	52	54	271	258
Nov	1-30	1.70	1.07	34	39	15	26
Dec	1-31	0.48	0.75	26	27	0	0
Year(Jan-Dec)		25.76	29.03	51	50	3373	3554
May-Sept		14.85	18.71	69	70	2675	3059

[1] 30 years normal
[2] GDD, 50° F base

Last Spring Frost May 6th (28° F)
First Fall Frost Sept 29th (30° F)

Influence of Anhydrous Ammonia Band Spacing on Irrigated Corn Grain Yield and Band Persistence.

M.V. Marake, D.H. Sander and D.T. Walters

Objectives:

1 To determine the effect of rate and spacing of anhydrous ammonia (AA) bands on irrigated corn yield.

2 To evaluate the persistence of the AA band as affected by concentration of applied N.

3 To compare AA and NH_4NO_3 with respect to residual NO_3-N and NH_4-N distribution and movement in the profile.

Materials and Methods:

Experiments were conducted at three locations in Nebraska in 1992. One was located at the Agricultural Research and development Center at Mead, Nebraska on a Sharpsburg silty clay loam. The other two were on farm sites located in Boone and York counties, Nebraska. The Boone site was located on a Hord silt loam soil. We lost the experiment at York due to a severe root worm infestation. The treatments were replicated four times in a randomized complete block design.

The treatments were as follows:

1 4 N rates (50, 100, 150 and 200 lbs N $acre^{-1}$) of anhydrous ammonia (AA) and NH_4NO_3 (AN) N sources.

2 Knife spacing (KS): 3 intervals (15, 30, and 60 inches).

Nitrogen was applied either as AN (broadcast) or AA at 15 inches (6 knives), 30 inch (3 knives) and 60 inch (2 knives) intervals. Cultural operations on farm sites were performed by the cooperating farmers except for N treatments which were applied prior to emergence with an N applicator calibrated at each knife outlet. Equivalent N concentrations were determined on the basis of knife spacing output at a given rate (table 1).

A gradient of five N concentration levels (0, 17, 33, 67, 133) was selected and sampled across N rates and knife spacing intervals in two replications. Soil samples were taken down to 15 inches depth at 3 inches intervals and alternate depth in the sampling grid (Fig. 1). Samples were taken with a 0.75 inch diameter hand probe guided by a steel template with 13 sampling slots one inch apart.

The AA bands were sampled four times during the growing season at 12, 19, 27 and 43 days intervals after N application and analyzed for NH_4-N and NO_3-N concentrations. Two rows were combine harvested for grain yield and a 10 ft row length harvested for stover yield.

Results and Discussion

Grain Yield

Table 2 shows the analysis of variance for grain yield at York and Saunders county locations in 1992. Grain yield averaged 135 bushels with a range of 55 to 219 bushels per acre in Saunders county and averaged 155 bushels ranging from 112 to 197 bushels per acre in Boone county.

Grain yield response to N rate was neither influenced by KS nor Rate*KS (Table 2). However, there was an apparent tendency for the 15 inch spacing to produce higher corn yield compared to both the 30 and 60 inch spacing at Boone county (Table 3). This observation follows previous trends where the narrow spacing intervals were slightly superior to the 60 inch spacing. Nevertheless, the data does not show a conclusive effect of knife spacing overall.

Grain yield response to the main effect of N rate showed a quadratic trend (Fig. 2) with maximum grain yield response reached between 150 and 200 lbs acre^{-1}. N source influenced grain yield at Mead with AA treatment yielding 18 bushels more per acre compared to NH_4NO_3 N source. However, there were no significant source differences at Boone county.

Soil NH_4-N and NO_3-N

Preliminary results for the 1992 growing season at the Saunders county location will be presented here. The persistence of the AA band was apparently influenced by N rate, time and knife spacing (Fig. 3). The hypothesis in this study was that increasing the knife spacing from 15 to 60 inches would result in much higher concentration in the bands at a given N rate. If such a hypothesis holds, then the center of the AA band would depress microbial activity due to high pH creating a sterile zone. Thus the center of the AA band should maintain a high concentration of NH_4-N (Non mobile N form) and preclude leaching losses. The data shows that the AA band persisted longer in the 60 inch band spacing compared to the narrow spacing intervals particularly at the highest N rate (Fig. 4) with the NH_4-N band staying intact up to 43 days after N application. Since the degradation of the NH_4-N band and the subsequent accumulation of NO_3-N were noticeably retarded initially, although rapid once it began after 27 days, low initial numbers of nitrifiers may have been limiting nitrification in the initial stages.

Mineralization of ammonia on the band was more rapid between 27 and 43 days after N application. The NO_3-N accumulation, however, does not seem to be in direct proportions to the rate of nitrification or disappearance of the NH_4-N band. The rapid nitrification of the AA band beyond 27 days did not produce a proportionally high NO_3-N even though the NH_4-N supply was noticeably exhausted in all knife spacing intervals at 43 days after N application. This effect may be a consequence of rapid loss of mineral N by immobilization or denitrification at increasing temperatures in the early summer, plant uptake or leaching losses out of the 15 inch sampled profile. However, there was a rapid increase of NO_3-N production with time up to a maximum of approximately 100 ppm (mg N kg^{-1} of soil) compared to the control treatment (Fig. 5).

Since the persistence of the AA band and subsequent accumulation of NO_3-N is also affected by plant uptake and/or N movement out of the root zone, total N uptake measurements and deep N samples taken in the fall will help us to determine the extend of crop N uptake and leaching regimes respectively. Nevertheless, the spring N data presented here seem to support our experimental hypothesis at least within the first 35 days of N application. The lack of significa nt grain yield response to N rate by knife spacing interaction indicates that knife spacing did not affect the availability of N across all rates. If knife spacing does not affect grain yield but enhance the persistence of the bands, then it could be a potential tool for N management. This result may have greater implications for N management in terms of both agronomic efficiency and environmental sensitivity.

Table 1. Equivalent N concentrations as a function of knife spacing and N rate.

	Knife spacing (inches)		
Rate (kg ha^{-1})	15	30	60
0	0	0	0
50	8	17	33
100	17	33	67
150	25	50	100
200	33	67	133

*0 N treatments were knifed without N application

Table 2. Analysis of variance for grain yield at Boone and Saunders Counties. 1992.

Source	Df	Boone Co.		Saunders Co.	
		Pr > F			
Rate	4	.01		.01	
Lin	1		.01		.01
Quad	1		.08		.03
KS	2	.79		.57	
15v30	1		.58		.37
30v60	1		.94		.95
Rate*KS	6	.41		.25	
Source	1	.30		.01	
Source*Rate	3	.39		.41	

*KS = Knife spacing

Table 3. Grain yield means at Boone and Saunders county as *influenced by N rate (lbs a^{-1})*, knife spacing and N source.

	Boone Co.					Saunders Co.				
	----------KS----------			---Source---		----------KS---------			---Source---	
Rate	15	30	60	AA	AN	15	30	60	AA	AN
50	147	123	123	123	163	95	130	112	130	95
100	146	158	151	158	144	109	125	139	125	122
150	169	174	153	174	187	146	153	153	153	141
200	172	161	162	161	168	161	147	149	147	126
Mean	159	154	147	154	166	128	139	138	139	121

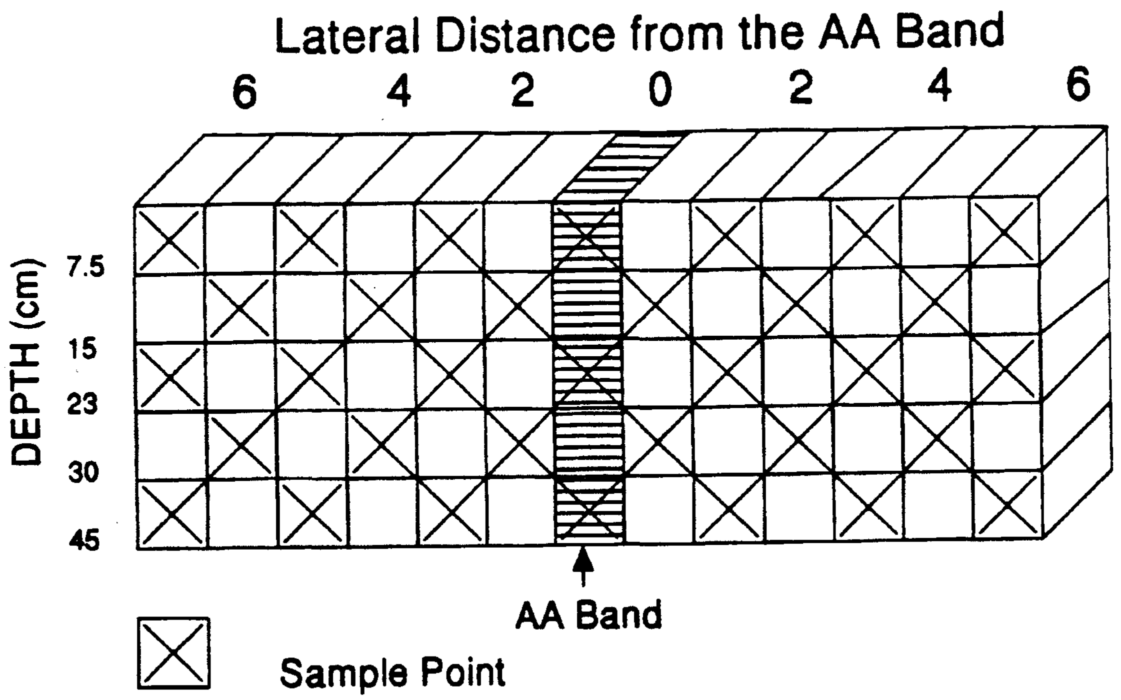


Fig. 1. Band sampling template

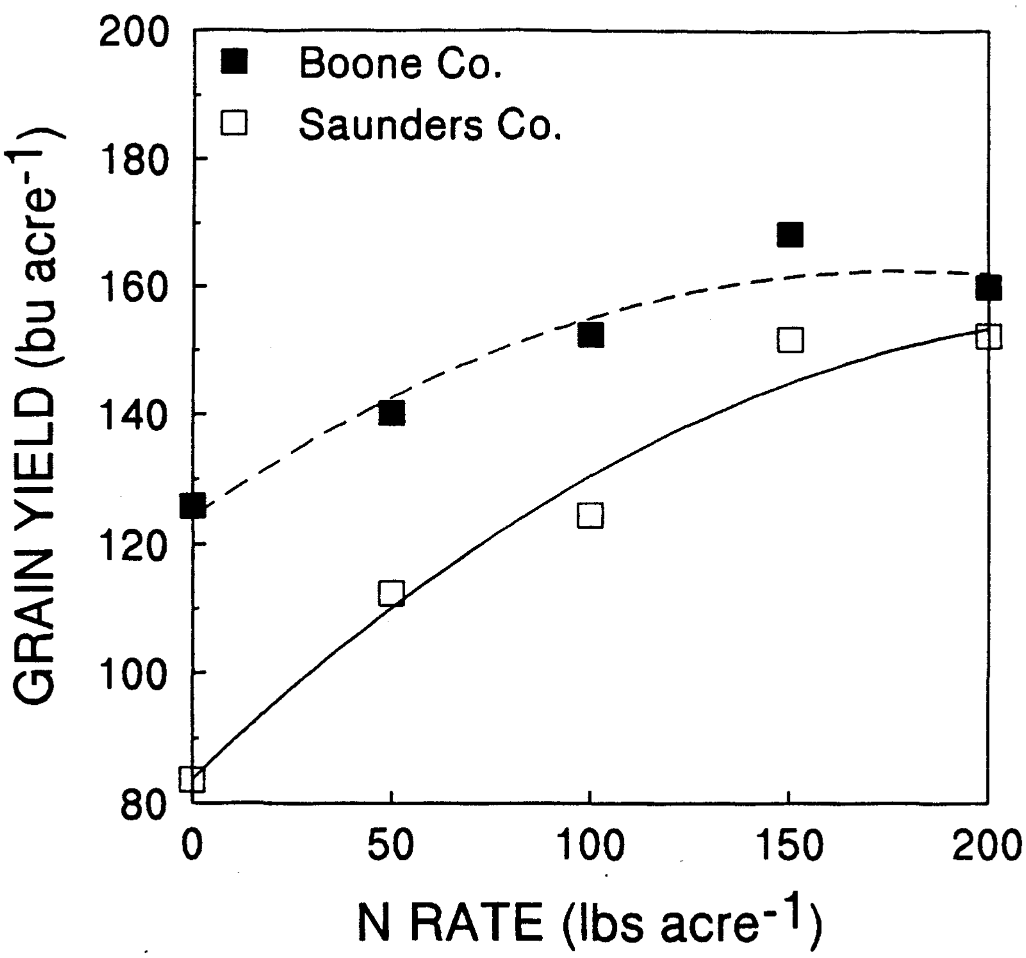


Fig. 2. Grain yield response as a function of N rate at Boone and Saunders county, Nebraska. 1992.

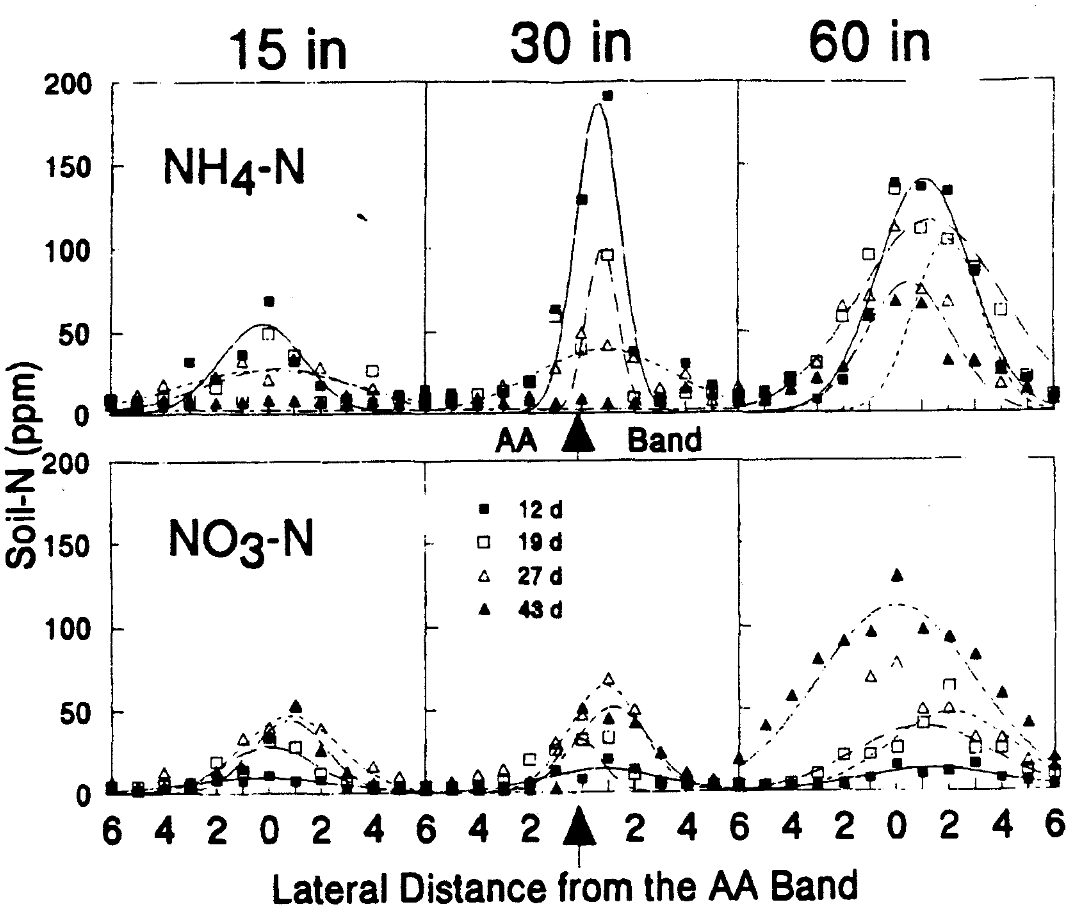


Fig. 3. Soil-N concentration as influenced by 100 lbs a^{-1} N rate and knife spacing at 12, 19, 27, and 43 days intervals from the time of N application in a Sharpsburg silty clay loam. Spring 1992.

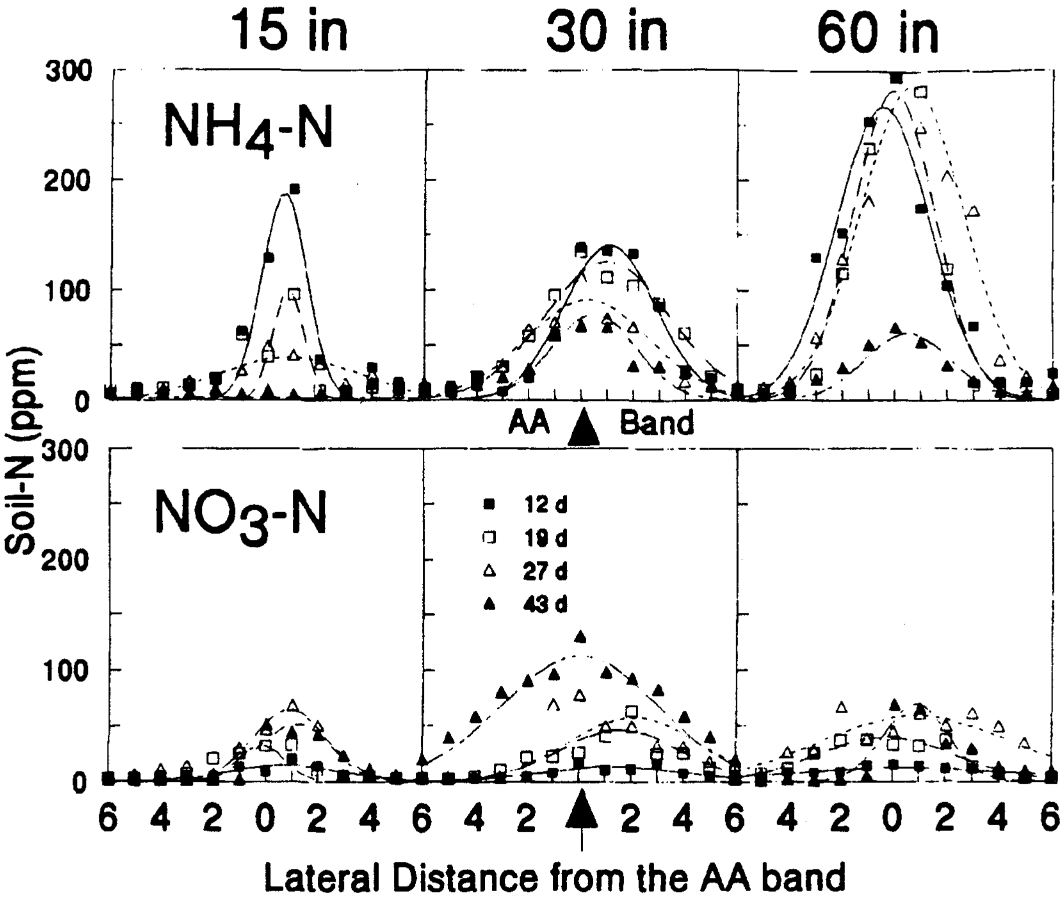


Fig. 4. Soil-N concentration as influenced by 200 lbs a^{-1} N rate and knife spacing at 12, 19, 27 and 43 days interval from the time of N application in a Sharpburg silty clay loam. Spring 1992.

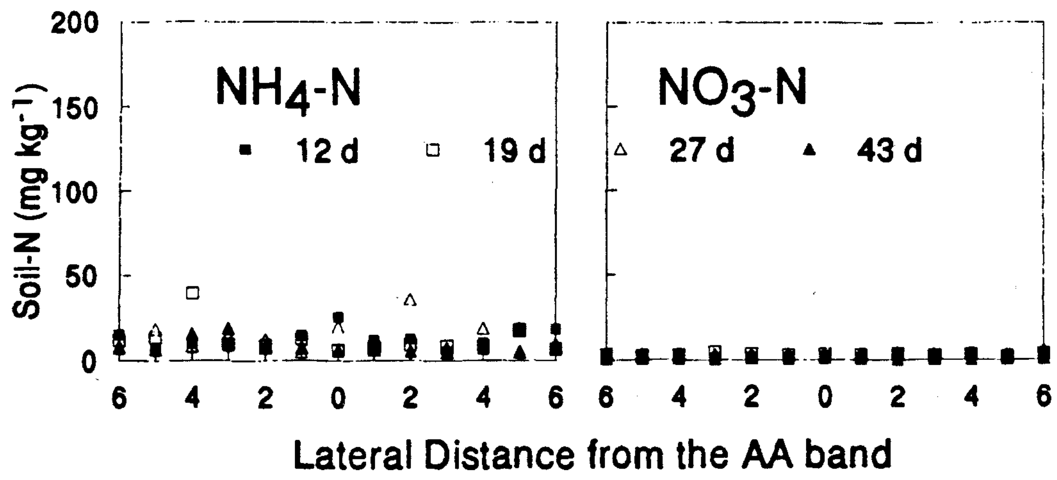


Fig. 5. Soil-N concentration in the control treatment at 12, 19, 27 and 43 days intervals from the time of N application in a sharpsburg silty clay loam. Spring 1992.

Variable Rate Nitrogen Fertilization With Furrow Irrigation - Milton Ruhter Farm

R. B. Ferguson

Introduction:

Recent advances in technology have allowed the summary of information about field variability into a quantified format which can be used to control various field operations automatically. The adjustments which some producers have made "by the seat of their pants" can now be controlled by computers. Considerable attention has been given to this technology (sometimes called farming by soils or farming by the foot) in popular farm magazines over the last couple of years. Much of the interest and technology to date has been oriented towards application of non-mobile nutrients, such as phosphorus and potassium. Adaption of this technology to anhydrous ammonia application equipment has created an interest in the technology because of its potential impact on groundwater quality. Additionally, the inherent variability found in soil nitrate levels with furrow irrigation makes the technology attractive in Nebraska.

Objective:

Investigate the potential for variable rate application of anhydrous ammonia to increase the nitrogen use efficiency of furrow-irrigated corn. The primary objective in 1992 was to gain preliminary information using a variable rate anhydrous ammonia applicator.

Procedure:

Two sites on farmers fields were sampled in the spring of 1992 on a grid basis for residual nitrate. Both sites were demonstration sites for the Mid-Nebraska Water Quality Demonstration Project. Soil samples were collected to a depth of four feet on a 200 ft grid. Maps of nitrate levels in these fields are shown in Figures 1 and 2. Figure 1 illustrates the distribution of residual nitrate in a field in Seward county on the Dean Rocker farm. This figure illustrates the effect of the irrigation water infiltration profile on residual nitrate. Residual nitrate generally increases with distance from the irrigation pipe. The increase in concentration at a distance of 700 - 900 ft, followed by a decrease, is likely related to other variables which were not mapped, such as elevation, clay content, compaction, differences in drainage, etc. The highest residual N levels, in the range of 120 - 160 lb N/acre in 4 ft, were found at the farthest downstream points.

Figure 2 illustrates the distribution of residual nitrate-N at the Milton Ruhter farm in Adams county. Nitrate-N levels in 4 ft ranged from approximately 15 lb/acre to over 230 lb/acre in this field. The site is relatively complex regarding how it is managed for irrigation, which explains some of the trends in residual nitrate. The field has a draw running across it approximately 2/3 of the distance from the "upper" end. Gated irrigation pipe is laid at both ends of the field, and water runs towards the draw. Residual nitrate levels are lowest at both ends of the field, and highest in the vicinity of the draw. Besides being the low point of the field, part of the draw area is also mapped as a Butler soil, which is less well-drained than the majority of the field, which is mapped as a Hord soil. A area of elevated nitrate is noted at one corner of the "upper" end of the field. This area was significantly cut and filled when the field was leveled for irrigation. The area is poorly drained, and generally observed by the cooperator to be less productive than the rest of the field. Both the corner of the field and the draw area apparently have a lower yield potential than the rest of the field, and consequently use less of the applied fertilizer nitrogen. It is likely that the high areas of residual nitrate are due to differences in irrigation water infiltration as well as yield potential of the soil.

A variable rate anhydrous ammonia applicator was used at the Ruhter farm to variably apply nitrogen according to the soil nitrate level. (The applicator was used at the Dean Rocker farm, but the computer program was not properly calibrated and excessive rates of nitrogen were applied.) The cooperator applied 30 lb N/acre as starter. The balance of the N required for an expected yield of 180 bu/acre was applied as sidedressed ammonia, with rates ranging from 0 to 185 lb N/acre, for total amounts of N in the field ranging from 30 to 215 lb N/acre. Four treatments were applied in a randomized complete block design with six replications. The four treatments were: variable N rate; uniform UNL recommended N rate (180 lb N/acre); -55 lb/acre rate (125 lb N/acre); and a +35 lb/acre rate (215 lb N/acre). Each treatment was applied to field length strips which were eight rows wide.

A research combine capable of measuring yield on-the-go from Kansas State University was used to harvest the strips. Yield from each strip was measured with a weigh wagon.

Results:

Average yields from the four treatments are shown in Table 1. Grain yields were reduced at the -55 lb N/acre rate, but were the same statistically with the other three treatments. Figure 3 illustrates the trend of grain yield across the field, with vertical bars indicating yield for individual strips. Grain yield was evidently influenced somewhat by the position of the strip in the field, with yield in the fourth through tenth strips somewhat lower than other strips no matter what the N rate. The total N applied is shown at the top of Figure 3. These total indicate the amount of N applied to the strip, not the rate per acre. Each strip was approximately 1.4 acres in area. The total strip application illustrates that the variable N rate approach did not apply less N than the uniform, recommended N rate of 180 lb N/acre, on average. The distribution of N was substantially different, however. Averaged across 6 reps of the variable rate treatment, the total amount applied to the strip was 252 lb of N. The total amount applied to the recommended N rate strips was 248 lb N, on average. At this site, the variable rate approach did not reduce the amount of N applied or affect yield, compared to the uniform recommended N rate. However, variable rate application did allow fertilizer N to be distributed much differently, which may increase fertilizer use efficiency and reduce the amount of nitrate-N left in the soil subject to leaching. Soil samples will be collected from these strips in the spring of 1993 to evaluate the effect of variable N application on residual N levels.

The spatial distribution of yield in the eastern third of the field is illustrated in Figure 4, produced from data collected by the yield mapping combine. At this time, the statistical relationship between residual N, variable fertilizer N, and yield as measured by the mapping combine or the weigh wagon has not been evaluated. Figure 4 illustrates general trends in yield for this portion of the field, with an average yield of 172 bu/acre, maximum yield of 224 bu/acre and minimum yield of 67 bu/acre. Areas designated by H or L on the map are areas of generally high (H) or low (L) yield.

Figure 1. Soil nitrate (lb/acre to 4 ft), Dean Rocker farm, 1992.

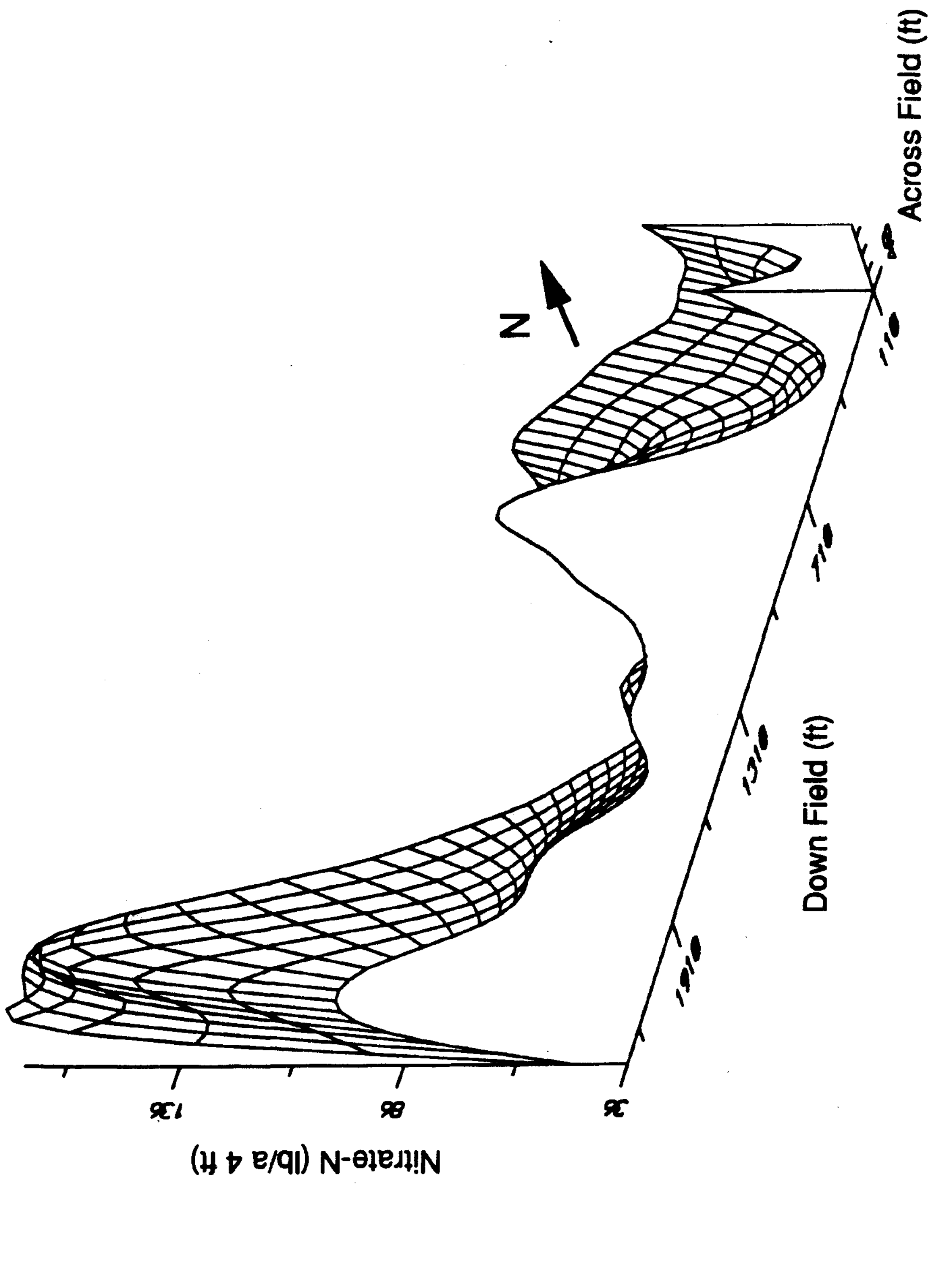


Figure 3. Strip applied N and grain yield, Milton Ruhter farm, 1992.

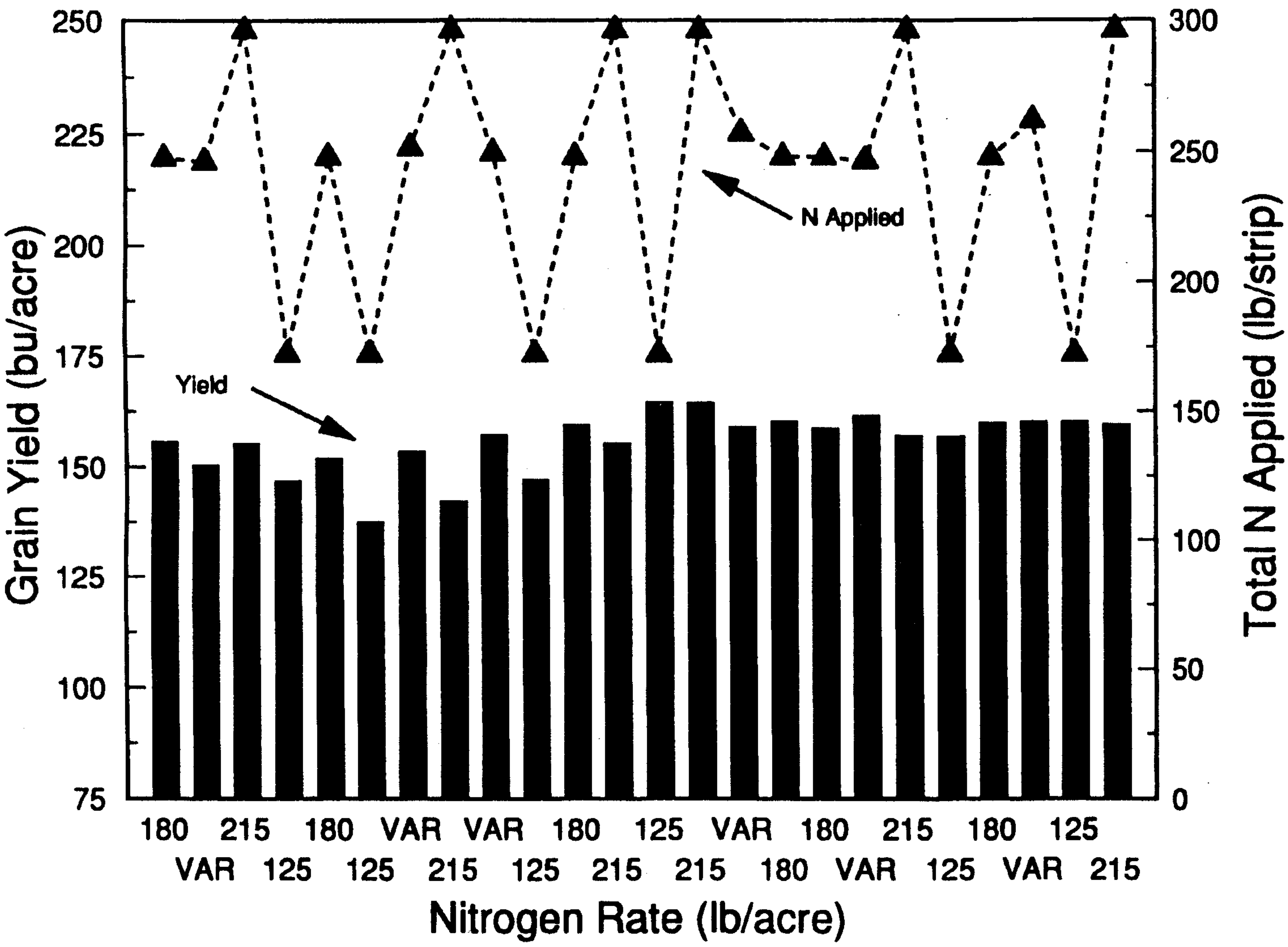


Figure 2. Soil nitrate (lb/acre to 4 ft), Milton Ruhter farm, 1992.

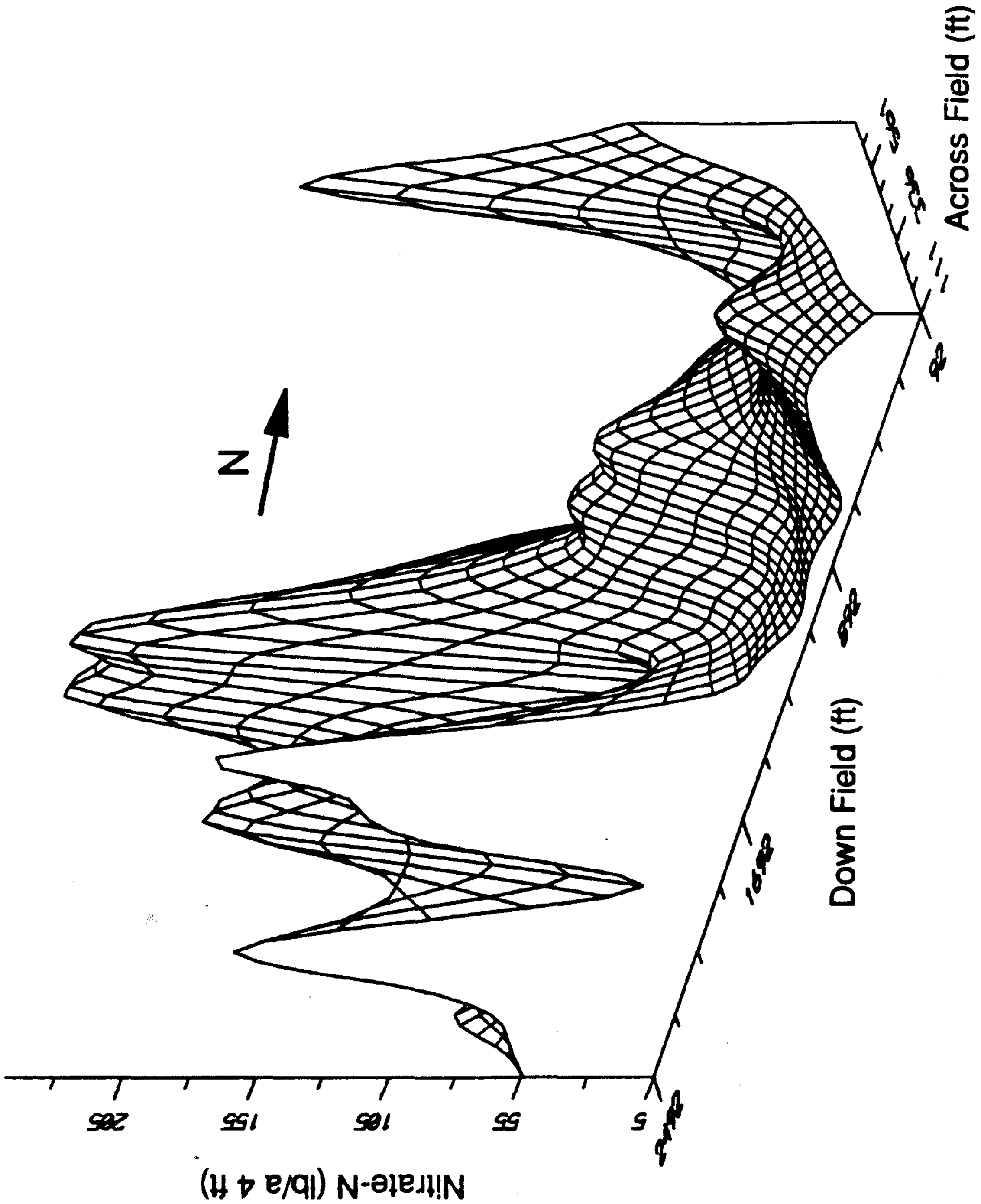


Figure 4. Grain yield map, eastern third of field, Milton Ruhter farm, 199

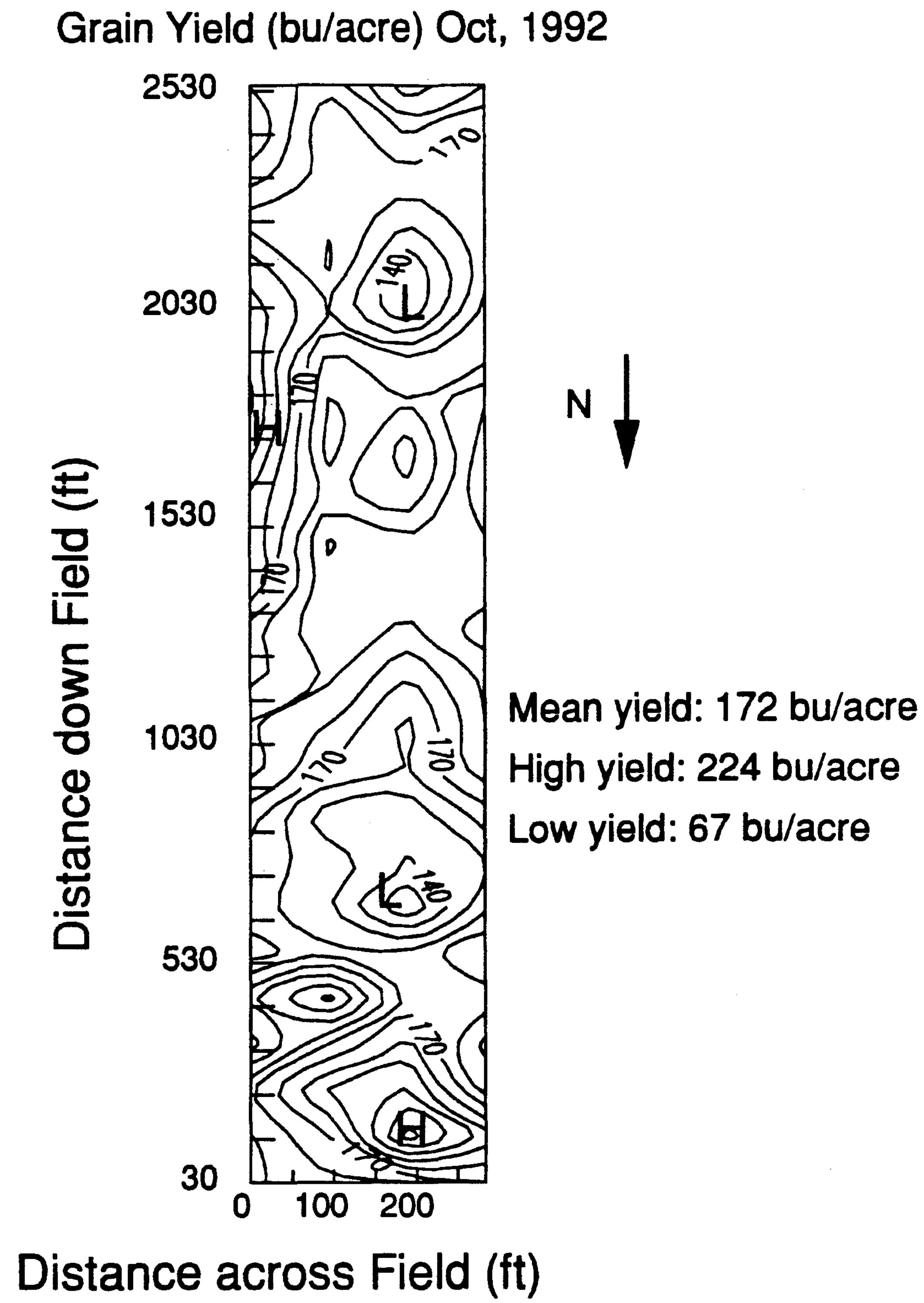


Table 1.Treatment N rates and mean yields, Milton Ruhter farm, 1992.

Treatment	Total N Rate (lb/acre)	Yield (bu/acre)
-55	125	152
REC	180	158
Variable	VAR	157
+35	215	155

Burlington Northern Nitrogen Management Study

R.B. Ferguson, G.W. Hergert, J.S. Schepers, and G.P. Slater

Objective:

Evaluate the effects of nitrogen (N) fertilizer rate, tillage, the nitrification inhibitor nitrapyrin, and fertilizer timing on N use efficiency of irrigated corn and the accumulation and movement of nitrate-N in soil.

Procedure:

This study, initiated in 1986, is located at the South Central Research and Extension Center farm near Clay Center. Soil type is a Crete silt loam. From 1986 through 1990, the study was one component of the Burlington Northern Foundation Water Quality Project. Since 1990, the study has been maintained on a scaled-down basis to evaluate long-term effects of treatments. Experimental variables have included: fertilizer N rate (0, 75, 150, 300 kg N ha^{-1} as sidedressed anhydrous ammonia); tillage (conventional chisel/disk or no-till); and nitrapyrin (0 or 0.5 kg ha^{-1}). From 1986 through 1989, corn hybrid was an additional variable (Pioneer 3377, 3475, 3551). From 1990 on, the hybrid variable was eliminated. From 1989 through 1991, sidedress timing was added as a variable (early sidedress at approx. V4, late sidedress at approx. V8).

Soil samples have been collected from the root zone to a depth of 1.8 m prior to planting and/or following harvest. Soil samples have also been collected during the growing season from the fertilizer band to a depth of 0.45 m. Both grain and stover yield were measured during the first three years of this study, with only grain yield measured the last four years.

Pioneer corn hybrid 3417 was planted April 29, 1992 at a rate of 27,500 seeds/acre. Early sidedress application was completed May 29 and late application June 22. A total of 19.78 inches of rainfall fell during the growing season (4/29 to 10/6) and was supplemented with 5.57 inches of irrigation water from a linear pivot. An August 4 hailstorm caused 50-75% leaf loss when the corn was in the soft dough stage. Hand harvesting was completed October 6, 1992.

Results and Discussion:

Grain Yield

Results from the first three years (1986-1989) have been summarized elsewhere (SSSAJ 55:875-880, 1991) and will not be addressed in detail here. Interactions of nitrapyrin and corn hybrid were evaluated primarily during this phase of the study. One finding from the first three years of this study was that the use of nitrapyrin with the late sidedress N application appeared to delay fertilizer N availability, perhaps through a temporary immobilization process, resulting in decreased fertilizer N recovery when nitrapyrin was used. Plots were split in 1989 to add a timing variable in order to evaluate the hypothesis that earlier sidedress application of N with nitrapyrin might allow any temporary immobilization to occur prior to the period of maximum N uptake by the crop. This summary will primarily concentrate on 1992 results and how they compare to the results over the past four years of this study.

Grain yields for 1989-92 are shown in Table 1. Yields in 1992 were reduced considerably because of hail damage. However, according to the analysis of variance for grain yield in Table 2, several significant differences in experimental variables were still evident. Yield means which were significant at P0.1 are given in Table 3. Analogous to previous years, grain yield was significantly reduced with no-till. This is likely the result of a compacted soil layer which was visible when soil sampling the no-till plots. There was also a significant N rate by tillage method interaction all four years, with the no-till treatments requiring more N to optimize grain yield. This trend is illustrated for 1992 in Figure 1.

Nitrapyrin has had minimal effect on grain yield over the four years, although nitrapyrin did decrease yield in 1991. There have been no significant interactions of nitrapyrin with N rate, tillage, or application date. Consistent with 1989 and 1990 findings, grain yield in 1992 was higher with early application of N as opposed to late application. However, there was no significant interaction of N application date and nitrapyrin to support the hypothesis that any effects of temporary immobilization with nitrapyrin would be minimized with early sidedress application. Figure 2 shows the interaction of tillage and nitrapyrin, averaged over hybrids and N rates at the late application date, over the course of the study. This figure illustrates the trend for reduced yield with no-till.

Soil Ammonium and Nitrate Levels

Soil samples have been collected during the season from the fertilizer band and analyzed for ammonium and nitrate-N. Table 4 contains the analysis of variance data for the mid-season band samples from 1990 through 1992. Samples were collected approximately three and six weeks after each fertilizer application. Cumulative ppm to a depth of 0.45 m are shown in Figure 3. There have been significant effects of both nitrapyrin and application date on ammonium and nitrate-N, but no significant interactions, with the exception of the nitrate-N level at the 75 kg N/ha rate, second sampling date, in 1990.

Figure 4 illustrates soil profile nitrate-N levels, to a depth of 1.8 m, over the course of the study. Nitrate-N levels declined from an initially high level at the two lower N rates, and remained constant or increased at the 300 kg/ha rate. Figure 5 illustrates the influence of tillage method on profile nitrate-N in the spring of 1992. This trend is representative of a significant N rate by tillage interaction on profile nitrate levels observed in recent years of the study. Nitrate-N levels are significantly lower under no-tillage compared to conventional tillage, particularly at the higher N rates and at deeper depths in the profile. This trend may be indicative of greater mineralization under conventional tillage, or greater leaching below the root zone occurring in the no-till treatment.

Summary:

Similar to data from previous years in the second phase of the study (1989 through 1991), 1992 findings provide no solid support for the hypothesis that earlier sidedress N application with nitrapyrin would minimize any temporary immobilization of ammonium N. Grain yield may not be the most sensitive variable to this effect. During the first three years of the study, total crop N recovery, in stover and grain, was influenced more by the presence of nitrapyrin than was yield. Unfortunately, total dry matter yield and N content has not been measured durint the last four years.

Tillage method has definitely influenced grain yield during the last four years of the study. No-till appears to be reducing fertilizer N use efficiency to some extent, thus reducing yield. However, there may also be a tillage/compaction interaction which is influencing yield and N use efficiency.

The study will be continued for 1992 without the N application timing variable.

Table 1. Complete listing of corn grain yields from 1989-1992.

Tillage	N Rate (kg/ha)	N Appl. Date	Nitra-pyrin	(Mg/ha) 1989*	1990	1991	1992
CT	0	Early	with	6.43	6.16	6.44	4.22
CT	0	Early	w/o	5.51	5.91	6.05	4.21
CT	0	Late	with	7.21	6.07	5.91	3.95
CT	0	Late	w/o	5.84	5.54	5.98	4.12
CT	75	Early	with	11.15	10.14	10.91	8.39
CT	75	Early	w/o	10.94	9.57	10.69	7.83
CT	75	Late	with	10.40	9.99	10.82	8.51
CT	75	Late	w/o	11.05	9.26	11.25	8.25
CT	150	Early	with	11.73	9.87	12.17	10.12
CT	150	Early	w/o	11.06	10.36	12.62	10.13
CT	150	Late	with	11.16	9.78	11.81	9.41
CT	150	Late	w/o	11.31	10.29	12.43	9.94
CT	300	Early	with	12.10	10.46	12.20	9.85
CT	300	Early	w/o	11.80	9.91	12.51	10.68
CT	300	Late	with	11.72	9.60	11.73	9.56
CT	300	Late	w/o	11.61	10.12	12.83	9.15
NT	0	Early	with	6.00	5.00	5.26	4.38
NT	0	Early	w/o	4.66	5.69	4.69	4.72
NT	0	Late	with	4.98	5.97	5.08	4.47
NT	0	Late	w/o	4.70	4.94	4.78	4.77
NT	75	Early	with	8.95	8.95	7.86	7.68
NT	75	Early	w/o	9.38	8.89	8.57	7.01
NT	75	Late	with	9.04	9.35	8.82	7.75
NT	75	Late	w/o	8.67	9.06	8.82	6.87
NT	150	Early	with	10.72	9.95	9.97	8.55
NT	150	Early	w/o	11.11	10.18	9.93	8.55
NT	150	Late	with	10.22	9.19	9.64	8.30
NT	150	Late	w/o	11.22	9.28	10.22	8.31
NT	300	Early	with	11.07	10.76	11.14	9.63
NT	300	Early	w/o	11.25	11.02	11.60	9.26
NT	300	Late	with	10.85	9.51	10.70	8.52
NT	300	Late	w/o	11.20	9.28	10.90	7.92

**1989 averaged over three hybrids*
CT = conventional tillage
NT = no-till

Table 2. Analysis of variance for grain yield, 1989-1992.

Source	PR>F			
	1989	1990	1991	1992
Rep	0.0001	NS	0.0016	0.0117
Tillage (T)	0.0001	0.0808	0.0001	0.0001
N Rate (NR)	0.0001	0.0057	0.0001	0.0001
NR*T	0.0027	0.0744	0.0179	0.0002
Nitrapyrin (NP)	NS	NS	0.0754	NS
T*NP	NS	NS	NS	NS
NR*NP	NS	NS	NS	NS
NR*T*NP	NS	NS	NS	NS
Application Date (AD)	0.0727	0.0183	NS	0.0293
T*AD	NS	NS	NS	NS
NR*AD	NS	0.0458	NS	0.0387
NR*T*AD	NS	0.0876	NS	NS
NP*AD	NS	NS	NS	NS
T*NP*AD	NS	NS	NS	NS
NR*NP*AD	NS	NS	NS	NS
NR*T*NP*AD	NS	NS	NS	NS
C.V. (%)	10.19	9.23	9.59	11.35

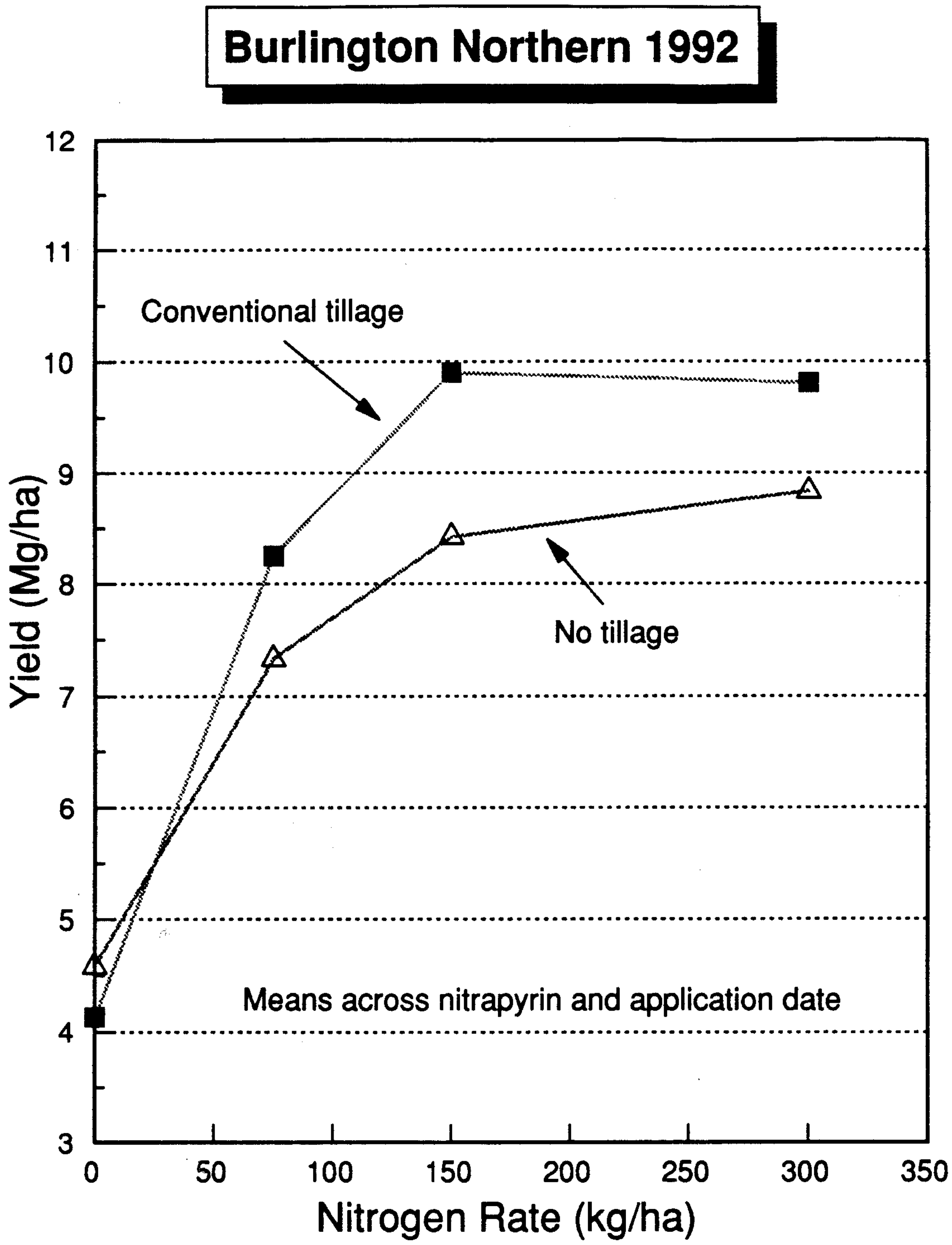
Note: NS = not significant

Table 3. Significant mean values for grain yield, 1989-1992.

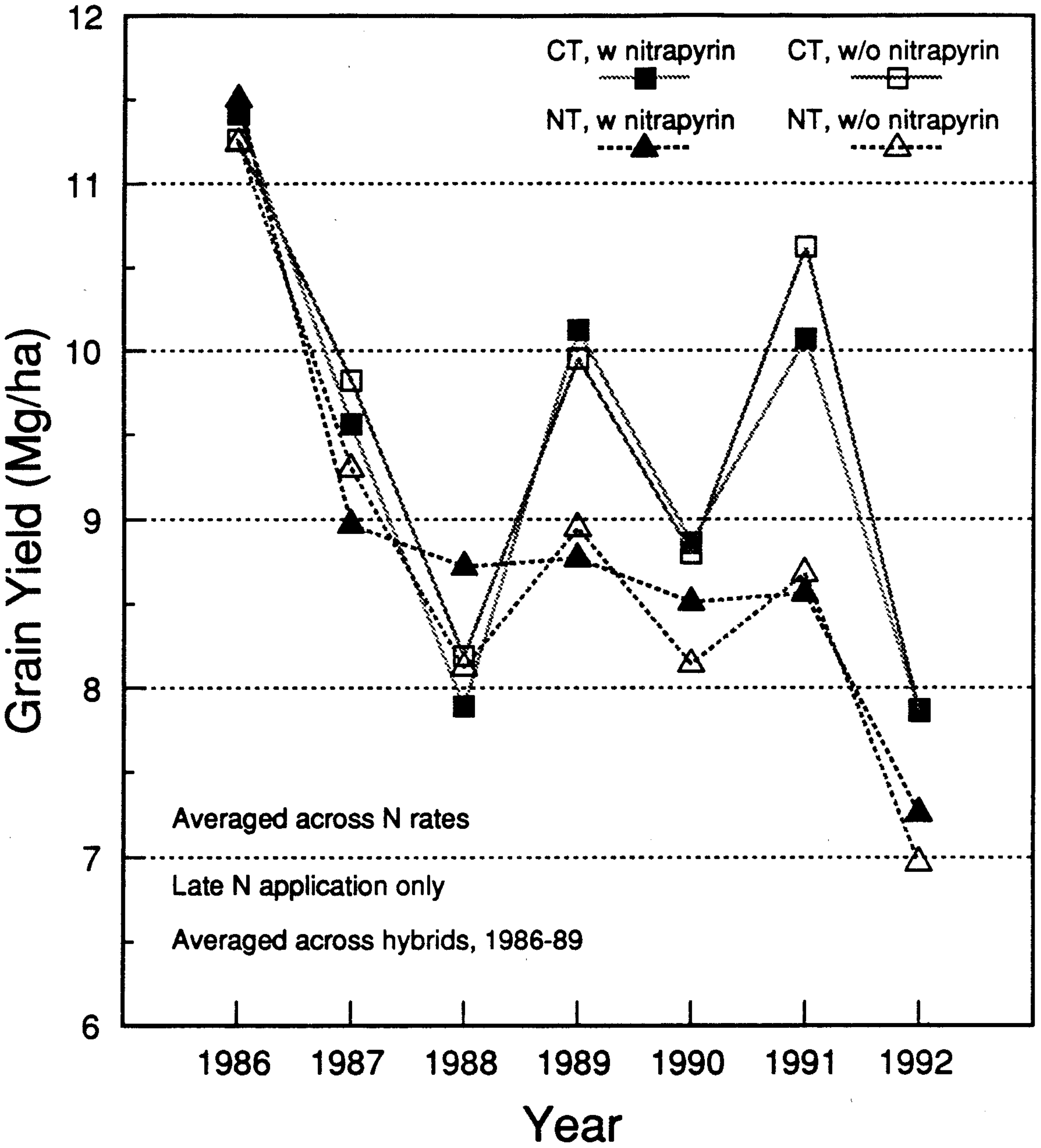
			Yield (Mg/ha)			
			1989	1990	1991	1992
Tillage		CT	11.34	9.96	11.84	8.02
		NT	10.21	9.63	9.86	7.29
N Rate* Tillage	CT	75	10.89	9.75	10.93	8.24
	CT	150	11.32	10.08	12.27	9.90
	CT	300	11.81	10.03	12.33	9.81
	NT	75	9.01	9.07	8.53	7.33
	NT	150	10.82	9.66	9.95	8.42
	NT	300	11.09	10.15	11.10	8.83
Nitrapyrin		With			10.66	
		W/o			9.86	
Application Date		Early	10.94	10.01		7.83
		Late	10.70	9.57		7.49
N Rate* Appl. Date	Early	75		9.40		7.73
	Early	150		10.10		9.34
	Early	300		10.55		9.86
	Late	75		9.42		7.84
	Late	150		9.65		8.99
	Late	300		9.64		8.78
N Rate*Tillage*Application Date						
CT	Early	75		9.86		
CT	Early	150		10.12		
CT	Early	300		10.19		
CT	Late	75		9.64		
CT	Late	150		10.05		
CT	Late	300		9.87		
NT	Early	75		8.94		
NT	Early	150		10.08		
NT	Early	300		10.90		
NT	Late	75		9.21		
NT	Late	150		9.25		
NT	Late	300		9.41		

Table 4. Mid-season fertilizer band soil samples, 1990-1993.
ANOVA of sum of ppm N in 0-6 and 6-12 in depth increments.

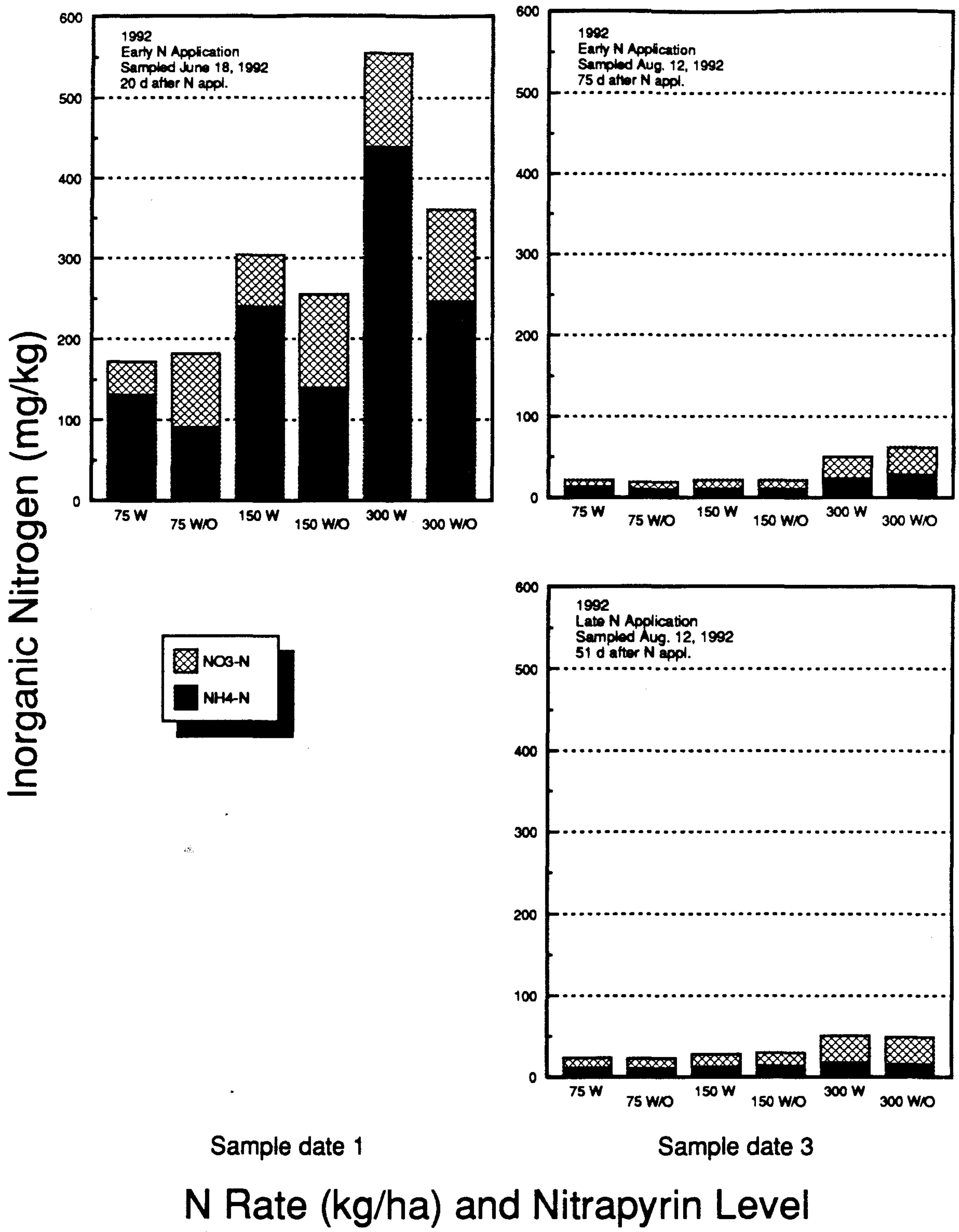
				PR>F					
				Band sample data 1		Band sample data 2		Band sample data 3	
Year	**N Rate (kg/ha)**	**Statistic**	**Independent Variable**	NH4-N	NO3-N	NH4-N	NO3-N	NH4-N	NO3-4
1990	**75**	PR>F	Nitrapyrin (NP)	**0.0269**	**0.0706**	**0.0746**	**0.003**		
			Appl Date	—	—	**0.0089**	NS		
			NP*Date	—	—	NS	**0.0632**		
		C.V.(%)		60.4	49.8	79.7	54.4		
	150	PR>F	Nitrapyrin (NP)	NS	NS	NS	NS		
			Appl Date (Date)	—	—	**0.0162**	NS		
			NP*Date	—	—	NS	NS		
		C.V.(%)		95.1	64.4	83.1	75		
	300	PR>F	Nitrapyrin (NP)	NS	NS	**0.0924**	NS		
			Appl Date (Date)	—	—	**0.0018**	NS		
			NP*Date	—	—	NS	NS		
		C.V.(%)		90.6	59.9	53	45.1		
1991	**75**	PR>F	Nitrapyrin (NP)	NS	NS	NS	NS	**0.0059**	NS
			Appl Date (Date)	—	—	NS	NS	NS	NS
			NP*Date	—	—	NS	NS	NS	NS
		C.V.(%)		37.3	67.8	88.3	65	33	44.1
	150	PR>F	Nitrapyrin (NP)	NS	NS	NS	NS	NS	NS
			Appl Date (Date)	—	—	**0.0177**	NS	NS	**0.0008**
			NP*Date	—	—	NS	NS	NS	NS
		C.V.(%)		108.9	50	70.4	49	58.8	24.8
	300	PR>F	Nitrapyrin (NP)	NS	NS	NS	**0.0618**	NS	NS
			Appl Date (Date)	—	—	NS	NS	NS	NS
			NP*Date	—	—	NS	NS	NS	NS
		C.V.(%)		32	57.9	71	42.7	56.3	28.3
1992	**75**	PR>F	Nitrapyrin (NP)	NS	**0.0020**	—	—	**0.0020**	NS
			Appl Date (Date)	—	—	—	—	NS	**0.0052**
			NP*Date	—	—	—	—	NS	NS
		C.V.(%)		60.0	11.8	—	—	9.1	15.2
	150	PR>F	Nitrapyrin (NP)	**0.0774**	**0.0165**	—	—	NS	NS
			Appl Date (Date)	—	—	—	—	NS	**0.0203**
			NP*Date	—	—	—	—	NS	NS
		C.V.(%)		20.9	20.3	—	—	31.6	31.2
	300	PR>F	Nitrapyrin (NP)	NS	NS	—	—	NS	NS
			Appl Date (Date)	—	—	—	—	NS	NS
			NP*Date	—	—	—	—	NS	NS
		C.V.(%)		28.3	42.3	—	—	59.0	25.9

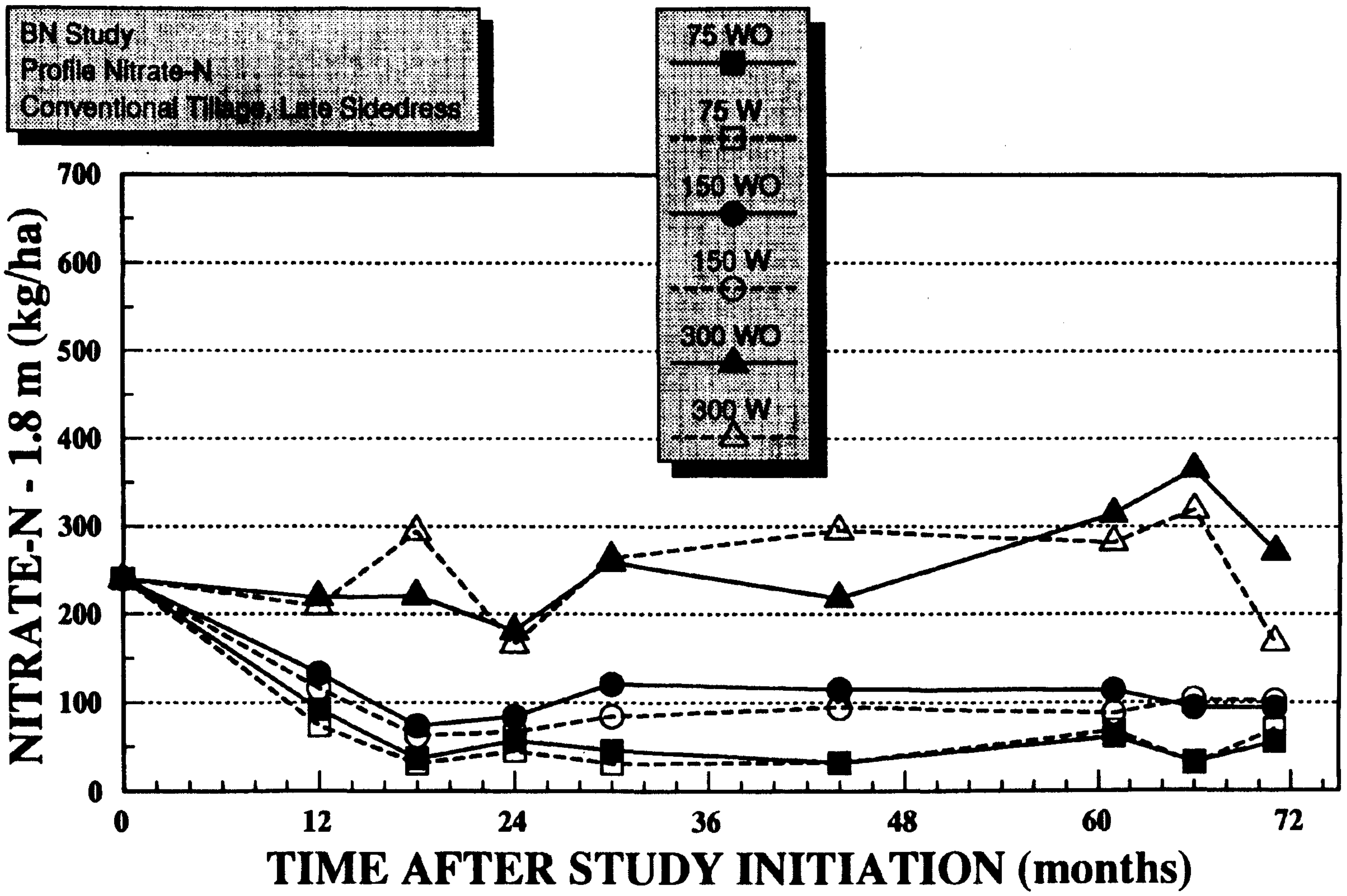

Burlington Northern 1992
12
11
10
9
8
7
6
5
4
3
Yield (Mg/ha)
Conventional tillage
No tillage
Means across nitrapyrin and application date
0
50
100
150
200
250
300
350
Nitrogen Rate (kg/ha)

Grain Yield, 1986-1992



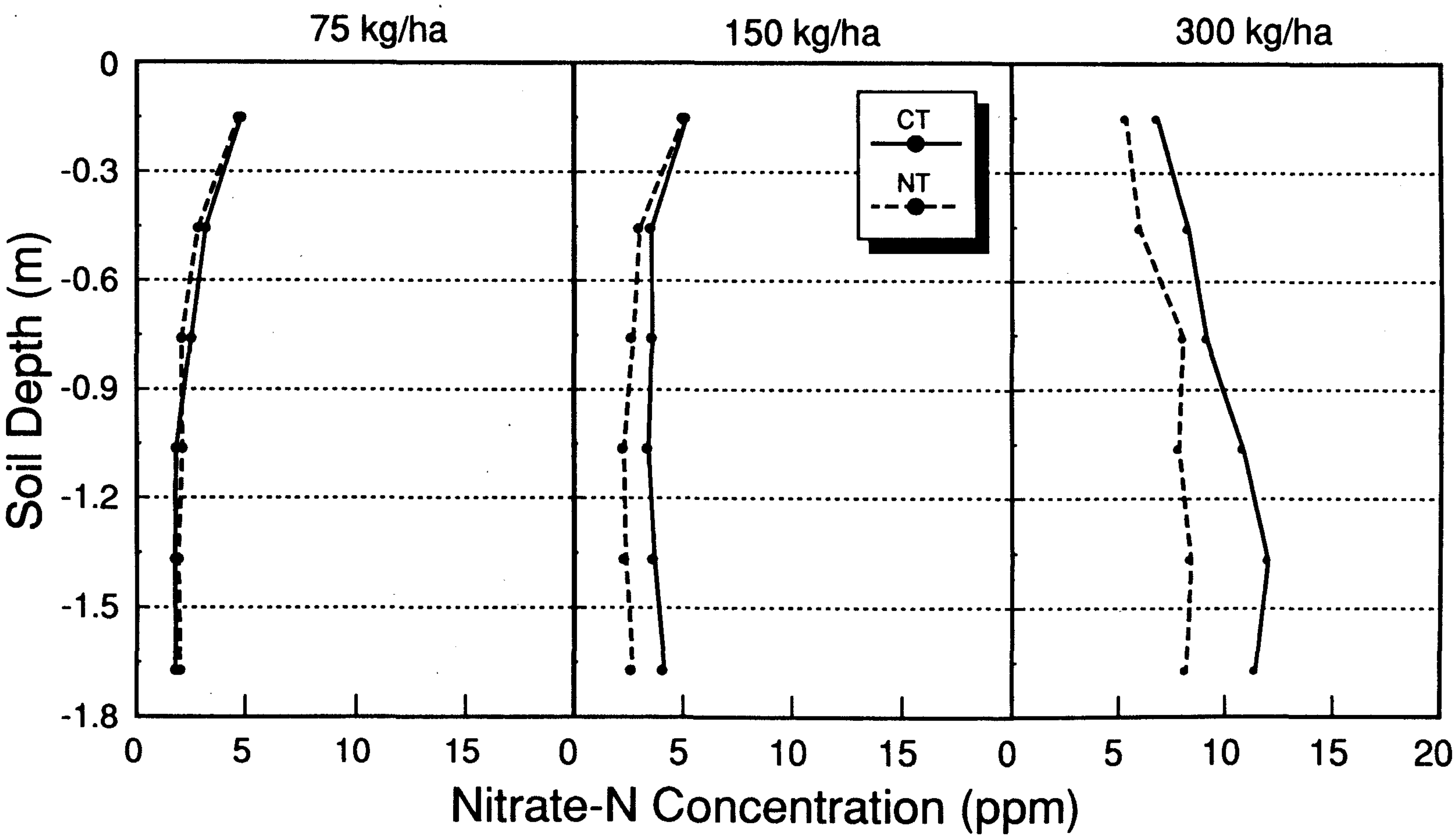
In-Season Fertilizer Band N, 1992





Preliminary 12-3-92

BN Nitrogen Study
Profile Nitrate-N
Spring 1992



The Effects Of A Urease Inhibitor On Volatile Ammonia Loss And Urea Hydrolysis On Irrigated, Ridge Till Corn

Timothy L. Murphy and Richard B. Ferguson

Objectives:

1 To evaluate the potential for yield reduction of irrigated corn due to volatile ammonia loss from a ridge-till system, as influenced by N source, N rate, and placement method.

2 To investigate the potential for N-(n-butyl) thiophosphoric triamide (NBPT), a urease inhibitor, to minimize yield reduction due to volatile ammonia loss, as influenced by N source, N rate, and placement method.

3 To evaluate the effect of NBPT on urea hydrolysis from two N sources.

Procedure:

The third and final year of this study, located in Clay County Nebraska, has been completed. Two nitrogen fertilizer rates (100 and 200 lb N/acre) were applied using four sources (urea, urea+NBPT, UAN solution, and UAN+NBPT solution). All sources were applied using two placement methods, broadcast (br) and surface banding (sb). Uan and UAN+NBPT were also applied as a knifed in (kn) placement method at the 200 lb N/acre rate only. Each treatment was replicated four times. The soil was a Crete silt loam.

Pioneer hybrid 3417 was planted on April 29, 1992. Hydrolysis rate cylinders were placed in the 200 lb N/acre, broadcast treatments of all four N sources on three replications. Fertilizer was applied on May 5, 1992. The cylinders were removed on May 7 and May 14. Their contents were blended and filtered with 1500 ml 2M KCl-PMA solution and then shaken for 15 minutes. An aliquot (120 ml) of each extract was frozen for later NO_3-N, NH_4-N, and urea-N analysis. The plots received 55-60 percent defoliation due to hail on August 4, 1992. The crop was in the early blister stage of development. Chlorophyll meter readings were taken on August 6, 13, and 20 as a result of this hail. Samples of the lower stalk were taken 12 days after black layer. These samples were analyzed for NO_3-N content. Whole plant samples were taken at physiological maturity for total dry matter yield and were analyzed for Kjeldahl-N concentration. The center two rows of each plot were machine harvested for grain yield on October 22, 1992.

Results:

Grain yields were influenced by treatment in 1992 (Table 1). Average yield ranged from 70.7 to 161.9 bu/acre. Analysis of variance (Table 2) showed that grain yield was not limited by N at the lower application rate except when UAN was the N source. There were no observed differences in yield between application methods at either N rate. Application method showed a significant difference in both apparent N recovery and dry matter yield. Apparent N recovery was also influenced by N rate.

1992 was a very good year to investigate the potential of urease inhibitors to reduce urea hydrolysis and subsequent ammonia loss. High relative humidity and temperature and low rainfall produced conditions conducive to urea hydrolysis and volatile ammonia loss (Table 3). NBPT had little effect on grain yield, apparent N recovery or dry matter yield when UAN was the N source. NBPT resulted in a significant difference in grain yield when urea was the N source. This same effect was seen in dry matter yield and apparent N recovery. It was very evident that NBPT helped to reduce volatile ammonia loss resulting from rapid urea hydrolysis in 1992.

Hydrolysis rate measurements were taken on days two and nine after fertilization. Weather data, prior to and following fertilization, is found in Table 3. As stated earlier, ideal conditions existed for hydrolysis of urea. Total N recovery was quite high for all sources except urea on day two (Table 4). Urea+NBPT had the highest recovery of all the N sources. Measurements of NH_4-N, NO_3-N, and urea-N within hydrolysis rate cylinders indicated a 100 percent loss of fertilizer N on both sample dates. Significant differences between N sources were seen in percent NH_4-N, NO_3-N, urea-N, and total N recovery on day nine. NBPT reduced the rate of urea hydrolysis from both UAN solution and urea, but effects were much more pronounced when urea was the N source.

This was the final year of this experiment.

Table 1. Comparison of nitrogen rate, sources, application methods, and the urease inhibitor NBPT for irrigated, ridge-till corn, 1992. Clay Center, NE.

Trt	N Source	N rate (lb/A)	Appl. Method	Grain Yield (bu/A)	Apparent N Recov. (%)	Dry Matter Yield (lb/A)
1	check	0	none	74.4	---.---	3834
2	uan	100	sb	135.5	46.25	4445
3	uan	100	br	132.2	51.98	5212
4	uan	200	sb	156.3	43.65	4632
5	uan	200	kn	156.5	44.58	4457
6	uan	200	br	149.8	45.73	5186
7	uan+I	100	sb	138.7	47.73	4262
8	uan+I	100	br	141.7	62.58	4637
9	uan+I	200	sb	161.9	46.20	5041
10	uan+I	200	br	130.8	41.93	5156
11	urea	100	sb	70.7	0.03	4050
12	urea	100	br	90.0	9.83	4026
13	urea	200	sb	76.0	0.00	3455
14	urea	200	br	72.8	0.93	4307
15	urea+I	100	sb	121.8	33.53	4331
16	urea+I	100	br	135.4	46.70	4508
17	urea+I	200	sb	137.5	33.50	4961
18	urea+I	200	br	142.3	42.13	5080
19	uan+I	200	kn	154.2	46.55	5157
20	uan	100	kn	151.9	65.78	4756
21	uan+I	100	kn	141.4	59.28	4275
		F Value		16.11	9.69	2.28
		PR > F		0.0001	0.0001	0.0079
		C. V.		11.9	33.0	13.8

Mean Values:	Variable	Grain Yield (bu/A)	Apparent N Recov. (%)	Dry Matter Yield (lb/A)
Source	uan	143.5 a	46.90 ab	4869 a
	uan+I	144.1 a	50.12 a	4748 a
	urea	76.5 b	5.09 c	3955 b
	urea+I	134.2 a	38.96 b	4720 a
	PR > F	0.0001	0.0001	0.0036
	C. V.	13.5	36.3	15.8
N Rate	100	127.7 a	39.07 a	4447 a
	200	128.3 a	31.97 b	4714 a
	PR > F	0.0448	0.0901	0.1170
	C. V.	13.5	36.3	15.8
Method	br	125.3 a	39.18 a	4776 a
	sb	124.8 a	32.08 b	4397 b
	PR > F	0.9125	0.0492	0.0527
	C. V.	13.5	36.3	15.8

Table 2. Analysis of Variance for grain yield, 1992.

Source	F Values	PR > F
Rep	1.37	0.2625
N Source	79.76	0.0001
Method	1.16	0.3222
N Rate	6.41	0.0143
N Source * Method	1.38	0.2523
N Source * N Rate	1.18	0.3264
Method * N Rate	2.17	0.1234
N Source * Method * N Rate	0.82	0.5170

Table 3. Weather information for the two week period following fertilization, 1992.
Clay Center, NE

Date	Temperature High °F	Temperature Low °F	Soil Temp. °F	Precip. (in)	Wind Speed (mi/hr)	Relative Humidity (%)
May 04	79	42	64	0.00	8	31
May 05*	67	37	63	0.00	7	41
May 06	70	31	61	0.00	8	41
May 07**	76	40	62	0.00	14	45
May 08	84	54	65	0.08	12	54
May 09	85	55	68	0.00	17	44
May 10	80	58	66	0.39	17	66
May 11	74	55	65	0.00	6	79
May 12	75	47	63	0.00	11	57
May 13	74	47	61	0.08	8	48
May 14**	81	47	67	0.00	6	66
May 15	87	58	72	0.00	14	70
May 16	87	57	71	0.43	12	65
May 17	68	48	65	0.00	7	75

* fertilized on May 5, 1992
** removed hydrolysis rate cylinders on days 2 and 9 after fertilization

Table 4. Comparison of hydrolysis measurements with and without the urease inhibitor NBPT broadcast at a rate of 200 lb/acre N, two and nine days after fertilization, 1992. Clay Center, NE.

		Fertilizer N Recovered As			
Source[1]	Day	NH_4-N (%)	NO_3-N (%)	Urea-N (%)	Total N Recovery (%)
uan	2	6.5 a	4.5 a	68.9 a	79.9 a
uan+I	2	5.6 ab	4.7 a	73.9 a	84.2 a
urea	2	0.0 c	0.0 b	0.0 b	0.0 b
urea+I	2	2.9 bc	0.6 b	84.2 a	87.6 a
PR > F		0.0108	0.0001	0.0001	0.0001
C.V.		44.5	25.3	15.1	15.4

		Fertilizer N Recovered As			
Source[1]	Day	NH_4-N (%)	NO_3-N (%)	Urea-N (%)	Total N Recovery (%)
uan	9	12.9 b	5.5 a	5.0 c	23.3 c
uan+I	9	11.8 b	5.7 a	21.6 b	39.1 b
urea	9	0.0 c	0.0 c	0.0 c	0.0 d
urea+I	9	27.6 a	2.5 b	55.8 a	85.9 a
PR > F		0.0001	0.0002	0.0001	0.0001
C.V.		11.2	23.6	29.6	18.6

[1] Hydrolysis rate measurements were not taken on the KN treatments

Nitrogen Fertilization of Smooth Brome

R.B. Ferguson and G.P. Slater

Objective:

To evaluate the long-term effects of nitrogen (N) fertilizer source, rate, and application method on yield and N use efficiency of smooth brome.

Procedures:

This study was initiated in 1986 at a site located at the USDA Meat Animal Research Center, adjacent to the UNL South Central Research and Extension Center, Clay Center. Soil type is a Crete silt loam. The study evaluates three sources of N; ammonium nitrate (AN), urea (U), and UAN solution (UAN) applied at rates of 50, 100, and 150 lb N/acre. Additionally, UAN solution is applied by three methods; broadcast (BR), knife (KN), and surface band (DR). Ammonium nitrate and urea are broadcast only. Knife and surface-band applications of UAN are applied on 15 inch centers. Treatments have been re-applied annually to the same plots since 1987. Fertilizer treatments, which are applied in early spring each year, were applied March 17, 1992. The brome plots were machine harvested July 10, 1992.

Results:

Yield, forage N content, and apparent N recovery for 1992 are shown in Table 1. As in past years, application of N significantly increased forage yield over check plots. When comparing fertilizer rates in 1992, the 150 lb/acre nitrogen rate resulted in the highest forage yield, although the 6-year results of this study demonstrate no significant yield increase above the 100 lb/acre N rate (Table 2). Yield variations among different nitrogen sources were noted in 1992. Broadcast urea and knifed-in treatments of UAN generated significantly lower yields than treatments of broadcast ammonium nitrate, broadcast UAN solution, or banded UAN solution. In past years, forage yield has not been significantly reduced with the use of urea. The knifed-in UAN treatment has had a significant negative effect on forage yield over the course of the study. The annual disturbance of the brome sod by the N applicator injection knives may contribute to stand problems or may set back the growth of the brome for a time.

Apparent N recovery was calculated based on yield and N content of the forage to give an estimate of how efficiently fertilizer N was used. Apparent N recovery was calculated as:

((Treatment N Uptake - Check N Uptake / Fertilizer N applied)*100)

Note: (N Uptake =
Forage Yield * Forage %N)

Apparent N recovery values for 1992 were relatively low (12 to 37%) in comparison to the summary over years (30 to 62%). What did stand out in 1992 was the fact that plots with the lowest % N recovery values yielded the least. Plots that received broadcast urea or knifed-in UAN solution had significantly lower % N recovery values than plots that received other N sources. These lower N recovery values likely contributed to the lower yields that were associated with those two N source/application method combinations.

Discussion:

Results in 1992 varied somewhat from past years of this study. Forage yield was significantly greater at the highest N rate, while the summary over all years indicates no significant yield increase was observed above 100 lb N/acre. Various factors each year, including residual soil N and growing season weather conditions, may play a role in determining the optimum N rate. The cool, wet spring and summer of 1992 may have been a factor as to why the brome plots responded so well to the higher N rates. Broadcast urea and knifed-in UAN solution produced lower yields than the other N treatments. Results of the knifed-in UAN were consistent with past years; however, the urea results were not. Ammonia volatilization from the surface-applied urea is a likely cause of the reduced forage yield and % N recovery that was observed. Lower % N recovery was also a factor in the lower yields from knifed-in UAN. It is important to point out, though, that there was improved yield response to both these treatment combinations at higher N levels. Over years data still suggests that application of ammonium nitrate or urea may result in greater N recovery than any application method of UAN solution. Nevertheless, except for knifed-in UAN, forage yield from all sources have been statistically equivalent over years..

Table 1. Comparison of nitrogen rate, sources, and application methods for smooth brome, 1992, Clay Center, Nebraska.

Trt #	N Rate (lb/A)	N Source	N Appl. Method	Forage Yield (lb/A @ 12.5% H2O)	Forage % N	Apparent % N Recovery
1	Check	----	----	2453	0.91	
2	KN Check	----	----	2668	0.96	
3	50	AN	BR	4370	1.03	
4	100	AN	BR	4784	1.23	
5	150	AN	BR	4937	1.21	
6	50	UREA	BR	2985	0.94	
7	100	UREA	BR	4046	0.96	
8	150	UREA	BR	4786	0.98	
9	50	UAN	BR	4184	0.93	
10	100	UAN	BR	5214	1.11	
11	150	UAN	BR	6067	1.27	
12	50	UAN	KN	3222	1.06	
13	100	UAN	KN	3632	1.23	
14	150	UAN	KN	4746	1.30	
15	50	UAN	DR	4131	1.00	
16	100	UAN	DR	5304	1.14	
17	150	UAN	DR	6222	1.35	
		LSD (0.05)		969	0.24	
		F VALUE		10.18	2.92	
		C.V.		15.8	15.5	
MEAN VALUES						
N RATE		50		3778 c	0.99 b	27.0 a
		100		4596 b	1.13 a	28.4 a
		150		5352 a	1.22 a	27.7 a
		PR>F		0.0001	0.0004	0.9229
		C.V.		14.9	15.2	41.7
N SOURCE		AN		4697 a	1.16 a	33.2 a
		UREA		3939 b	0.96 b	12.7 c
		UAN-BR		5155 a	1.10 a	32.8 a
		UAN-DR		5219 a	1.16 a	37.0 a
		UAN-KN		3866 b	1.19 a	22.7 b
		PR>F		0.0001	0.0121	0.0001
		C.V.		14.9	15.2	41.7

Table 2. Comparison of nitrogen rate, sources, and application methods for smooth brome, 1987-92, Clay Center, Nebraska.

Trt #	N Rate (lb/A)	N Source	N Appl. Method	Forage Yield (lb/A @ 12.5% H2O)	Forage % N	Apparent % N Recovery
1	Check	----	----	2452	1.42	
2	KN Check	----	----	2627	1.51	
3	50	AN	BR	5309	1.74	
4	100	AN	BR	5692	2.02	
5	150	AN	BR	5027	2.16	
6	50	UREA	BR	4903	1.61	
7	100	UREA	BR	5573	1.92	
8	150	UREA	BR	5515	2.12	
9	50	UAN	BR	4447	1.54	
10	100	UAN	BR	4920	1.86	
11	150	UAN	BR	5327	1.94	
12	50	UAN	KN	3146	1.58	
13	100	UAN	KN	3853	1.93	
14	150	UAN	KN	4920	2.08	
15	50	UAN	DR	4553	1.67	
16	100	UAN	DR	5035	1.81	
17	150	UAN	DR	5336	2.08	
		LSD (0.05)		1863	0.47	
		F VALUE		14.09	11.68	
		C.V.		28.6	18.4	
		MEAN VALUES				
N RATE		50		4472 b	1.63 c	53.7 a
		100		5015 a	1.91 b	47.8 ab
		150		5225 a	2.07 a	39.8 b
		PR>F		0.0001	0.0001	0.0039
		C.V.		26.8	17.1	68.4
N SOURCE		AN		5343 a	1.97 a	62.1 a
		UREA		5330 a	1.88 ab	55.6 ab
		UAN-BR		4898 a	1.78 b	40.5 cd
		UAN-DR		4974 a	1.85 b	47.4 bc
		UAN-KN		3973 b	1.86 ab	29.8 d
		PR>F		0.0001	0.0095	0.0001
		C.V.		26.8	17.1	68.4

Evaluation of Soil Testing for Nitrate-Nitrogen

Edwin J. Penas

Objective:

Demonstrate the validity of using soil tests for nitrate-nitrogen as a guide for determining the amount of nitrogen fertilizer needed to produce a crop of corn or grain sorghum.

Procedure:

Twenty fields were selected for demonstration sites. At 15 sites, two rates of nitrogen were compared. One of these sites received a single rate of nitrogen where two previously applied rates of nitrogen resulted in different amounts of nitrate-nitrogen in the soil. At one site, soybeans followed corn that received two rates of nitrogen in 1991. Three rates of nitrogen were employed at the other five sites.

Soil samples were collected prior to plot establishment. Fertilizer application rates were based on soil tests, previous crop, and expected yield. Field-length plots were used except in two sites in Cuming County (Kn). Fertilizer was applied by the cooperating farmer or fertilizer dealer.

Grain yields in the field length plots were determined using the cooperating farmer's combine and weighing the harvested grain on a portable weigh wagon. At the two sites where less than field-length plots were harvested, samples were hand-harvested, shelled, weighed, and subsampled for moisture.

Results and Discussion:

Data collected from twenty sites in 1992 are presented in Tables 1 and 2 and discussed below.

Two Rates of Nitrogen

Data are summarized in Table 1. Corn was grown after soybeans (6 sites), after alfalfa (2 sites), after corn (2 sites) and after wheat (1 site). Grain sorghum followed corn (2 sites) and grain sorghum (1 site). The effect of nitrogen rates applied to corn was evaluated in soybeans that followed (1 site).

Corn after Soybeans

The suggested rate of nitrogen was adequate to produce corn yields at expected yields or higher at all six sites. Additional nitrogen did not increase yields at three sites and reduced yield at one site. At two sites, grain yield was increased by the higher amount of nitrogen. In both cases, yields exceeded expected yield by 40 bushels per acre.

Corn after Alfalfa

The application of nitrogen did not increase corn yields where corn followed alfalfa at two sites. Yields were higher than expected (130-140 bu/ac); however, nitrogen released by mineralization of legume residue was adequate for maximum yields.

Corn after Corn

The application of nitrogen did not increase yield in a field that had a long history of manure application. These plots were repeated on a 1991 site (no response in 1991).

At the other site, one rate of nitrogen was applied over strips applied the previous year. Although the soil nitrogen was higher in those strips that received the higher rate of nitrogen in 1991, the amount of nitrogen that was applied based on the lower soil nitrogen level was adequate for an optimum yield.

Corn after Wheat

This site had a history of large quantities of manure application and soil nitrogen level was extremely high. Nitrogen fertilizer did not affect grain yield of corn.

Grain Sorghum after Corn

Grain sorghum followed drought stressed corn at two sites. At one site soil nitrogen was high which resulted in no additional nitrogen fertilizer suggested. This field did receive excess amounts of rainfall and nitrate leaching was likely. Hence, the application of nitrogen did increase grain yield. Soil samples were collected after harvest and only about 30 pounds of nitrate-nitrogen was found in a 4-foot depth of soil, regardless whether nitrogen was applied or not.

At the other site, 25 lbs of nitrogen was suggested for 100 bu/ac grain sorghum. Since this low rate was not possible with existing equipment, a 50 lb/ac nitrogen application was compared with none. The applied nitrogen did increase yield at this site.

Grain Sorghum after Grain Sorghum

At this site, the suggested rate of nitrogen was adequate to produce maximum yield. The higher amount did not increase yield above the suggested rate even though the yield was 14 bu/ac higher than expected yield.

Soybeans after Corn

This was a residual study to determine the effect of nitrogen applied to corn the previous year on soybeans the following year. No effects were observed or measured.

Three Rates of Nitrogen

Data for these five sites are summarized in Table 2. Corn was grown after soybeans at two sites and after corn at three sites.

Corn after Soybeans

At both sites, the suggested rate of nitrogen was adequate for optimum yields. Increasing the amount of nitrogen applied did not increase grain yield even though yield levels exceeded expected yield. Reducing the amount of nitrogen applied below the suggested amount did result in lower yield at the non-irrigated site but not at the other site.

Corn after Corn

The amount of nitrogen suggested based on soil test was adequate for optimum yields at all three sites even though yield levels were higher than the expected yield. At one site, reducing the amount of nitrogen applied 40 lbs/ac below suggested rate did result in reduced grain yield.

At one site where soil nitrogen was high, the application of nitrogen did not increase grain yield. At the other site where soil nitrogen was high, 50 lbs/ac of nitrogen did not increase yield significantly; however, using 100 lbs/ac of nitrogen did increase yield. This increase in yield, which exceeded expected yield by 69 bu/ac was equal to the cost of the fertilizer.

Summary

These data demonstrate that soil tests for nitrate-nitrogen provide viable guidelines to determine the nitrogen fertilizer needs of corn and grain sorghum. In most cases, the suggested amount was adequate even though yields were higher than expected. Mineralization of nitrogen from organic matter was a major nitrogen contribution in 1992, especially since some leaching and denitrification did occur.

Table 1. Influence of nitrogen fertilizer on corn, grain sorghum, and soybeans at fifteen locations, 1992.

	Low N Rate	High N Rate	Difference
Burt County (Mu)			
31 lbs N/ac 4 feet (Expected yield = 130 bu/ac @ 90 lbs/ac)			
Corn after soybeans, non-irrigated			
Applied Nitrogen, lbs/ac	90	137	47
Grain Yield, bu/ac	148	170	22***
Grain Moisture, %	19.7	19.9	0.2
Grain Test Weight, lbs/bu	55.8	56.0	0.2
Cass County (St)			
131 lbs N/ac 4 feet (Expected yield = 125 bu/ac @ 0 lbs/ac)			
Corn after soybeans, non-irrigated			
Applied Nitrogen, lbs/ac	0	60	60
Grain Yield, bu/ac	140	135	-5*
Grain Moisture, %	23.9	24.4	0.5**
Grain Test Weight, lbs/bu	53.7	53.5	-0.2
Dodge County (Ho)			
50 lbs N/ac 4 feet (Expected yield = 120 bu/ac @ 60 lbs/ac)			
Corn after soybeans, non-irrigated			
Applied Nitrogen, lbs/ac	60	110	50
Grain Yield, bu/ac	129	135	6
Grain Moisture, %	19.8	19.8	0
Grain Test Weight, lbs/bu	52.3	52.4	0.1
Dodge County (VS)			
68 lbs N/ac 4 feet (Expected yield = 120 bu/ac @ 40 lbs/ac)			
Corn after soybeans, non-irrigated			
Applied Nitrogen, lbs/ac	40	90	50
Grain Yield, bu/ac	161	163	2
Grain Moisture, %	20.5	20.7	0.2
Grain Test Weight, lbs/bu	56.0	56.1	0.1

Table 1 continued

	Low N Rate	High N Rate	Difference
Nemaha County (Ni)			
80 lbs N/ac 4 feet (Expected yield = 120 bu/ac @ 20 lbs/ac)			
Corn after soybeans, non-irrigated			
Applied Nitrogen, lbs/ac	20	70	50
Grain Yield, bu/ac	141	168	27***
Grain Moisture, %	19.8	19.1	-0.7**
Grain Test Weight, lbs/bu	56.4	57.3	0.9***
Washington County (St)			
53 lbs N/ac 4 feet (Expected yield = 120 bu/ac @ 60 lbs/ac)			
Corn after soybeans, non-irrigated			
Applied Nitrogen, lbs/ac	60	110	50
Grain Yield, bu/ac	177	176	-1
Grain Moisture, %	23.6	23.8	0.2
Grain Test Weight, lbs/bu	53.3	53.2	-0.1
Cuming County (Kn)			
No soil test (Expected yield = 110 bu/ac @ 0 lbs/ac)			
Corn after alfalfa, non-irrigated			
Applied Nitrogen, lbs/ac	0	40	40
Grain Yield, bu/ac	140	144	4
Grain Test Weight, lbs/bu	54.1	54.2	0.1
Cuming County (Me)			
No soil test (Expected yield = 120 bu/ac @ 0 lbs/ac)			
Corn after alfalfa, non-irrigated			
Applied Nitrogen, lbs/ac	0	40	40
Grain Yield, bu/ac	127	135	8
Grain Moisture, %	21.1	21.2	0.1
Grain Test Weight, lbs/bu	53.1	52.7	-0.4

Table 1 continued

	Low N Rate	High N Rate	Difference
Cuming County (Kn)			
No soil test, repeat plots from 1991			
Corn after corn, non-irrigated			
Applied Nitrogen, lbs/ac	0	40	40
Grain Yield, bu/ac	141	143	2
Grain Test Weight, lbs/bu	53.7	54.1	0.4
Cuming County (Kr)			
88 lbs N/ac applied (Expected yield = 115 bu/ac @ 90 lbs/ac & 54 lbs soil N)			
Corn after corn, non-irrigated			
Soil Nitrogen, lbs/ac 3 feet	54	74	20
Grain Yield, bu/ac	136	138	2
Grain Moisture, %	20.1	20.2	0.1*
Grain Test Weight, lbs/bu	52.9	52.8	-0.1
Saunders County (Be)			
482 lbs N/ac 4 feet (Expected yield = 160 bu/ac @ 0 lbs/ac)			
Corn after wheat, irrigated (not in 1992)			
Applied Nitrogen, lbs/ac	0	50	50
Grain Yield, bu/ac	155	162	7
Grain Moisture, %	22.6	22.9	0.3
Grain Test Weight, lbs/bu	54.0	54.2	0.2
Lancaster County (Do)			
143 lbs N/ac 4 feet (Expected yield = 100 bu/ac @ 0 lbs/ac)			
Grain sorghum after corn, non-irrigated			
Applied Nitrogen, lbs/ac	0	70	70
Grain Yield, bu/ac	106	126	20***
Grain Moisture, %	17.7	17.2	-0.5***
Grain Test Weight, lbs/bu	58.9	60.0	1.1***

Table 1 continued

	Low N Rate	High N Rate	Difference
Lancaster County (Ti)			
117 lbs N/ac 4 feet (Expected yield = 100 bu/ac @ 25 lbs/ac)			
Grain sorghum after corn, non-irrigated			
Applied Nitrogen, lbs/ac	0	50	50
Grain Yield, bu/ac	87	100	13***
Grain Moisture, %	18.4	18.4	0
Grain Test Weight, lbs/bu	55.2	54.9	-0.3
Saline County (Ri)			
62 lbs N/ac 4 feet (Expected yield = 80 bu/ac @ 40 lbs/ac)			
Grain sorghum after grain sorghum, non-irrigated			
Applied Nitrogen, lbs/ac	36	66	30
Grain Yield, bu/ac	94	94	0
Grain Moisture, %	15.7	15.6	-0.1
Grain Test Weight, lbs/bu	59.7	59.7	0
Saunders County (Ha)			
Residual study - N applied to corn previous year			
Soybeans after corn, non-irrigated in 1992			
Applied Nitrogen, lbs/ac	0	50	50
Seed Yield, bu/ac	55	55	0
Seed Moisture, %	12.2	12.2	0
Seed Test Weight, lbs/bu	55.5	55.4	-0.1

*, **, ***: Significantly different @ 0.10, 0.05, and 0.01 probability.

Table 2. Influence of nitrogen fertilizer on corn, grain sorghum, and soybeans at five locations, 1992.

	Rate of Nitrogen			Difference	
	Low	Med	High	M-L	H-M
Burt County (Fe)					
48 lbs N/ac 4 feet (Expected yield = 135 bu/ac @ 80 lbs/ac)					
Corn after soybeans, non-irrigated					
Applied Nitrogen, lbs/ac	40	80	120	40	40
Grain Yield, bu/ac	147	159	161	12***	2
Grain Moisture, %	21.0	20.7	20.9	-0.3*	0.2
Grain Test Weight, lbs/bu	55.6	55.5	55.6	-0.1	0.1
Burt County (Mo)					
45 lbs N/ac 4 feet (Expected yield = 190 bu/ac @ 150 lbs/ac)					
Corn after soybeans, not irrigated in 1992					
Applied Nitrogen, lbs/ac	110	150	190	40	40
Grain Yield, bu/ac	198	199	200	1	1
Grain Moisture, %	20.3	20.5	20.3	0.2	-0.2
Grain Test Weight, lbs/bu	55.5	55.5	55.5	0	0
Lancaster County (Ba)					
80 lbs N/ac 4 feet (Expected yield = 180 bu/ac @ 150 lbs/ac)					
Corn after corn, not irrigated in 1992					
Applied Nitrogen, lbs/ac	110	150	190	40	40
Grain Yield, bu/ac	189	199	198	10**	-1
Grain Moisture, %	21.7	22.1	21.8	0.4	0.3
Grain Test Weight, lbs/bu	56.3	56.4	56.3	0.1	-0.1

Table 2 Continued

	Rate of Nitrogen			Difference	
	Low	Med	High	M-L	H-M
Saunders County (Ju)					
191 lbs N/ac 4 feet (Expected yield = 120 bu/ac @ 0 lbs/ac)					
Corn after corn, non-irrigated					
Applied Nitrogen, lbs/ac	0	60	100	60	40
Grain Yield, bu/ac	153	153	157	0	4
Grain Moisture, %	18.2	18.1	18.1	-0.1	0
Grain Test Weight, lbs/bu	57.8	57.6	58.0	-0.2	0.4*
Saunders County (Sc)					
216 lbs N/ac 4 feet (Expected yield = 100 bu/ac @ 0 lbs/ac)					
Corn after corn, non-irrigated					
Applied Nitrogen, lbs/ac	0	50	100	50	50
Grain Yield, bu/ac	156	160	169	4	9**
Grain Moisture, %	19.8	19.6	19.7	-0.2	0.1
Grain Test Weight, lbs/bu	56.4	56.6	56.4	0.2	-0.2

*, **, ***: Significantly different @ 0.10, 0.05, and 0.10 probability.

Horizontal Sampling to Assess Agrichemical Movement.

William L. Powers, Patrick Shea, David Marx, and Gary Wieman

Objectives:

1 To develop a technique for taking undisturbed, horizontal soil cores for chemical and physical analysis.

2 To test the hypothesis that horizontal coring is superior to vertical coring for assessing the downward movement of agrichemicals.

Procedure:

Modern agriculture has become very dependent on chemicals. Some of these agrichemicals are now being detected in the nation's ground water supplies. Management practices must be developed to reduce the movement of these agrichemicals to the ground water. To test such practices, soil samples must be taken from various depths below fields and analyzed. However, the variability in the concentration of a chemical at a given depth requires many samples to obtain a mean value that represents the system. The vertical holes drilled to obtain these many samples often alter the natural flow patterns of the research site so that any long-term research might be biased. A sampling technique is needed which has less potential for altering the flow patterns and that will improve the measurement of the depth of movement of these agrichemicals. Horizontal soil sampling might be one such technique.

To meet <u>objective number one</u> horizontal boring equipment was adapted to hold a hollow tube core barrel liner. It was then field tested. Two pits (one on either end of a 20' plot) were dug and the sampling device inserted into the wall of one pit. The horizontal samples were extracted, examined, and determined to be relatively undisturbed. The bore hole was checked to make sure it was horizontal by measuring the depth to the entrance and exit points in the two pits. Horizontal samples were then extracted from three depths and bore hole entrance and exit points measured to make sure they are all in a vertical plane.

The difference in depth of the entrance and exit holes was within a preset tolerance of 7 cm except the top bore hole where a tight layer at 60 cm had forced the core barrel closer to the surface at the exit end of the bore hole. It is felt that this problem could be elevated by putting the bore hole further above (or below) the tight layer in the soil. Examination of horizontal bore holes drilled at three depths showed that they were drilled within 7 cm inches of a vertical plane. Thus, a technique for horizontal drilling is available for testing the hypothesis that horizontal coring is superior to vertical coring for assessing the downward movement of agrichemicals (<u>objective number two</u>).

Water Movement in Soils and Porous Media

D. Swartzendruber

Objective:

The general objective of this report is to analyze and quantify the processes by which water flows into and through porous media and soils under both saturated and unsaturated conditions. Swelling and non-swelling soils are considered.

Procedure:

As far as reasonably possible, each flow process is approached as a mathematical boundary-value problem to be solved by classical mathematical means or by computer if necessary. Experiments are conducted in the laboratory with vertical flow columns on which measurements of water content and soil bulk density are obtained by the attenuation of dual-energy gamma radiation. Other flow measurements are taken as needed.

Results and Discussion:

For downward water infiltration into soil, effort continues on comparing a quasi-solution equation with a very precise computer solution. The goal of the comparisons is to evaluate the accuracy of the quasi solution for describing water infiltration in practical terms, and thus to determine the extent to which the use of the simpler, quasi-solution form is justified. Research also continues on the quantitative manner in which a parameter of the quasi-solution equation depends on the depth of water ponded on the soil surface. This too should assist in assessing the role of the quasi solution in practical infiltration measurements.

For horizontal water movement in unsaturated soil, a recent finding suggests that some soils behave as semi-rigid--a category intermediate between a truly rigid soil and a soil that swells (bulk density decreases) when wetted with water. The semi-rigid behavior is characterized by a time exponent n that is less than the value 1/2 for a classical rigid soil. Effort is underway to determine the actual value of n 1/2 for soils other than the Salkum silty clay loam for which the semi-rigid behavior was first discovered. Also being considered is whether a possible fractal nature of soil is affecting flow behavior.

An empirical infiltration equation, in which cumulative water infiltration is taken as a power function of time, has come to be associated with A.N. Kostiakov. Instead of cumulative infiltration, however, reconsideration shows that it was the hydraulic conductivity which he postulated to be a power function of time. Furthermore, within the setting he posed, there is no rational way of converting the hydraulic-conductivity form to the cumulative-infiltration form. It is therefore recommended that the cumulative-infiltration form be attributed to M.R. Lewis, who made direct and unequivocal use of the cumulative form and appears to have been the first to do so.

A Natural Gradient Transport Study of Selected Herbicides

S. K. Widmer and R. F. Spalding

Introduction

Most pesticide detections in groundwater are in areas most vulnerable to leaching. These areas are characterized as having permeable soils and short distances to groundwater. In Nebraska, 70% of detections are in shallow sand and gravel aquifers that occur in river and creek valleys (2). In recent years, an emphasis on the fate and transport of contaminants in aquifers has become an important area of investigation. Several studies have focused on determinations of movement, retardation, and transformation of chemicals in aquifers, and have provided insight into their *in situ* chemical behavior (1,3,4)

The purpose of my investigation is to determine the behavior of trace quantities of commonly-detected pesticides and their degradates in sand and gravel aquifers beneath agricultural regions. Since trace herbicide quantities are the norm in non-point contaminated groundwater, these experiments relate directly to commonly-occurring groundwater contaminant levels. The behavior of pesticide degradates, whose toxicity and environmental fate are still unknown, may be important since they may become an integral part of the problem.

Experimental Site

The study was conducted in a shallow sand and gravel aquifer near Fremont, Nebraska. The aquifer composition (matrix) is characterized by fluvial deposits of Quaternary Age sands and gravels, representative of that found throughout the Platte River Valley. The measured average rate of groundwater flow at the study site was 15 cm day^{-1} (0.5 ft. day^{-1}.)

A system of multi-level samplers (MLS) was used to delineate the solute plume. Fences of MLSs were arranged in arcs, such that 8 arcs were longitudinally located within the 7.3 meters (24 feet) monitored. Multi-level samplers are constructed as in Spalding *et al.* (5) and are screened at 0.30-meter (1-ft.) depth intervals from 2.7 to 6.1 m (9 to 20 ft.). The injection well was a 10.2 cm (4 in.) diameter schedule 40 PVC pipe screened from 3.7 to 4.3 m (12 to 14 ft.). This well was located 0.9 m (3 ft.) upgradient from the nearest MLS.

Experimental Methods

Injection and monitoring of solutes. Injection studies at the Fremont site were conducted in 1991 and 1992. The 1991 study involved an injection of approximately 15 mg L^{-1} sodium bromide, 3 g L^{-1} atrazine, 2 g L^{-1} alachlor, and 10g L^{-1} cyanazine and metolachlor. A second injection conducted in 1992 included approximately 10 mg L^{-1} sodium bromide, 1 g L^{-1} butachlor, and 3 g L^{-1} atrazine, deethylatrazine and deisopropylatrazine.

The spiking solutions were prepared in the laboratory from pure crystalline or liquid standards in 4 L of distilled, deionized water. These were diluted to approximately 1300 L (350 gal.) in the field using water from a well near the site and mixed constantly. Approximately 950 L (250 gal.) were injected over a 7-10 hour period; a constant rate of injection was attempted. Samples were collected periodically from the pump outlet to determine the exact composition and homogeneity of the solution.

Sample collection from the MLS began 5 hours after start of the injection. Sampling frequency decreased as travel time increased. Samples were obtained using peristaltic pumps; three tube volumes were removed prior to sample collection in one-liter pre-combusted amber glass bottles. Samples were kept on ice until their arrival at the laboratory. Analysis for the bromide tracer was conducted on-site in 1991 to serve as a screening tool for the collection of larger samples for pesticide analysis. Approximately 1000 samples were collected and analyzed for pesticide concentrations for each experiment.

The solute plumes generated by the injections were monitored over a two- and three-month period for the first and second injections, respectively, over which the solutes migrated 7.3 meters (24 ft.) in the longitudinal direction. The plumes remained well-defined throughout the experiments, and ranged less than 2 meters in the lateral and transverse directions.

Frequent sampling allowed the construction of detailed breakthrough curves (plots of concentration as a function of time.) Typical breakthrough curves are shown in Fig. 2. Breakthrough curves broadened as the travel distance and time increased. For a conservative solute, broadening is due to dispersion, and the peak area remains constant. For a non-conservative solute, broadening may be due to physical and chemical interactions, and peak area may be reduced if the solute undergoes transformation and/or nonreversible sorption.

Over 4 million liters (1 million gal.) were pumped from the aquifer upon the completion of the first experiment; approximately 8 million liters (2 million gal.) were removed following the second injection. In both cases, all subsequent samples showed background concentrations of all analytes.

Chemical Analyses. Bromide analysis was conducted using an ion-selective electrode coupled with a single-junction reference electrode. Pesticide analyses were by solid-phase extraction, with solute identification and quantification by GC/MS. Atrazine and its degradates were quantified by isotope dilution using internal standards of ^{13}C-labeled atrazine, deethyl- and deisopropylatrazine (DEA and DIA.) Analyses of blanks and fortified blanks showed that the analytical methodology was quantitative for all analytes without introducing interferences.

Data Analysis. Breakthrough curves were fitted to an asymmetric double sigmoidal model. From the fitted curves, parameters such as the peak area and the time required to reach half-maximum concentration may be easily obtained. Comparison of the breakthrough curves for the conservative tracer (bromide) and each pesticide provides a measure of pesticide retardation in the aquifer. A retardation factor (R) may be calculated as the ratio of the time required for a pesticide to reach half-maximum concentration to that for bromide. Persistence of the injected compounds is indicated by constant peak areas.

Results And Discussion

Retardation. Butachlor was the most highly retarded compound injected (R=1.8). The triazines atrazine and cyanazine (R=1.2) were slightly less mobile than the acetanilides alachlor and metolachlor (R=1.1). The atrazine metabolites showed differing retention behavior; deethylatrazine (R=1.1) was more mobile than atrazine, while deisopropylatrazine (R=1.3) was less mobile. Retardation factors were constant over time and distance for all compounds, and atrazine showed the same retardation behavior in both injection experiments. Laboratory batch equilibration sorption studies and characterization of the aquifer material through particle size, carbon and mineralogical determinations may help explain differing retardation behaviors.

Persistence. No detectable loss of metolachlor, cyanazine, atrazine, DEA or DIA was observed. Atrazine persistence is verified by static levels of the metabolites DEA and DIA. Some loss of parent alachlor was evidenced over a two-month period, since the peak area in a MLS in the final fence was roughly 70% of that in the first fences. This was a significantly greater decrease in peak area than that observed for the conservative tracer, which showed a decrease in peak area of less than 15%.

Butachlor loss was also significant, with the peak area in the fifth fence (after two months) approximately 30% of that in the first MLS.

Conclusions

Differential retardation of structurally-similar compounds was demonstrated. Although the differences in solute transport velocity were small, on the order of 1.5 cm day^{-1} (0.5 in. day^{-1}) for a 0.1 difference in R, such distinctions may be made using a well-defined sampling network, intense sampling, and precise chemical analyses. Since the plumes remained well-defined throughout both experiments, the persistence of the injected herbicides could be estimated from the reduction in area under the breakthrough curves as travel time and distance increased.

This research has demonstrated the utility of *in situ* experiments in determining the transport characteristics and persistence of contaminants under natural aquifer conditions. While such studies are time- and labor-intensive, they are valuable for obtaining reliable estimates of contaminant retardation and transformation under a given set of conditions, necessary for accurate modeling and prediction. An impending characterization of the aquifer material of this study will be useful for modeling as well as contamination prevention and remediation efforts.

References

1 Agertved, J., K. Rügge, and J. F. Barker. 1992. *Transformation of the herbicides MCPP and atrazine under natural aquifer conditions.* Ground Water. 30(4): 500-506.

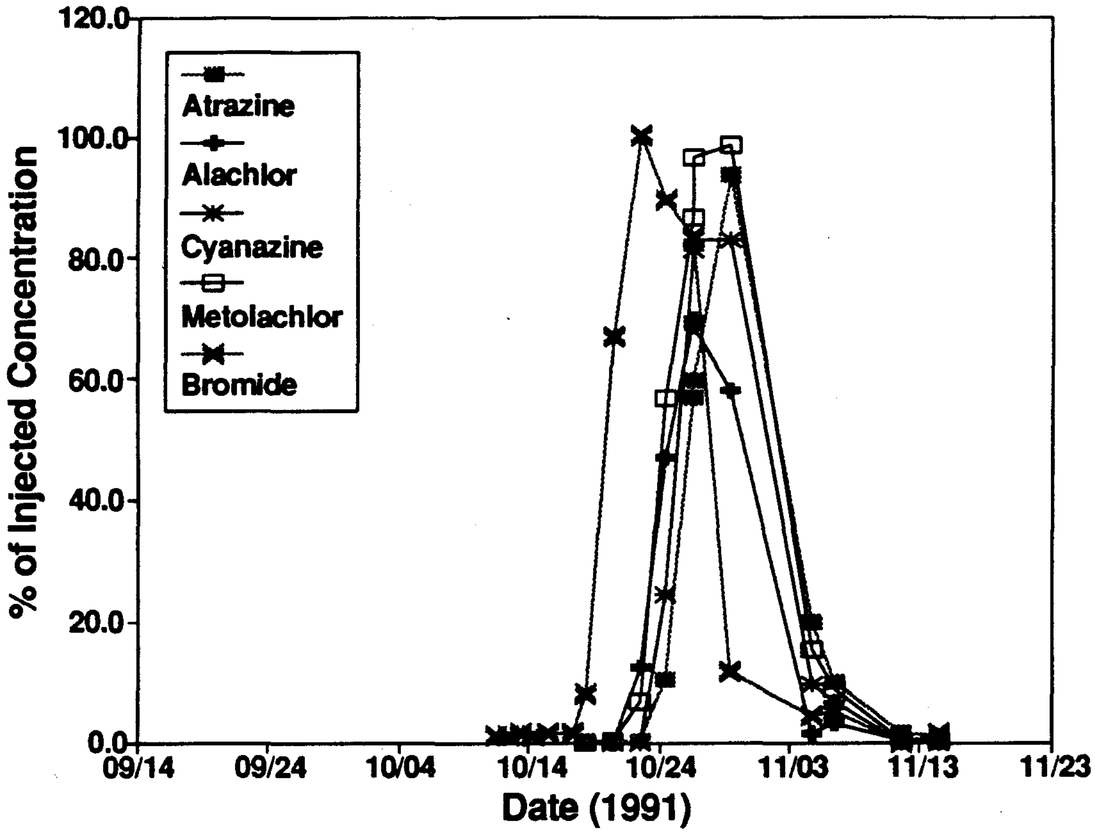
2 Exner, M. E. and R. F. Spalding. 1990. *Occurrence of pesticides and nitrate in Nebraska's ground water.* Water Center, Institute of Agriculture and Natural Resources, Univ. of Nebraska.

3 Mackay, D. M., D. L. Freyberg, P. V. Roberts, and J. A. Cherry. 1986. *A natural gradient experiment on solute transport in a sand aquifer: 1. Approach and overview of plume movement.* Water Resources Research. 22(13): 2017-2029.

4 Roberts, P. V., M. N. Goltz, and D. M. Mackay. 1986. *A natural gradient experiment on solute transport in a sand aquifer: 3. Retardation estimates and mass balances for organic solutes.* Water Resources Research. 22(13): 2047-2058.

5 Spalding, R. F., M. E. Exner, and M. E. Burbach. 1991. *Economical monitoring procedure for assessing agrochemical nonpoint source loading in unconsolidated aquifers.* In R. G. Nash and A. R. Leslie [eds.] *Groundwater Residue Sampling Design.* ACS Symposium Series 465. American Chemical Soc., Washington, D.C.

Figure 1. Breakthrough curves for MLS F13 at a depth of 3.3 m (11 ft.) in 1991 injection.



Tillage, Rotation and N Rate Effects on Dryland Corn Production and Nitrogen Uptake in Northeastern Nebraska

D.T. Walters and C.A. Shapiro

Objectives:

1 To determine the effects of tillage on corn yield when grown in rotation with soybeans or continuously with or without a hairy vetch cover crop.

2 To determine the effect of rotation and cover crop on the status of soil nitrate-N under different tillage regimes.

Procedures:

Three corn crop sequences: continuous corn (CC), corn-soybean (CB) and continuous corn with a hairy vetch (Vicia villosa) cover crop (CCV) were established in 1985 under three tillage systems: spring disk (DK), spring plow (MP) and no-till (NT) at the Northeast Research and Extension Center, Concord, NE. Five N rates (0, 40, 80, 120 and 160 kg N/ha) within each tillage x cropping system were applied annually (1985-88 and 1991-92) to corn as broadcast NH_4NO_3 prior to tillage in the spring. Nitrogen fertilizer has not been applied to soybeans. This experiment was designed as a spit-split plot RCB with tillage as the main plots (100' x 210'), rotations as the sub-plots (100' x 35'), and N rates as the sub-sub plots (20' x 35'). Soil type is a Kennebec silt loam (Cumulic hapludoll).

Nitrogen fertilizer was not applied in 1989 or 1990 as residual fertilizer NO_3-N concentrations had built up to levels exceeding 250 kg N/ha due to drought conditions. Corn (Pioneer 3417, 110d RM) was planted on May 7, 1992 at 44,000 plant/ha in 0.75m rows. Fonofos was applied to all corn for rootworm control at planting. Soybeans (C&D 241) were planted on May 24, 1991. Weeds were chemically controlled on all plots with the addition of a cultivation in the DK and MP treatments on June 3 and 25, 1992. Corn grain was combine harvested from 24m of row on October 30, 1992. Soybeans were combine harvested on October 13.

Hairy vetch had been broadcast into standing corn at a rate of 25 kg seed/ha in August of 1986-1990. No vetch was planted in August of 1993 as this treatment has been discontinued. However, since the CCV treatment has resulted in an accumulation of residual soil NO_3-N, the residual effects this treatment on soil NO_3-N and corn yield are reported here. Residual soil NO_3-N was determined to a 1.5 m depth by sampling each tillage x rotation plot in 30 cm increments in the 0, 80 and 160 kg N/ha treatments. Gravimetric soil water content was also determined within each tillage/rotation treatment at the time of soil NO_3-N sampling (April 29).

Results:

Growing season precipitation (May-Sept) was 11.4" (289mm) above normal in 1992 with very consistent rainfall throughout the months of June, July and August. In addition, heat stress common during the months of July and August was not a problem as average temperatures were approximately 6^{0} F lower that normal. A late spring frost 19 days after planting had no adverse effect on the corn crop. Corn grain yield averaged 7.7 Mg/ha (145 bu/acre) recording the best year of the study. Precipitation for the months of April and May was below normal and soil water content measured on April 29 reflected the previous years tillage and cropping system effects on water use. Soil water content in the spring of 1990 and 1991 was significantly drier under MP than other tillage systems and soil water content overall had not reflected a recharge below the 90 cm depth since the fall of 1988. In the spring of 1992, soil water content was again significantly lower under MP than DK or NT and following the 1991 soybean crop. There was no tillage x rotation interaction for soil water content at any depth. (Figure 1)

Residual soil NO_3-N (RSN) concentrations were significantly reduced by both cropping system and tillage treatment (Figure 2). When compared to the previous spring (1991) RSN levels were reduced for all treatments. RSN levels were less under NT at the 160 kg N ha^{-1} rate reflecting a trend in RSN utilization under NT following the 1988-89 drought years which significantly reduced the amount of RSN under NT. Similarly, RSN levels under the CCV treatment were significantly greater than CC at the 1.2 m depth where 160 kg N ha^{-1} had been applied in 1991. Rotations CB and BC in Figure 2 have received 3 and 2 cycles of N application vs 5 for CC and CCV rotations. These data suggest that RSN is a significant N source for corn under NT in dryland conditions if N fertilization is withheld as in 1989-1990. Also, as rotation of corn with soybean results in less N loading over time, there is less probability of ground water NO_3-N contamination than with continuous corn. RSN levels were lowest under CC for the first time since sampling began in 1988. This reduction is assumed to be due to leaching losses of N as total N removal by CC has consistently been lower than rotated corn. In addition, the lower stover yield of corn would imply less water use and therefore greater potential leaching hazard under CC. Since we began annual soil NO_3-N sampling in 1988, 90% of the RSN in the top 1.5 m of soil has resided in the upper 90 cm indicating very little leaching load. However, in the spring of 1992, that figure has changed to 80% residing in the top 1.2 m indicating appreciable leaching of N below the 90 cm depth.

Corn grain yields in 1992 were an average of 15% higher when rotated with soybean and, where no N fertilizer had been applied, CB averaged 37 bu a^{-1} or 33% greater than CC or CCV. This trend was consistent across tillage treatments. Crop response to N rate averaged 1.75 Mg ha^{-1} (34 bu a^{-1}) up to a rate of 120 kg N ha^{-1} for CC and CCV rotations. Corn response to N fertilization rate following soybean was a mere 0.4 Mg ha^{-1} up to a rate of 80 kg N ha^{-1} (Figure 3). The differences in CC and CCV response curves suggest that RSN may have different use efficiency than fertilizer N as the level of RSN was the only significant difference between CC and CCV rotation plots in the spring of the year. Since the soil profile was drier under CCV, less leaching of RSN occurred following the high rainfall experienced during 1992 growing season. Soybean yields averaged 2.8 Mg ha^{-1} (48 bu a^{-1}) and, as we have experienced since 1986, have not been affected by tillage or previous N rate.

Table 1. Analysis of variance for selected variables, tillage x rotation x N rate. Concord, NE, 1992.

Source	df	Grain Yield	Grain N(%)	Grain N removal	Popu- lation	Stover yield	Stover N(%)	Stover N removal	G/S Ratio	Soybean yield
		Prob > R								
<u>Tillage</u>	2	NS	NS	NS	NS	NS	NS	NS	NS	NS
NT vs REST	1	NS	NS	NS	NS	NS	NS	NS	NS	NS
MP vs DK	1	NS	NS	NS	NS	NS	NS	NS	NS	NS
<u>Rotation</u>	2	0.001	0.001	0.001	.07	0.001	0.001	0.001	0.014	
CB vs REST	1	0.001	0.001	0.001	NS	0.001	0.001	0.001	0.006	
CC vs CCV	1	0.005	NS	0.002	0.046	0.003	NS	0.002	NS	
<u>Till x Rotation</u>	4	NS	NS	NS	.001	NS	NS	NS	NS	
(NTvsREST)x(CBvsREST)		1	NS	NS	NS	.001	NS	NS	NS	NS
(NTvsREST)x(CCvsCCV)	1	NS	NS	NS	NS	NS	NS	NS	NS	
(MPvsDK)x(CBvsREST)	1	NS	NS	NS	.02	NS	NS	NS	NS	
(MPvsDK)x(CCvsCCV)	1	NS	NS	NS	NS	NS	NS	NS	NS	
<u>N Rate</u>	4	0.001	0.001	0.001	0.003	0.001	0.001	0.001	NS	
NR Lin	1	0.001	0.001	0.001	0.025	0.001	0.001	0.001	NS	
NR Quad	1	0.014	NS	0.035	0.001	0.008	NS	NS	NS	
<u>Till x NR</u>	8	NS	0.134	NS	NS	.08	NS	NS	NS	
(NTvsREST)x(NR Lin)	1	NS	0.006	NS	.01	NS	NS	NS	NS	
(NTvsREST)x(NR Quad)	1	NS	NS	NS	NS	NS	NS	NS	NS	
(MPvsDK)x(NR Lin)	1	NS	NS	NS	NS	NS	NS	NS	NS	
(MPvsDK)x(NR Quad)	1	NS	NS	NS	NS	0.02	NS	NS	NS	
<u>Rotation x NR</u>	8	0.004	NS	0.06	NS	0.17	NS	NS	NS	
(CBvsREST)x(NR Lin)	1	0.001	NS	0.001	NS	NS	NS	NS	NS	
(CBvsREST)x(NR Quad)	1	NS	NS	NS	NS	0.01	NS	NS	NS	
(CCvsCCV)x(NR Lin)	1	NS	NS	NS	NS	NS	NS	NS	NS	
(CCvsCCV)x(NR Quad)	1	NS	NS	NS	NS	NS	NS	NS	NS	
Till x Rot x NR	16	NS	NS	NS	NS	NS	NS	NS	NS	

NS = Not significant at P < 0.10

Table 2. **Main effect and 2-way interaction means for corn grain yield, N content, N removal, population and soybean yield, 1992.**

Source	Corn grain yield*	N	Grain N removal	Population	Soybean yield*
	Mg/ha (bu/a)	%	kg/ha	1000/ha	Mg/ha (bu/a)
Tillage					
Disk	7.77(146)	1.41	111	4.59	2.78(48)
Sp. Plow	7.58(143)	1.42	109	4.67	2.97(51)
No-till	7.68(145)	1.40	108	4.80	2.64(45)
Rotation					
Corn/Soy (CB)	8.40(158)	1.48	125	4.74	
Cont. Corn (CC)	7.14(135)	1.36	98	4.58	
Cont. Corn w/vetch (CCV)	7.49(141)	1.39	105	4.74	
Till x Rotation					
Disk CB	8.46(159)	1.48	126	4.55	
CC	7.21(136)	1.35	98	4.55	
CCV	7.68(144)	1.41	109	4.66	
Sp.Plow CB	8.18(154)	1.49	123	4.35	
CC	7.14(134)	1.37	99	4.78	
CCV	7.42(140)	1.40	105	4.90	
No-till CB	8.55(161)	1.48	127	5.32	
CC	7.08(133)	1.25	96	4.40	
CCV	7.41(140)	1.36	102	4.67	
N-rate (kg/ha)					
0	6.85(129)	1.34	93	4.38	
40	7.34(138)	1.35	100	4.74	
80	7.86(148)	1.44	114	4.82	
120	8.15(154)	1.45	118	4.85	
160	8.19(154)	1.47	121	4.65	
Till x N-rate					
Disk 0	6.95(131)	1.38	97	4.36	
40	7.41(140)	1.35	101	4.66	
80	7.93(149)	1.43	114	4.75	
120	8.24(155)	1.44	118	4.63	
160	8.34(157)	1.47	123	4.54	

Table 2. Main effect and 2-way interaction means for corn grain yield, N content, N removal, population and soybean yield, 1992 (Continued).

Source		Corn grain yield*	N	Grain N removal	Popu-lation	Soybean yield*
		Mg/ha (bu/a)	%	kg/ha	1000/ha	Mg/ha (bu/a)
Till x N-rate (Con't)						
Sp. Plow	0	6.65(125)	1.36	93	4.59	
	40	7.27(137)	1.38	102	4.68	
	80	7.85(148)	1.43	113	4.83	
	120	7.92(149)	1.46	116	4.79	
	160	8.20(154)	1.47	121	4.49	
No-till	0	6.94(131)	1.30	91	4.18	
	40	7.35(138)	1.31	97	4.88	
	80	7.78(147)	1.45	114	4.87	
	120	8.30(156)	1.44	120	5.13	
	160	8.05(152)	1.48	120	4.92	
Rotation x NR						
CB	0	8.13(153)	1.41	116	4.49	
	40	8.25(155)	1.44	119	4.77	
	80	8.56(161)	1.52	130	4.83	
	120	8.57(161)	1.51	129	4.80	
	160	8.48(160)	1.54	131	4.82	
CC	0	6.18(116)	1.30	81	4.04	
	40	6.60(124)	1.29	86	4.63	
	80	7.21(136)	1.37	99	4.65	
	120	7.78(147)	1.40	109	5.01	
	160	7.94(149)	1.42	113	4.54	
CCV	0	6.23(117)	1.33	83	4.59	
	40	7.17(135)	1.31	95	4.81	
	80	7.79(147)	1.42	112	4.97	
	120	8.10(153)	1.43	116	4.75	
	160	8.17(154)	1.46	120	4.59	

* Grain yield as Mg/ha is for dry matter yield, bu/A adjusted to 15.5% moisture for corn and 13% for soybeans.

Table 3. Main effect and 2-way interaction means for stover yield, N content, N removal, and G/S ratio, 1992 (Continued).

Source		Stover Yield	N	Stover N Removal	Grain/Stover Ratio
		Mg/ha	%	kg/ha	
<u>Till x N rate (Con't)</u>					
Sp. Plow	0	5.94	0.35	21	1.13
	40	7.56	0.36	27	0.98
	80	7.52	0.40	30	1.05
	120	7.18	0.40	28	1.12
	160	7.30	0.44	32	1.13
No-till	0	5.75	0.37	22	1.24
	40	6.35	0.38	24	1.17
	80	6.79	0.38	26	1.15
	120	7.11	0.43	30	1.21
	160	7.32	0.43	31	1.12
<u>Rotation x N rate</u>					
CB	0	6.64	0.38	26	1.23
	40	6.91	0.40	28	1.22
	80	7.33	0.43	32	1.18
	120	6.97	0.43	30	1.28
	160	7.89	0.45	35	1.09
CC	0	5.39	0.33	18	1.19
	40	6.32	0.33	21	1.06
	80	6.79	0.35	23	1.08
	120	6.72	0.38	26	1.17
	160	6.75	0.40	27	1.18
CCV	0	5.80	0.35	21	1.08
	40	6.89	0.33	23	1.06
	80	7.05	0.40	28	1.12
	120	7.56	0.40	30	1.09
	160	7.15	0.42	30	1.15

Figure 1. Gravimetric soil water content, spring 1992, with statistically significant single degree of freedom contrasts for the tillage and rotation main effects.

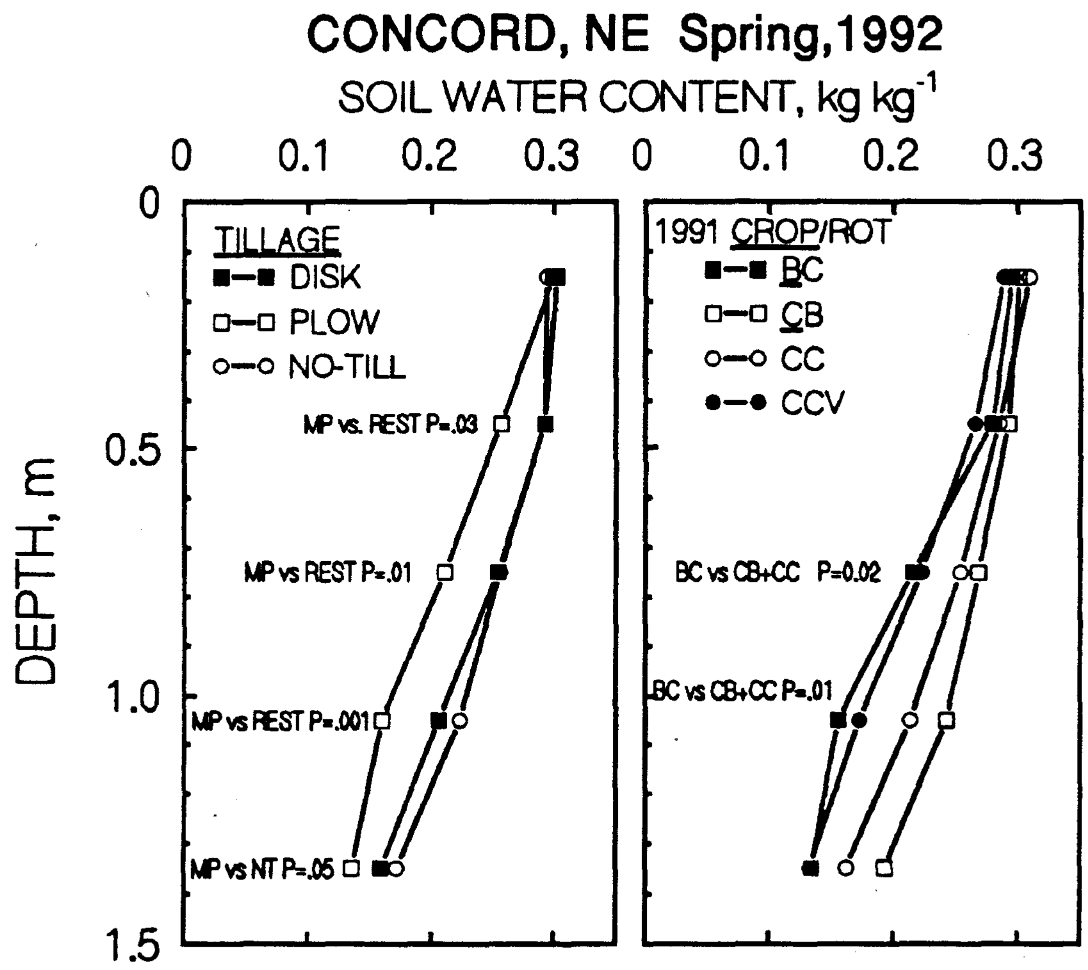
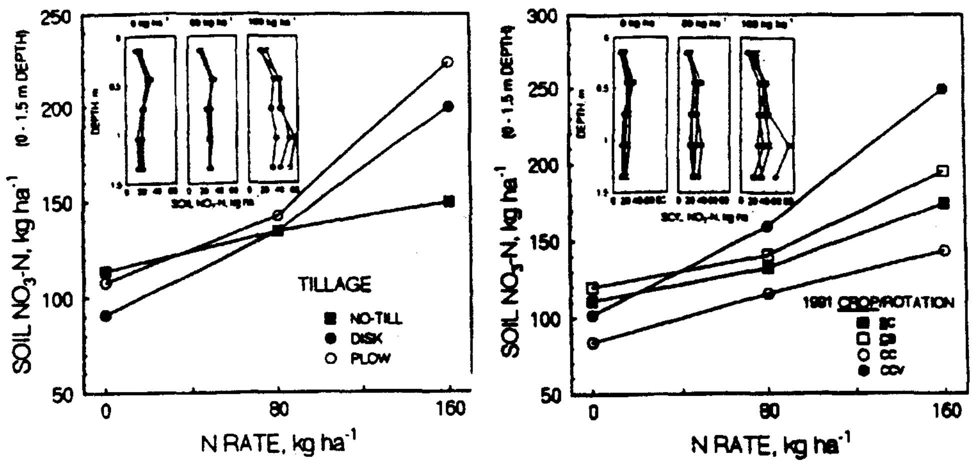
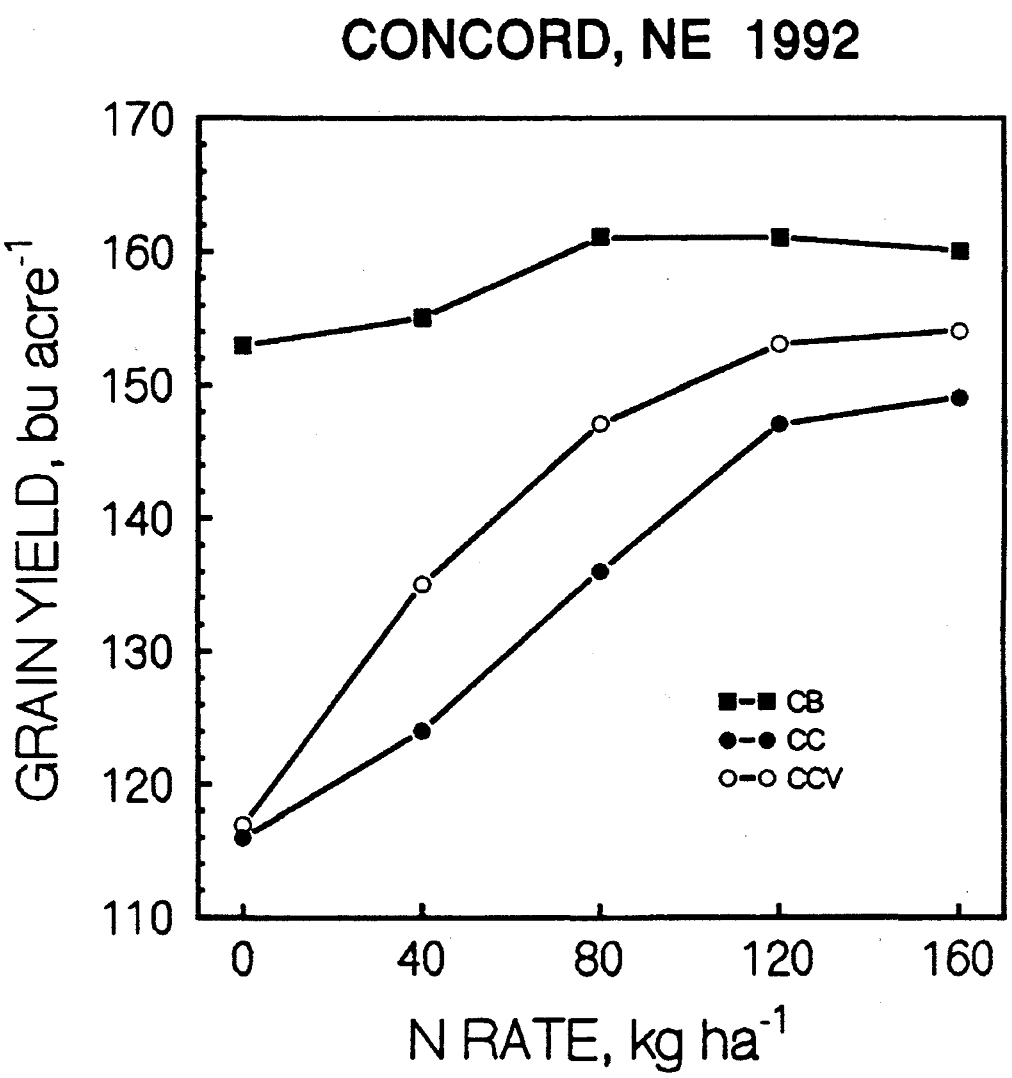


Figure 2. Residual soil NO3-N to a depth of 1.5 m, spring 1992.



Source	df	Analysis of Variance
		---- Prob > F ----
Tillage	2	NS
NT vs REST	1	NS
DK vs MP	1	NS
Rotation	3	.03
CC vs CCV	1	.004
CB vs CC	1	NS
CB+BC vs CC+CCV	1	NS
N rate	2	0.001
N Lin	1	0.001
Till x Rotation	6	NS
NT vs REST x (CC vs CCV)	1	NS
x (CB vs CC)	1	NS
x(CB+BCvsCC+CCV)	1	NS
DK vs MP x (CC vs CCV)	1	NS
x (CB vs CC)	1	NS
x (CB+BC vs CC+CCV)	1	NS
Rotation x NR	6	0.34
CC vs CCV x (NRL)	1	0.03
CB vs CC x (NRL)	1	NS
CB+BC vs CC+CCV x (NRL)	1	NS
Till x NR	4	.12
NT vs REST x (NRL)	1	0.012
DK vs MP x (NRL)	1	NS
Till x Rotation x NR	12	NS

Figure 3. Corn grain yield as influenced by N fertilization rate and rotation, Concord, NE, 1992.



Quantifying Nitrate Leaching Under Continuous Corn Versus a Corn-Soybean Rotation

Gary W. Hergert, Norman L. Klocke, and Joel P. Schneekloth

Objectives:

1 Quantify mineral nitrogen leaching losses on a year around basis for continuous no-tillage corn and for no-till corn and soybeans in a corn-soybean rotation.

2 Quantify the portion of residual nitrate from corn fertilization that is taken up by the following soybean crop or corn crop to determine rotation nitrogen use efficiencies.

Results and Discussion

Field and Equipment Characteristics

Fourteen monolithic percolation lysimeters were installed and instrumented for soil water extraction during 1989 and 1990 in the cropping systems experiment at the WCREC at North Platte. The lysimeters are 3 feet in diameter and 8 feet deep. The 80 by 80 foot plots have been in their respective crop rotations for 8 years. The plot area is irrigated with a solid set sprinkler system. There are six replicated plots of continuous corn and four replicates of the corn-soybean rotation (8 plots) with each crop present each year. The soil is a structured silt loam (Cozad silt loam-Fluventic haplustoll). Soil water content in the field and in the lysimeters is measured weekly with neutron attenuation. Soil temperature is measured by thermocouples installed at 6 depths in four lysimeters and the field. Rain gauges and a weather station were located in the experiment area to track evapotranspiration with the modified Penman method. Fully irrigated crop yields have been measured since 1985 and soil samples to a 4 foot depth were taken each season following harvest and analyzed for nitrate-N from all replicates.

Crop Yield

The 5 year average corn yield (1988-1992) for continuous corn was 183 bu/A whereas corn in the corn-soybean rotation yielded 193 bu/A. This was statistically significant rotation effect (PrF=.05). The five year soybean yield was 60 bu/A. The five year average fertilizer N rate for continuous corn was 195 lb/A and for corn following soybean was 165 lb/A. The yearly N loading for corn-soybean was less than half of continuous corn.

Soil Nitrate

Residual soil nitrate-N was significantly lower in the corn-soybean rotation compared to continuous corn even though there was year to year variation (Table 1). Soil nitrate levels are low compared to many production fields but have not affected crop yields. The levels show that proper nitrogen fertilizer management can reduce carryover nitrate-N which will ultimately influence long term nitrate leaching potential.

Leaching Losses

Irrigation management has reduced leaching losses but leaching has occurred. Spring precipitation has caused most of the leaching. Soil water losses from continuous corn were higher than from the corn-soybean rotation (Table 2). Soybean left the soil drier at the end of the season than corn even with close irrigation scheduling, consequently leaching losses from corn following soybean were lower than following corn (Table 2).

The soil in the lysimeters was taken from the borders of the plots where the lysimeters were installed. The residual nitrate levels in these columns showed an average of 275 lb nitrate-N in the top 4 feet and 140 lb nitrate-N/A in the 4 to 8 foot depth. The lysimeter leaching losses measured during 1991 and 1992 were influenced by lower crop yields in these border areas in previous years. These areas received the same N rate as the main plot but did not receive as much irrigation which caused the higher residual nitrate levels. In spite of this fact, the leaching losses from the corn-soybean rotation were lower than continuous corn (Table 3). The values represent what might be expected with current best management practices, but may be high due to leaching of previous residual nitrate.

Flow-weighted soil water nitrate-N concentrations (Table 4) are high compared to drinking water standards but show what is normal in a crop production situation. The encouraging fact, however, is that during the last year nitrate-N concentrations in soil water have been steadily declining reflecting the influence of more closely matched production, N rates and irrigation (Fig. 1, 2, 3).

Table 1. Soil nitrate-N following continuous corn or corn-soybean.

	Continuous Corn	Corn in corn-soybean	Soybean in corn-soybean
	lb/A in 4 feet		
1988	30	53	53
1989	62	36	34
1990	77	54	36
1991	97	43	25
1992	69	55	39
avg.	67	48	37

Table 2. Soil water losses from lysimeters in continuous corn or corn-soybean.

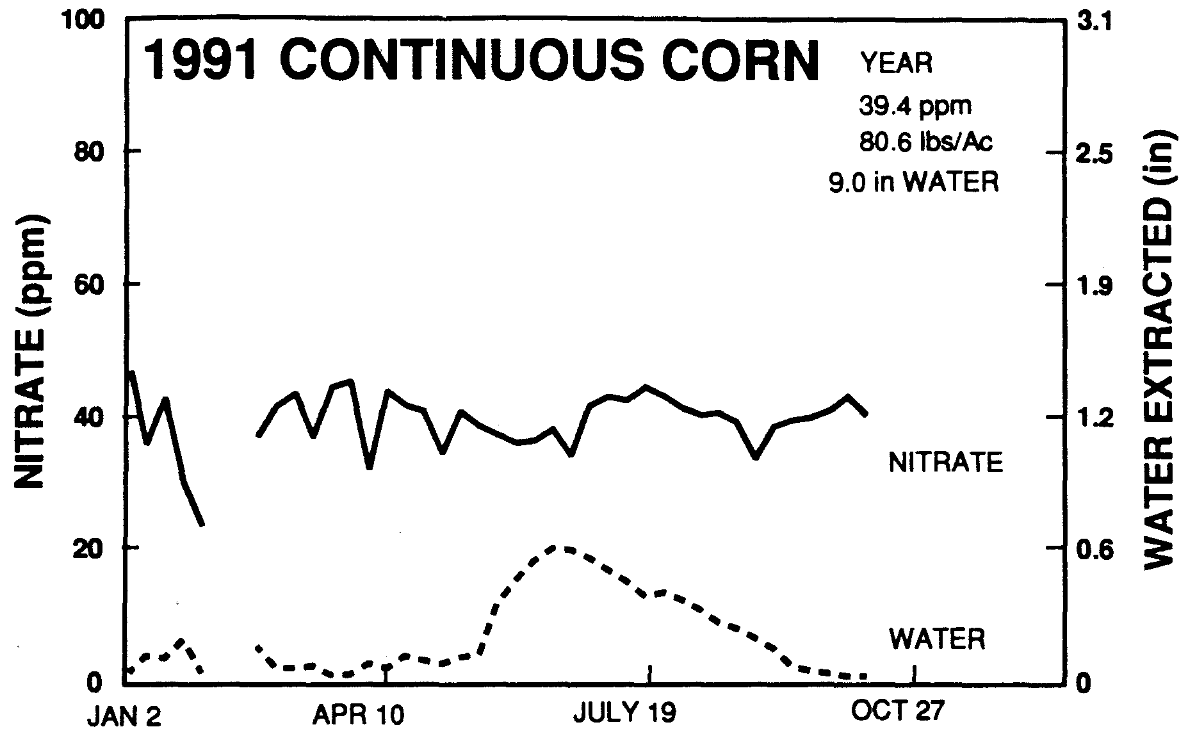
	Continuous corn	Corn-soybean rotation	Corn in corn-soybean	Soybean in corn-soybean
	inches			
1991	9.0	4.5	0.8	8.2
1992	10.4	7.7	6.2	9.2
avg.	9.7	6.1	3.5	8.7

Table 3. Nitrate-N losses from lysimeters in continuous corn or corn-soybean.

	Continuous corn	Corn-soybean rotation	Corn in corn-soybean	Soybean in corn-soybean
	lb/A			
1991	81	37	16	57
1992	71	82	43	121
avg.	76	59	29	89

Table 4. Flow-weighted soil water nitrate-N from lysimeters in continuous corn or corn-soybean.

	Continuous corn	Corn-soybean rotation	Corn in corn-soybean	Soybean in corn-soybean
	ppm			
1991	39	33	89	30
1992	30	47	30	58
avg.	35	43	37	45



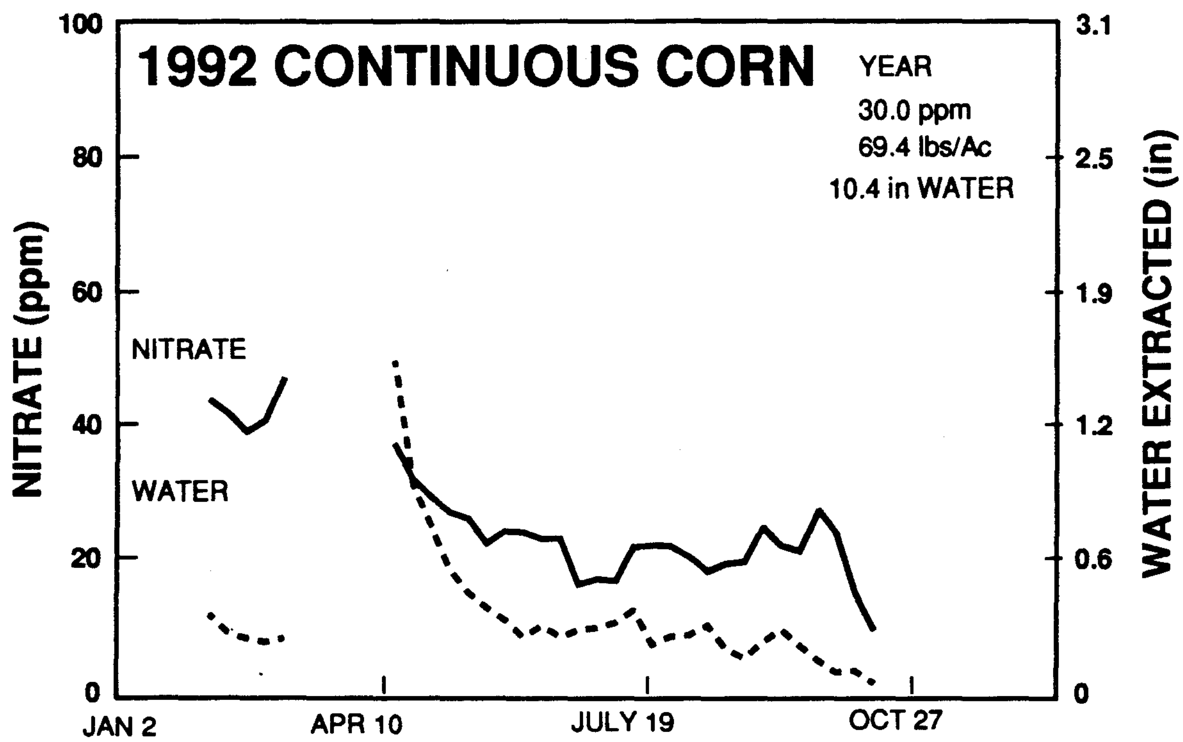


Fig. 1. Soil water and nitrate-N in soil water extracted from lysimeters in continuous corn.

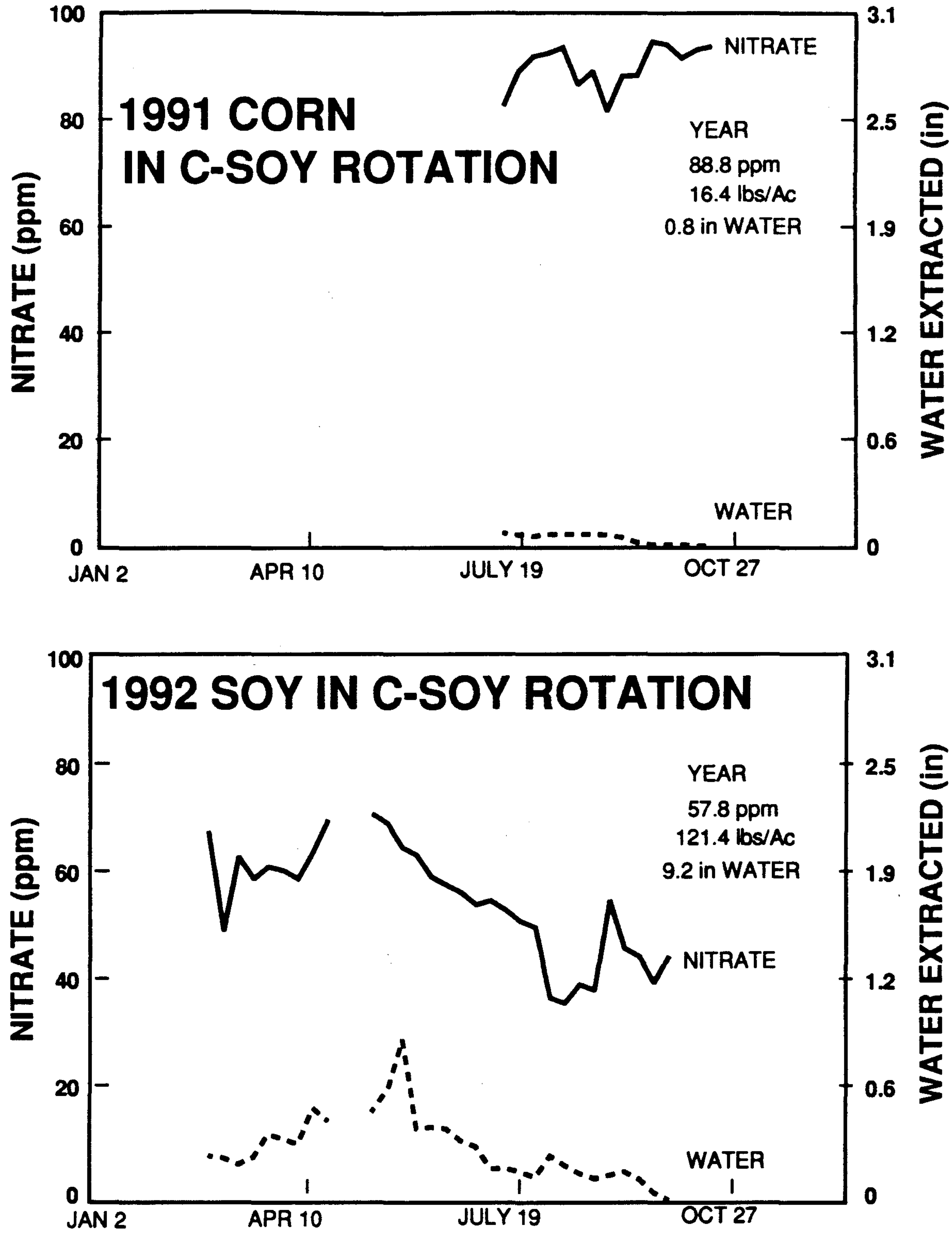
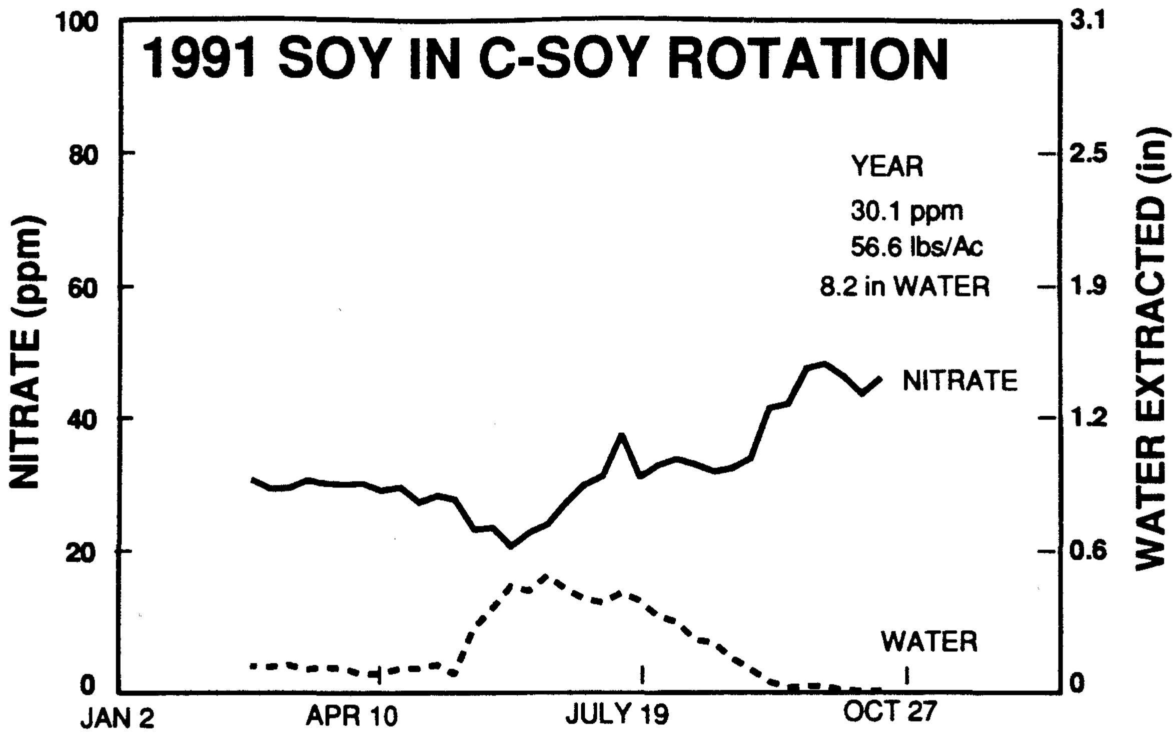


Fig. 2. Soil water and nitrate-N in soil water extracted from lysimeters in corn in the corn-soybean rotation.



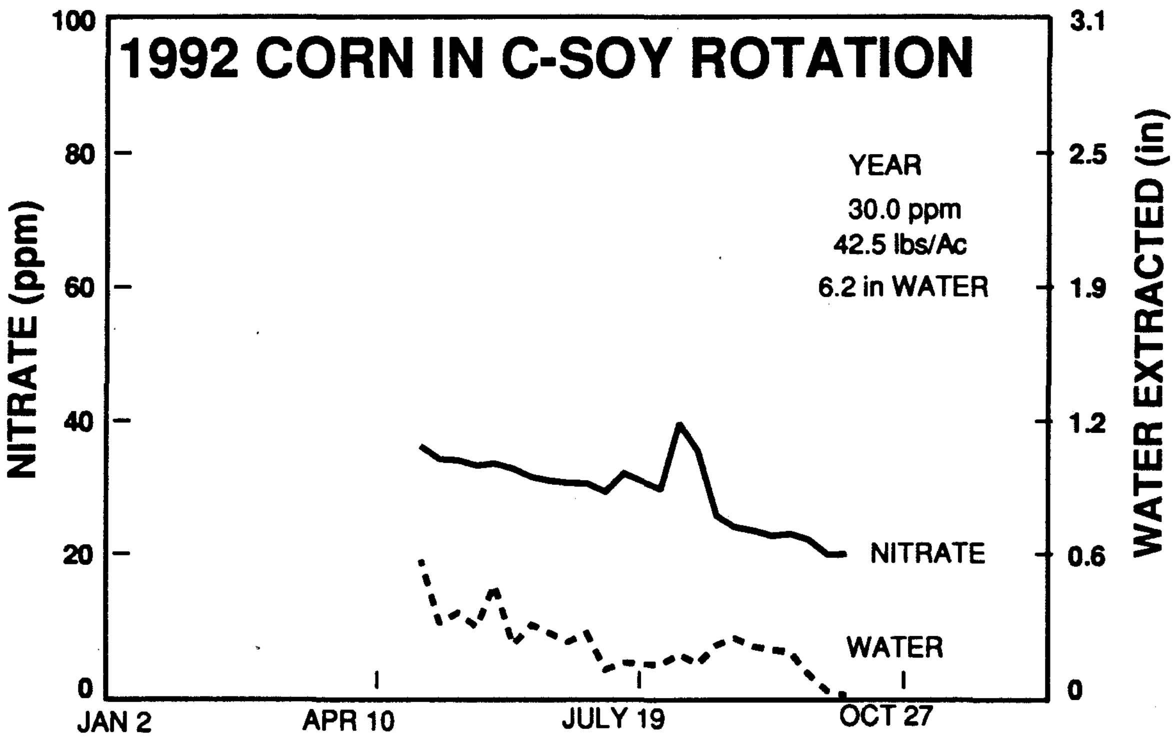


Fig. 3. Soil water and nitrate-N in soil water extracted from lysimeters in soybean in the corn-soybean rotation.

Cover Crop Dry Matter Production for Several Planting and Harvest Dates

J. F. Power

Objectives:

To compare growth rate and dry matter production for several planting and harvest dates for crop species that may be used from cover crops.

Procedure:

Rye and a number of legume species were grown for four years at the Agronomy Farm near Lincoln. In all years these species were planted after corn in either spring (April 27-May 17) or summer (June 25-July 14). Above ground growth was harvested July 3-11, August 8-13, and after the first killing frost each year, and dry weights were determined.

Results and Discussion:

When cover crops are used, information is needed on the relative growth rates of potential species for the time of the year during which the cover crop will be grown. Unfortunately there is little published literature that provides information on side-by-side comparisons of growth of different species. This lack of information prompted this study.

A number of different species were evaluated each year. Because of wide variation in growing conditions among years, data are given for only those species grown three or more years. Often summer drought restricted germination and initial growth for the mid-summer seeding. Consequently in most years there was no significant growth by August sampling date to permit measurement of dry weights. Thus only dry weights after frost are reported for the mid-summer planting.

Average dry matter production for species produced for three years are given in Table 1. For the spring planting, dry matter production by soybean was outstanding throughout the entire season. However at the July sampling, dry matter production by both field peas and hairy vetch surpassed that of soybean. While these same two species plus sweet clover exhibited good growth by the August sampling, dry weights for soybean at this time were 1000 to 2000 kg ha^{-1} greater, however. Likewise for the fall sampling, soybean dry weights were almost double those of the next best species - hairy vetch and crimson clover. For the mid-summer planting, again soybean exhibited greatest growth by time of frost, followed by hairy vetch and alfalfa. Rye seeded at either of these dates exhibited only modest growth rates in comparison to the above legumes.

Table 2 provides similar data for those species grown all four years. Results were similar to those for the three year average (Table 1) in that soybean was a leading producer in all years. For spring growth (to the July sampling) field peas and hairy vetch were also productive. At later samplings, hairy vetch continued to exhibit good growth, but much less than soybean. For the summer seeding, soybean, hairy vetch, and alfalfa were best for dry matter production.

These results suggest that hairy vetch is relatively well adapted for growth in this region regardless of planting or harvest date. For spring plantings, field peas or soybean would also be a good choice. If the spring seeded cover crop is to remain on the land beyond early July, soybean would definitely be first choice. If the cover crop is to be planted in mid-summer (such as after wheat harvest), again soybean and hairy vetch would be good selections. Alfalfa (especially non-dormant cultivars) might also be considered.

Table 1. Average (3 year) dry weight of cover crops at several planting and harvest periods.

Planting:	4/27 - 5/17			6/25 - 7/14
Harvest:	7/3-11	8/8-13	Fall+	Fall
	dry weight, $kgha^{-1}$			
Soybean	1230	4580	6450	2360
Field pea/AWP++	1860	2070**	M***	940
Hairy vetch	1490	3590	3960	1760
Alfalfa*	490	1610	2050	1600
Rye	830	1350**	1190	1050
White clover	340	870	1210	160
Sweet clover	950	2110	2520	710
Crimson clover	830	1810**	3300	500
LSD0.05	200	450	630	240

\+ After Frost
++ Austrian winter pea
* cv Perry and Salton
** 2 year average (matured in one year)
*** Matured 2 or more years by harvest

Table 2. Average (4 year) dry weight of cover crops at several planting and harvest periods.

Planting:	4/27 - 5/17			6/25 - 7/14
Harvest:	7/3-11	8/8-13	Fall+	Fall
	dryweight, kg ha^{-1}			
Soybean	1500	6820	7080	2000
Field pea/AWP++	1880	2520	M**	920
Hairy vetch	1440	4270	4190	1940
Alfalfa*	410	1830	2170	1670
Rye	1220	1740	M	1150
LSD0.05	190	570	680	230

+ After Frost
++ Austrian winter pea
* cv Perry and Salton
** 2 year average (matured in one year)
*** Matured 2 or more years by harvest

Nutrient and Mass Loss of Beef Feedlot Manure During Composting

B. Eghball, and J. F. Power

Objective:

The objective of this study was to determine the amount of nutrient and mass loss during composting of beef feedlot manure under field conditions.

Introduction

Composting manure is a useful method of producing a stabilized product that can be stored or spread with little or no fly breeding potential. Other advantages of composting include killing pathogens and weed seeds, and improving handling characteristics by reducing its weight, volume and associated odors. Nutrient loss, specifically nitrogen (N), reduces potential of compost as a plant nutrient source. Quantification of amount of nutrient and mass loss during composting is important for understanding the composting process and implementing methods for conservation of nutrients, and reducing potential adverse environmental impacts.

Procedure:

Beef feedlot manure was composted in a windrow on a concrete area at the University of Nebraska Agricultural Research Center near Mead. The area was enclosed on all sides with metal sheets, 0.2 m high, to prevent runoff loss. Runoff and leachate from the composting manure during rainfall were collected in a plastic tank (4000 liters in capacity) through drainage pipes. The amount of solution in the tank was determined and a representative sample was taken within 24 h after each rainfall event for chemical analysis. Electrical conductivity, pH, organic carbon (C), nitrate, ammonium, total N, total P, K, Na, Mg, and Ca of the samples were determined. A rain gage was placed in the experimental area to determine the amount of rainfall after each occurrence. A sample of rain water was also collected as background for the chemical properties tested. Dry weight of the material being composted was determined at the beginning and at the end of the process. Total amounts of mass and nutrient lost during composting was determined by the difference between the amounts at the beginning and at the end of the composting period. The amount of manure and nutrient loss by runoff was determined by measuring amounts in the leachate. A model-3 CSIRO data logger with 6 temperature sensors was used to determine the temperature of the composting manure at three depths of 0.25, 0.55, and 0.85 m within the pile. The composting row was about 1 m high. The material was mixed with a front-end loader every 7-10 d or as required based on moisture and temperature status of composting material.

Results And Discussion

Nutrient contents of beef feedlot manure before and after composting are given in Table 1. The manure mass loss during 110 days of composting was 20% of total mass (Table 2). The mass loss was lower than the normal range of 35-50% because the C:N ratio of the manure used was 12:1 which was narrower than the usual 20:1 or wider. Carbon source was not added to the composting manure because we decided to compost the manure as was removed from the feedlot. Volume loss during composting was about 30% as approximated visually. Nitrogen loss during composting was 42.5% of the total manure N (Table 2). Of the total amount of N lost, 3.2 % was removed by runoff and 96.8% was apparently volatilized. Volatilization of N as ammonia seems to be the major mechanism for N loss during composting. Some loss of N as a result of denitrification during composting has also been reported. However, denitrification requires the manure to be saturated and since we kept the composting manure at 40-60% moisture throughout the period, denitrification of N was probably minimal. Phosphorus loss during composting was 37.6 % of total manure P. Runoff accounted for 90% of the P lost, with the remainder (10.0%) unaccounted for. Unlike N, runoff loss is the main mechanism of P loss during composting. Potassium and Na loss during composting were 16.5 and 24% of manure K and Na, respectively. Calcium and Mg loss in runoff was low (% each), but , there was some increase in the total amount of Ca after composting. The extra amount was probably added to the compost by the well water used to keep the composting pile moist. Temperature reached 60 ^{o}C (140 ^{o}F) within 24 hours of starting the composting process at all depths within the compost pile. Temperature within the composting pile was not affected by time of the day as the temperature remained constant all day, even at 0.25 m depth. Temperature remained around 55-65 ^{o}C until day 65 of the composting period. By day 68, the temperature decreased to 40 ^{o}C (104 ^{o}F) indicating the end of the thermophilic process. After this, the pile was no longer turned, and the material was allowed to cure for an additional 43 days. During this time, the temperature of the composting material was near the ambient. The composted material was then applied to the field.

Table 1. Concentration of nutrients in the feedlot manure before and after composting in the open in 1992.

Variable	Total N	NO_3-N	NH_4-N	P	K	Na	Ca	Mg
	$mg\ kg^{-1}$							
Initial manure	15160	27	848	5358	11231	2262	10234	4180
Composted	10945	117	165	4180	11771	2157	17932	5567

Table 2. Mass and nutrient balance of beef feedlot manure composted in the field in 1992.

Variable	Mass	N	P	C	K	Na	EC*	Ash
	Kg						$S\ m^{-1}$	%
Initial manure	7002	106.1	37.5	1384	78.6	15.8	1.21	58.7
Composted manure	5575	61.0	23.3	533	65.6	12.0	0.74	80.8
Total loss	1427	45.1	14.2	851	13.0	3.8	--	--
Runoff loss	50	1.5	12.8	8	5.3	1.4	--	--
	%							
Total loss**	20.4	42.5	37.9	61.5	16.5	24.1	--	--

* Electrical conductivity was measured on 2:1 manure or compost to water ratio; $S\ m^{-1}$=10 mmho cm^{-1}.

** As a percentage of the amount in initial manure

Effect of Residual Phosphorus Bands on Crop Yield and Their Persistence in the Soil

Mohammed A. Zerkoune, D.H. Sander and C.A. Shapiro

Objectives

1 to determine the residual value of undisturbed P fertilizer bands over 4-year period.

2 to develop strategies to evaluate such bands for fertilizer recommendation adjustment.

Procedures

A long term experimental site was selected in the fall of 1988 on an eroded Sharpsburg sicl in Lancaster County growing continuous wheat from 1988 to 1990 and growing sorghum in 1991-92. Soil was selected for low P availability (8 mg P kg^{-1} Bray and Kurtz no 1).

Treatments were established to provide an evaluation of banded P applied 1, 2, 3 and 4 years. Four P rates were applied (7.5, 15, 22.5 and 30 kg P/ha on the Sharpsburg soil) as ammonium polyphosphate (10-34-0, N-P-K) with four replications in a complete randomized block design. The 1992 data represents sorghum grain yield following a single P application in 1988, 1989, 1990 and 1991; two year cumulative applications in 1988, 1989, 1990 and 1991; three year cumulative applications in 1988, 1989, 1990, 1989, 1990 and 1991; and four year cumulative applications in 1988, 1989, 1990 and 1991. Phosphorus fertilizer was knifed into the soil to a depth of about 10 cm in 38 cm spacings. Bands were marked with nylon twine attached to the applicator's knife and placed in the band along the length of the plot. In 1988, bands were marked with wire flags on both ends of plot.

Ammonia was applied to provide a total of 120 kg N ha^{-1}. Tillage was limited to disking for wheat during 1989 and 1990 growing seasons and no till the last two years. Weeds were controlled with herbicide. Plant samples were collected at flowering stage on 60 cm of row, and analyzed for total P. Yield results in 1992 represented the fourth and final year for the experiment.

Soil was sampled in August 1992. Nine soil cores 1.8 cm apart, 20 cm deep by 5 cm increment were taken across the P band using a template constructed to provide continuous sampling across the band. Two additional cores were taken outside the band area (14 cm from each side of the band). Each soil sample was a composite of four soil cores from four repeated template samples. In addition ten soil cores were taken at random from a depth of 20 cm to form a composite sample for each treatment. All soil samples were air dried and ground to pass 2 mm sieve and analyzed for Bray and Kurtz #1 P.

A modified exponential decay model was used to describe the lateral P movement from the band center. Nonlinear regression was used to obtain an equation to describe the nature of the P band.

$$P = \alpha \exp(-\beta d) + C$$

Where P = soil test value, d = lateral distance from the band, α and β are curves fitting parameters and C = soil test value outside the band.

Soil P values obtained from both sides of the band were averaged to determine the equation.

The expected mean P soil test as affected by year and rate of application was calculated by dividing the integrated exponential equation by the band spacing, but both values are shown in Figure 1.

Results and Discussion

Grain yield

Sorghum grain yield was affected by both the rate and year of P application. Yield was increased from 8.6 Mg ha^{-1} when no fertilizer P was added to 10.8 Mgha^{-1} when 30 kg P ha^{-1} were applied annually from 1988 to 1991 (Table 1). Fertilizer P knifed in the soil in the fall of 1990 and 1991 performed similarly in 1992 sorghum yield. When comparing P banded once and P banded repeatedly, yield response was greater with latter, indicating P residual effects due to previous applications. A Bray and Kurtz P from 10 random samples indicated a significant increase in Bray and Kurtz values when fertilizer P was knifed repeatedly (Table 4). Bands applied in both 1988 and 1989 or in 1990 only, performed equally in term of grain yield indicating that the residual P applied in 1988 and in 1989 might be as effective as a single application in 1990. When comparing yield response from three cumulative P applications in 1988, 1989 and 1990, to a single application in 1991 or to two year applications in 1990 and 1991, similar yield was obtained. This indicates that applying P in three consecutive years, 1988, 1989 and 1990 will result in P availability build up that is as effective as applying P in 1991 only or 1990 and 1991. Finally, the residual value of P added in 1988 may not be effective since yield obtained from four year P applications 1988 to 1991 and from three year P application are not significantly different at the 10 percent level.

Plant Uptake

Early plant and grain uptake was increased linearly with P rate application. Bands applied in 1988 and 1989 did not affect early plant uptake, but those applied in 1990 and 1991 did increase early plant uptake from 12.8 kg P ha^{-1} when no P was applied to 14.9 and 14.8 kg P ha^{-1} when P was applied in 1990 and 1991, respectively. The cumulative effect of multiple P application on early plant and grain uptake was similar to grain yield.

When comparing the 1991 band with the 1990 and 1991 band application, the latter resulted in significantly higher plant uptake (14.8 and 16.9 kg P ha^{-1} for early plant uptake). For the same year comparison, grain P uptake increased from 28.4 kg P ha^{-1} to 30.1 kg P ha^{-1}, but was not significantly different.

The residual effect of any multiple applications result in higher early plant and grain uptake than any single P application, with the exception of 1988 and 1989, which did not surpass the 1990 nor 1991 P application. Moreover, the significance of the residual P value can be appreciated when comparing the 1991 P application to 1988, 1989 and 1990, which are found to be equally effective in plant uptake.

Soil Analysis

The residual values of the band sampled at the end of harvest shows the effect of both time and rate of application on P residual in the band. The results indicate that the cumulative application of fertilizer favored the residual buildup of P in the band area. Four cumulative years of fertilizer application resulted in higher available P than any single, two or three combined applications. Similarly when comparing the single application in 1991 to two consecutive applications in 1990 and 1991, the latter resulted in higher available P (Table 4). Moreover, a significant increase of available P was observed when three or four year fertilizer applications were averaged across P rates. The fertilizer P banded in 1988 or 1989 did not show any increase in P availability.

Sampling the P band indicated the soil affected area had not changed appreciably in size over time in Sharpsburg Soil (Fig 1). The P distribution near the band is well described by a modified exponential decay model with R^2 of 0.97 or higher for the 30 kg P ha^{-1} rate. For bands applied at 30 kg P ha^{-1} in 1988 and for the 7.5 kg P ha^{-1} rate had R^2 of about 0.80. Low R^2 are obviously to be expected when bands are no longer present.

The 7.5 kg P ha^{-1} rate always resulted in small band size. The 30 kg P ha^{-1} band applied in 1989, 1990 and 1991 have very high residual. The 1989 is nearly equal to the 1991 band. The 30 kg P ha^{-1} band applied, in 1988, appears to have been mixed with disking prior planting in fall of 1989. This treatment will be re-sampled.

Table 1 Residual effect of deep banding of fertilizer P on sorghum grain yield on Sharpsburg Soil in 1992

P Rate	1988	1989	1988 89	1990	1991	1988 89-90	1990 91	1989 90-91	1988 89-90 91	Mean
	Year of application									
	Mg ha^{-1}									
0										8.6
7.5	8.2	8.8	8.5	8.6	9.2	9.2	9.7	9.8	10.2	9.1
15	8.8	9.2	9.4	9.6	9.5	10.3	9.7	9.9	10.3	9.6
22.5	9.2	9.6	9.8	9.9	10.2	10.3	10.8	11.4	10.8	10.2
30	10.0	9.6	9.6	11.0	10.7	10.1	10.7	11.5	11.9	10.6
Year mean	**9.1**	**9.3**	**9.3**	**9.8**	**9.9**	**10.0**	**10.2**	**10.7**	**10.8**	

LSD comparison for year of application

1988	-	ns	ns	*	*	*	*	*	*
1989		-	ns	*	*	*	*	*	*
1988-89			-	ns	*	*	*	*	*
1990				-	ns	ns	ns	*	*
1991					-	ns	ns	*	*
1988-89-90						-	ns	*	*
1990-91							-	ns	*
1989-90-91								-	ns

Source of variation	Analysis of variance
	Prob > F
Rate (R)	0.0001
lin	0.0001
quad	0.8779
Year of Application(Y)	0.0001
Y*R	0.8611

* = Significant at 10 % level; ns = non significant.

Table 2 Residual effect of deep banding of fertilizer P on sorghum grain P uptake on Sharpsburg Soil, 1992

	Year of application									
P Rate	1988	1989	1990	1988 89	1991	1990 91	1988 89-90	1989 90-91	1988 89-90 91	mean
	kg ha^{-1}									
0										23.3
7.5	24.6	24.5	24.5	27.4	25.9	27.0	29.3	26.2	25.5	26.1
15	25.8	23.0	25.8	26.6	25.6	30.2	30.9	28.4	29.0	27.3
22.5	28.8	27.6	28.2	30.3	28.2	31.0	32.7	36.1	35.2	31.0
30	28.7	29.8	31.4	28.7	33.7	32.5	29.5	35.8	38.2	32.0
Year mean	**26.8**	**26.2**	**27.5**	**28.3**	**28.4**	**30.1**	**30.7**	**31.6**	**31.8**	

LSD comparison for year of application

1988	-	ns	ns	ns	ns	*	*	*	*
1989		-	ns	ns	ns	*	*	*	*
1990			-	ns	ns	*	*	*	*
1988-89				-	ns	ns	*	*	*
1991					-	ns	*	*	*
1990-91						-	ns	ns	ns
1998-89-90							-	ns	ns
1989-90-91								-	ns

Source of variation Analysis of variance

	Prob > F
Rate (R)	0.0001
lin	0.0001
quad	0.9959
Year of Application(Y)	0.0001
Y*R	0.3056

* = Significant at 10 % level, ns = non significant

Table 3 Residual effect of deep banding of fertilizer P on sorghum early plant P uptake on Sharpsburg Soil, 1992

P Rate	Year of application									
	1988	1989	1988 89	1990	1991	1988 89-90	1990 91	1989 90-91	1988 89-90 91	Mean
	kg ha^{-1}									
										12.8
7.5	10.6	12.0	11.4	11.9	12.6	12.1	12.2	14.4	12.5	12.2
15	12.8	12.9	12.9	13.7	14.4	14.6	17.6	16.4	17.7	14.8
22.5	14.0	12.9	15.7	15.7	15.2	15.4	16.2	19.4	20.6	16.1
30	16.4	15.4	17.9	18.3	16.7	17.8	19.9	17.7	21.2	17.9
Year mean	**13.4**	**13.3**	**14.5**	**14.9**	**14.7**	**15.0**	**16.7**	**16.9**	**18.0**	

LSD comparison for year of application									
1988	-	ns	ns	*	*	*	*	*	*
1989		-	ns	*	*	*	*	*	*
1988-89			-	ns	ns	ns	*	*	*
1990				-	ns	ns	*	*	*
1991					-	ns	*	*	*
1988-89-90						-	ns	*	*
1990-91							-	ns	*
1989-90-91								-	ns

Source of variation	Analysis of variance
	Prob > F
Rate (R)	0.0001
lin	0.0001
quad	0.2464
Year of Application(Y)	0.0001
Y*R	0.1639

* = Significant at 10 % level, ns = non significant

Table 4 Year and rate of P application on P availability as extracted by on Bray & Kurtz P in 1992

P Rate	Year of application 1988	1989	1990	1991	1988 89	1990 91	1989 90-91	1988 89-90 91	1988 89-90	Mean
	mg kg^{-1}									
0										7 . 8
7.5	9.0	8.2	8.4	8.7	8.3	10.6	8.9	10.1	8.3	8.9
15	7.9	8.3	8.9	9.8	7.9	11.9	11.0	11.6	9.2	9.6
22.5	9.3	9.3	10.2	8.6	10.0	13.9	13.1	13.7	17.8	11.8
30	9.6	9.6	8.4	9.1	18.5	10.9	17.5	18.6	20.2	13.6
Year mean	**8.9**	**9.8**	**9.0**	**9.1**	**11.2**	**11.8**	**12.6**	**13.5**	**13.9**	

LSD comparison for year of application

1988	-	ns	ns	ns	*	*	*	*	*
1989		-	ns	*	*	*	*	*	*
1990			-	ns	*	*	*	*	*
1991				-	ns	ns	ns	*	*
1988-89					-	ns	ns	*	*
1990-91						-	ns	*	*
1989-90-91							-	ns	ns
1988-899-90								-	ns

Source of variation	Analysis of variance Prob > F
Rate (R)	0.0001
lin	0.0001
quad	0.3686
Year of Application(Y)	0.0001
Y*R	0.0140

* = Significant at 10 % level, ns = non significant

Table 5 Exponential decay model for determining residual P fertilizer band in Sharpsburg sicl soil

P rate kgha^{-1}	year of appl.	Parameters α	β	C	R^2	Soil test mg P kg^{-1} δ	δδ
0		-	-	5.5	-	-	-
	1988	2.669	0.219	5.0	0.78	6.6	9.0
	1989	2.898	0.555	4.6	0.80	5.3	8.2
7.5	1990	2.110	1.998	6.4	0.94	6.5	8.4
	1991	2.755	1.348	6.0	0.83	6.3	8.7
	1988	2.673	0.798	8.0	0.88	8.4	9.6
	1989	21.065	1.099	6.0	0.92	8.5	9.6
30	1990	25.390	1.425	6.2	0.98	8.6	8.4
	1991	26.260	2.086	8.1	0.99	9.8	9.1

Model $P = \alpha^* \exp(-\beta^* d) + C$; α, β = curve fitting parameters, C = P, value outside the band
δ = calculated P value when dividing the integrated exponential function over the band spacing
δδ measured P value from a composited 10 random samples

Comparison of Erosion Rates Estimated Using the Cesium-137 Methods and USLE

T. Oztas, A.J. Jones, L.N. Mielke and R.B. Grossman

Objectives

To develop a depth dependent model for predicting soil erosion from ^{137}Cs activity and to compare model results with the proportional method and Universal Soil Loss Equation (USLE).

Procedure

Research was conducted on a 6.5 ha cultivated field approximately 20 km east of Lincoln, NE. Slopes on this Sharpsburg silty clay loam (Typic Argiudoll) ranged from 2 to 9%. The field was divided into a grid pattern having 6 cells in the N-S direction and 10 cells in the E-W direction. Each cell area was 30.5 x 30.5 m^2. A soil core, 40 cm in length and 6.4 cm diameter, was extracted from each grid point using a hydraulic soil sampler. Each core was divided into 10 cm increments and analyzed for ^{137}Cs activity at the Water Quality and Watershed Research Laboratory, Durant, OK. Concurrently, three soil cores were also extracted from a noneroded nontilled grassland site having a Sharpsburg silty clay loam soil and located 14 km from the research site. This grassland site served as our reference location to determine the baseline ^{137}Cs activity in the area.

Annual erosion rates for C and D slopes, 2-5% and 5-9% respectively, were estimated using residual ^{137}Cs activity in soil profiles and by the USLE.

Cesium-137 Methods

Proportional Method

The proportional method assumes that ^{137}Cs is distributed uniformly throughout the entire tillage layer and that the amount of ^{137}Cs lost with eroded soil was directly proportional to the depth of tilled soil removed by erosion (2). Annual erosion rate estimated by the proportional method is:

$$A = \frac{^{137}Cs_r - {}^{137}Cs_e}{^{137}Cs_r} \times d_t \times q_b \times 100/t$$

where

A = annual erosion rate, Mg ha^{-1} y^{-1}

$^{137}Cs_r$ = total ^{137}Cs activity in surface 20 cm of the reference sites, Bq m^{-2}

$^{137}Cs_e$ = total ^{137}Cs activity in surface 20 cm of eroded sites, Bq m^{-2}

d_t = depth of tillage, cm (20 cm)

q_b = bulk density, Mg m^{-3} (1.04 Mg m^{-3})

t = years elapsed since the beginning of major deposition period (1960-1987).

Parabolic Method

The parabolic method developed in this research assumes that the depth distribution of ^{137}Cs in the reference site at the time of sampling in 1987 was the same as the original depth distribution of ^{137}Cs at the research site in 1960. Depth of soil lost from the eroded research site since 1960 was predicted by solving a cubic equation based on the cumulative ^{137}Cs activity of the reference site. The third-order polynomial is:

$$Y = a_0 + a_1X^3 + a_2X^2 + a_3X$$

where

Y = cumulative ^{137}Cs activity at eroded sites, Bq m^{-2}

X = soil depth lost, cm

a_0 = cumulative ^{137}Cs activity in the reference site, Bq m^{-2}

a_1, a_2, and a_3 = regression coefficients,

Once the depth (d) of soil lost is estimated, the annual erosion rate (E) is calculated using the bulk density of the surface soil and the time that has elapsed since the beginning of major deposition of ^{137}Cs.

$$E = \frac{d \times q_b}{t} \times 10000$$

where

E = annual erosion rate, Mg ha^{-1} y^{-1}

d = depth of soil lost, m

q_b = bulk density, Mg m^{-3}

t = years elapsed between the beginning of deposition period of fallout Cs^{137} and soil sampled (1960-1987).

Universal Soil Loss Equation (USLE)

The Universal Soil Loss Equation (USLE) was developed to estimate the longtime average soil losses by sheet and rill erosion from specific field areas in specific cropping and management systems by Wichmeier and Smith in the late 1950s. The USLE is

$$A = R\,K\,LS\,C\,P$$

where

A = annual erosion rate, Mg ha^{-1} y^{-1}

R = a factor for annual rainfall erosivity, MJ mm ha^{-1} h^{-1} y^{-1},

K = a factor for soil erodibility, Mg ha h ha^{-1} MJ^{-1} mm^{-1},

LS = a factor for slope length and slope steepness (topographic factor),

C = a factor for cover and management,

P = a factor for conservation practices.

Results and Discussion

The baseline ^{137}Cs activity in the area was 4260 Bq m^{-2}. About, 80% of ^{137}Cs remained in the surface 10 cm depth. Only 5% of ^{137}Cs activity was below 15 cm. Eroded site grid points, C and D slopes, had less ^{137}Cs activity than the reference value. Average ^{137}Cs activity was 1672 Bq m^{-2}. Approximately 65% of ^{137}Cs activity was in the top 10 cm and 30% was in the 10 to 20 cm soil layer.

The proportional method assumes that ^{137}Cs activity is uniform within the tillage layer and that all ^{137}Cs is within the tillage depth. However, the depth distribution pattern of ^{137}Cs in eroded sites showed that most ^{137}Cs was in the top 10 cm and decreased rapidly with soil depth. ^{137}Cs has not been mixed homogeneously to a depth of 20 cm over the past 27 years because of changing tillage practices. Plowing, used in the early years after fallout, began to incorporate ^{137}Cs to 20 cm; however, disking to 5-10 cm has been routinely used in recent years. In addition, ^{137}Cs was found below the depth of tillage. As a result, the assumption of the proportional method were not valid for our study.

Since similarity in the depth distribution patterns of ^{137}Cs activity in the reference and eroded sites, it would seem that after a long period (20-30 years) the vertical distribution of ^{137}Cs in a reference site could be assumed to be similar to the initial depth distribution of ^{137}Cs in a cultivated field. Difference in cumulative ^{137}Cs activity between the two sites was primarily attributed to erosion. Thus, soil loss estimations were considered using parabolic method based on cumulative ^{137}Cs activity curves of the reference and eroded sites.

The depth of soil lost from eroded C and D slope sites were estimated about 5.5 cm for C slopes and 7.5 cm for D slopes using the parabolic method (Fig. 1). Equivalent annual erosion rates were 21.1 and 28.8 Mg ha^{-1} y^{-1} for C and D slopes, respectively, as compared to 41.2 and 51.4 Mg ha^{-1} y^{-1} using the proportional method. On the average, annual erosion rate for the research field was estimated 24.7 Mg ha^{-1} y^{-1} and 47 Mg ha^{-1} y^{-1} by the parabolic and proportional method, respectively.

Annual erosion rates by the USLE for C and D slopes were 15.8 and 35.4 Mg ha y^{-1} for C and D slopes respectively (Table 1). Average erosion rate for the field was 25 Mg ha^{-1} y^{-1}. Comparison of erosion rates by the ^{137}Cs methods and USLE are given in Fig.2. It shows that annual erosion rates may be predicted more closely to the USLE by the parabolic approach than the proportional method.

Literature Cited

1 **Borchers, G. A., D. Witte, S. Hartung, and J. D. Overing.** 1984. Soil Survey of Cass County Nebraska U. S. Dept. Agric. Washington, D. C.

2 **De Jong, E., C. Wang, and H. W. Rees.** 1986. Soil redistribution on three cultivated New Brunswick hillslopes calculated from ^{137}Cs measurements, solum data, and the USLE. Can. J. Soil Sci. 66:721-730.

3 **Jones, A.J., and W.G. Hance.** 1988. Universal Soil Loss Equation: a handbook for Nebraska producers. Nebraska Cooperative Extension Service. EC 88-116.

4 **Wischmeier, W.H., and D.D. Smith.** 1978. Predicting rainfall erosion losses-a guide to conservation planning. U.S.D.A. Agriculture Handbook No. 60.

Figure 1. Estimating depth of soil lost using the parabolic method.

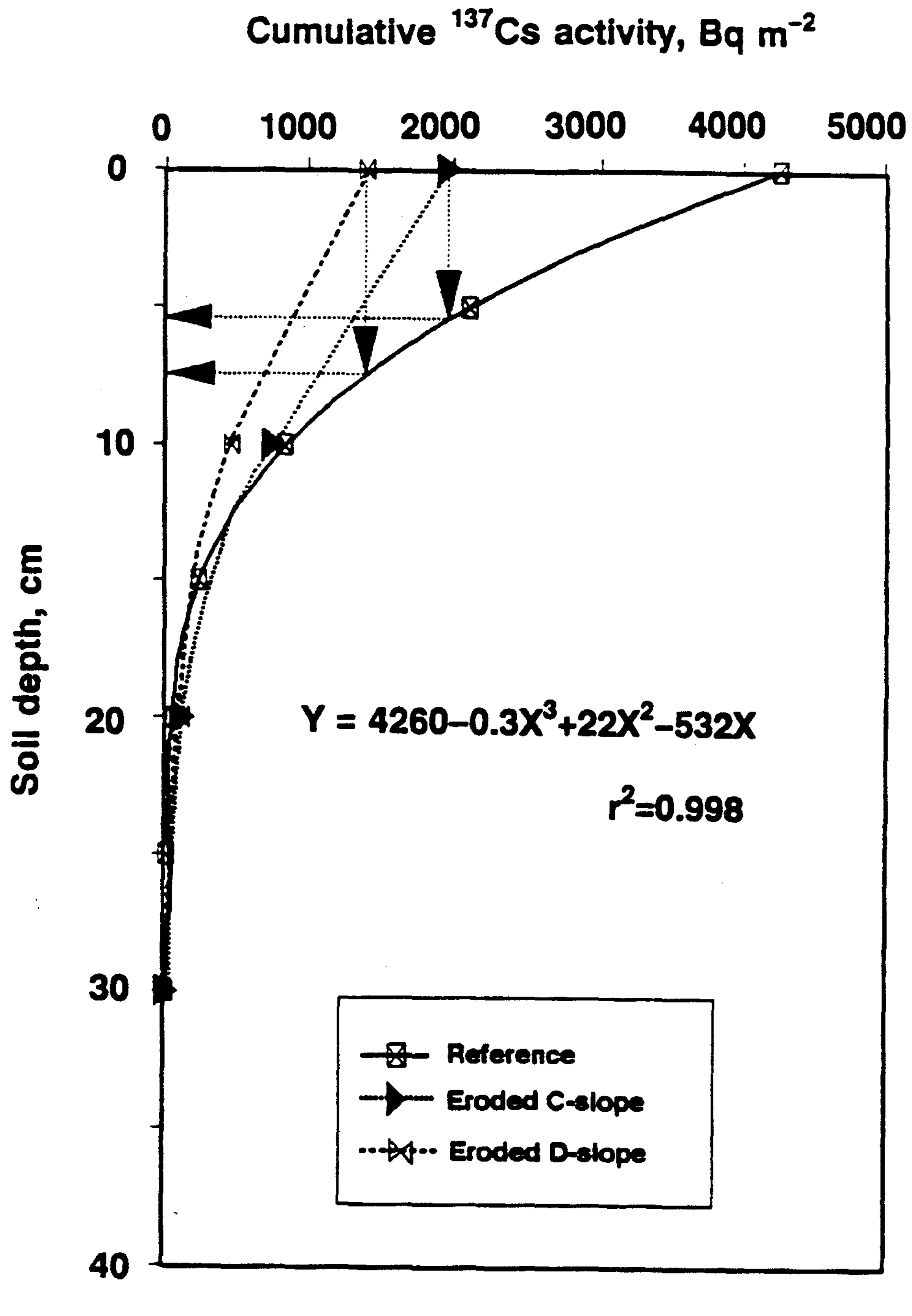


Figure 2. Comparison of annual erosion rates estimated by the ^{137}Cs methods and USLE.

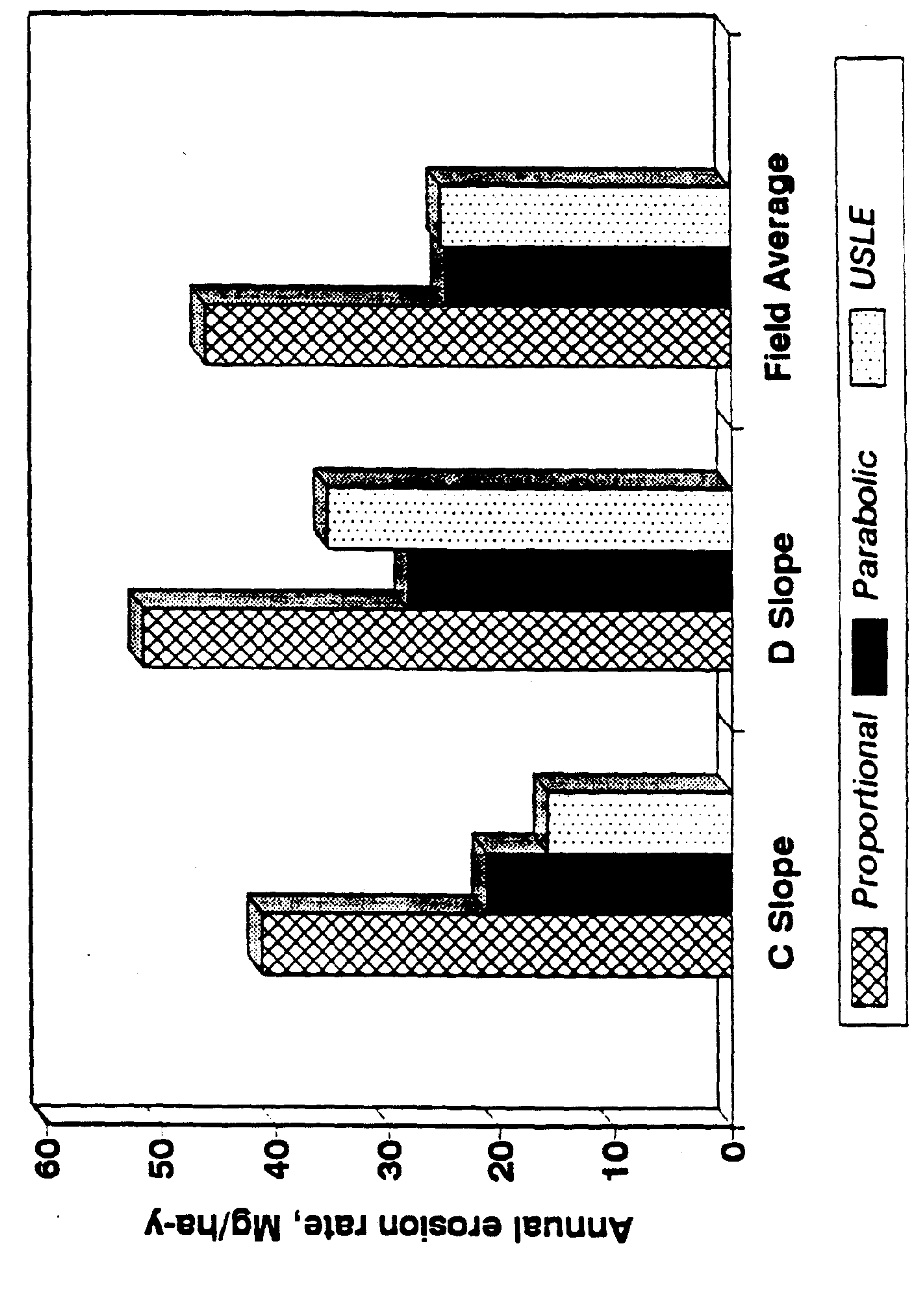


Table 1. Annual erosion rates estimated by the USLE.

Period	R [a] MJ mm ha^{-1} h^{-1} y^{-1}	K [b] Mg ha h ha^{-1} MJ^{-1} mm^{-1}	L m	S %	LS [c]	L m	S %	LS	Rotation	Residual	C	P	Erosion Rate Mg ha^{-1} y^{-1} (C-slopes)	Erosion Rate Mg ha^{-1} y^{-1} (D-slopes)
1960-69	2979	0.042	200	4	0.528	200	7	1.18	Wheat/Corn (Sorghum)	Clean till	0.25	1.0	16.5	36.9
1970-79	2979	0.042	200	4	0.528	200	7	1.18	Wheat/Corn (Sorghum)/ Soybean	Clean till	0.28	1.0	18.5	41.3
1980-87	2979	0.042	200	4	0.528	200	7	1.18	Wheat/Corn (Sorghum)/ Soybean	Minimum till (Row crop) Clean till (wheat)	0.19	1.0	12.5	28.0
Average, Mg ha^{-1} y^{-1}													15.8	35.4
Field Average, Mg ha^{-1} y^{-1}													25.0	

Erosion Patterns Using Geostatistical Analysis of ^{137}Cesium

T. Oztas, A.J. Jones and C. Gotway

Introduction

The application of Geostatistics can be used wherever a continuous measure is made on a sample at a particular location in space, and where a sample value is expected to be affected by its position and its relationships with its neighbors (1).

The first step of geostatistical study is to define the spatial dependence of the variable of interest. A semivariogram can be used to describe this spatial variation. It expresses the spatial dependence as a function of the distance between the pairs of samples (lag). The semivariance, $\gamma(h)$, for the sampling interval h is given as: (2)

$$\gamma_* (h) = \frac{1}{2N(h)} \Sigma \left[Z(x_i) - Z(x_i + h) \right]^2$$

where

N(h) = the number of experimental pairs separated by a distance h,

$z(x_i)$ = measured sample value at point i,

$z(x_i + h)$ = measured sample value at point i+h.

In general, as the separation distance between pairs increases, the semivariogram value for the corresponding distance increases. At one point, an increase in the separation distance no longer causes an increase in the semivariance, and the semivariogram value becomes more or less constant. The value at which the graph flattens is called the sill of the semivariogram. The maximum separation distance where the semivariogram reaches its sill defines the range of influence over which samples of the variable are spatially dependent. When the distance of sample separation is zero, the semivariogram must always pass through the origin. However, many soil properties have nonzero variances (4) as the distance tends to zero. This nonzero variance is called the nugget variance. The difference between sill variance and nugget variance is called spatial variance.

The second step, kriging, spatial interpolation technique, provides the best linear unbiased predictor of a property at unsampled locations based upon the degree of spatial dependence between sampled sites.

Objectives

To quantify the spatial distribution of ^{137}Cs using geostatistical techniques and to identify erosion patterns within the field.

Procedure

The research site was a 6.5 ha cultivated field in western Cass County, NE. The soil was Sharpsburg silty clay loam (Typic Argiudoll) with slope ranging from 0 to 9%.

The research field was gridded on the square at a 30.5 m intervals. A soil core, 40 cm deep and 6.4 cm diameter, were collected using a truck mounted hydraulic probe at each grid point. Soil samples were sectioned into 10 cm increments and analyzed for ^{137}Cs at he Water Quality and Watershed Research Laboratory (ARS), Durant, OK. Cumulative ^{137}Cs activity at a grid point was obtained by integrating ^{137}Cs activity values through the soil profile to a depth of 40 cm.

Annual erosion rates were estimated using the parabolic method by assuming that the present (1987) depth distribution pattern of ^{137}Cs in the reference sites was similar to the initial (1960) depth distribution of ^{137}Cs in the research field.

The experimental semivariogram model was exponential with isotropic geometry for data used in this study. The general form of the exponential model with a nugget variance is: (3)

$$\gamma(h) = C_0 + C\,[1 - exp\,(-h/A_0)\,]$$

where

h = distance parameter controlling the spatial extent of the function (lag interval)

C_0 = nugget variance,

C = spatial variance, and

A_0 = range of influence parameter.

The fitted models were considered in block kriging. ^{137}Cs activity estimates were obtained at 3.8 m intervals (1/8 of the full cell length) using the maximum 9 nearby data points.

The GS$^+$ geostatistical software (2) was used to develop the semivariograms and kriging processes.

Results and Discussion

The normal plot in the UNIVARIATE procedure showed that the ^{137}Cs data were normally distributed with the exception of 4 outliers. Therefore, the experimental semivariograms were performed using the untransformed data.

The directional semivariograms were calculated at angles of 0^o (north to south), 45^o (northeast-southwest), 90^o (east-west) and 135^o (southeast-northwest) and a maximum distance of 30.5 m between sampled points (Fig.1). There was no distinct differences in the structure in the four direction for the lags less than 213 m, which was equal to 60% of the maximum distance of 356 m. Therefore, distribution of ^{137}Cs was assumed isotropic, and a single semivariogram analysis was performed. The exponential model was the best fit with a r^2=0.922 (Fig.2).

$$\gamma(h) = 1000 + 733400\,[1 - exp\,(-h/16)]$$

The nugget variance, intercept, which was 0.15% of the sill suggests that spatial variance accounts for most of the variation in the ^{137}Cs activity within the field.

The exponential model indicates a continuous process, therefore there is no limit to the spatial dependence of ^{137}Cs (5). However, the practical range in the exponential model is assumed $3A_0$, at which the model includes 95% of the sill (3).

The range of influence of the exponential model was 48 m. It implies that samples separated by a distance less than 48 m are spatially related. Conversely, samples separated by distances greater than 48 m are not spatially related to each other.

After the spatial structure was identified, block kriging was performed to interpolate ^{137}Cs values for unsampled locations at 3.8 m intervals (1/8 of the full cell length) and using the maximum 9 data points. Kriging estimates at the original sample points were compared to corresponding observed values. Estimated values were very close to observed values at 95% of the time. The sum of the differences between observed values and kriging estimates was nearly zero.

The second objective of this study was to identify the erosion patterns within the field. For this purpose, block kriging estimates were mapped based upon the depth of soil lost estimated using the parabolic method.

^{137}Cs activity remaining in the field was between 491 and 4900 Bq m^{-2}. The reference ^{137}Cs activity was 4260 Bq m^{-2}. The depth of soil lost by erosion estimated by the parabolic method varied from 0 to 12.5 cm among the cells. Distributions of the depth of soil lost by erosion is shown in Fig.3. The white areas on the distribution maps show the most severely eroded parts of the field. However, dark colored areas indicate the cells with high ^{137}Cs activity. It is very clear to see the erosion patterns within the field, especially the gully which lies from the north center of the field to the northwest corner.

Finally, an erosion pattern based upon the depths of soil lost was drawn (Fig.4). This pattern may be used as a reference for the future studies conducted in the same research field and management decisions.

References Cited

1 **Clark, I.** 1979. Practical geostatistics. Applied. Sci. Publ. LTD. London.

2 **Gamma Design Software.** 1992. GS^{+} geostatistics for agronomic and biological sciences. Version 2.10. Michigan.

3 **Journel, A. G., and CH. J. Huijbregts.** 1978. Mining geostatistics. Academic Press.

4 **Trangmar, B. B., R. S. Yost, and G. Uehara.** 1985. Application of geostatistics to spatial studies of soil properties. Advances in Agronomy. 38:45-92.

5 **Webster, R., and M. A. Oliver.** 1990. Statistical methods in soil and land resource survey. Oxford University Press.

Figure 1. Directional semivariograms of cumulative ^{137}Cs activity.

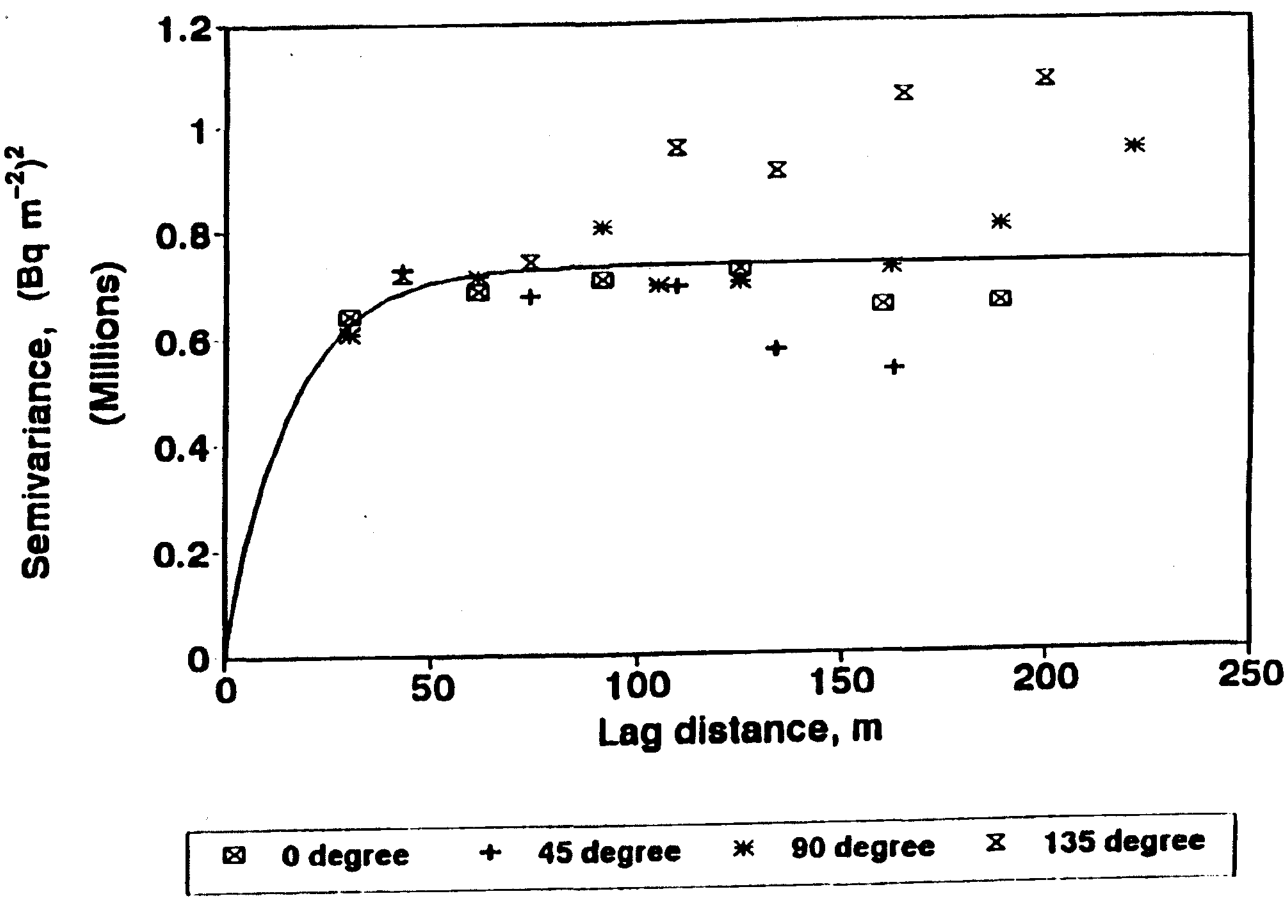


Figure 2. The exponential semivariogram model with isotropic geometry for cumulative ^{137}Cs activity.

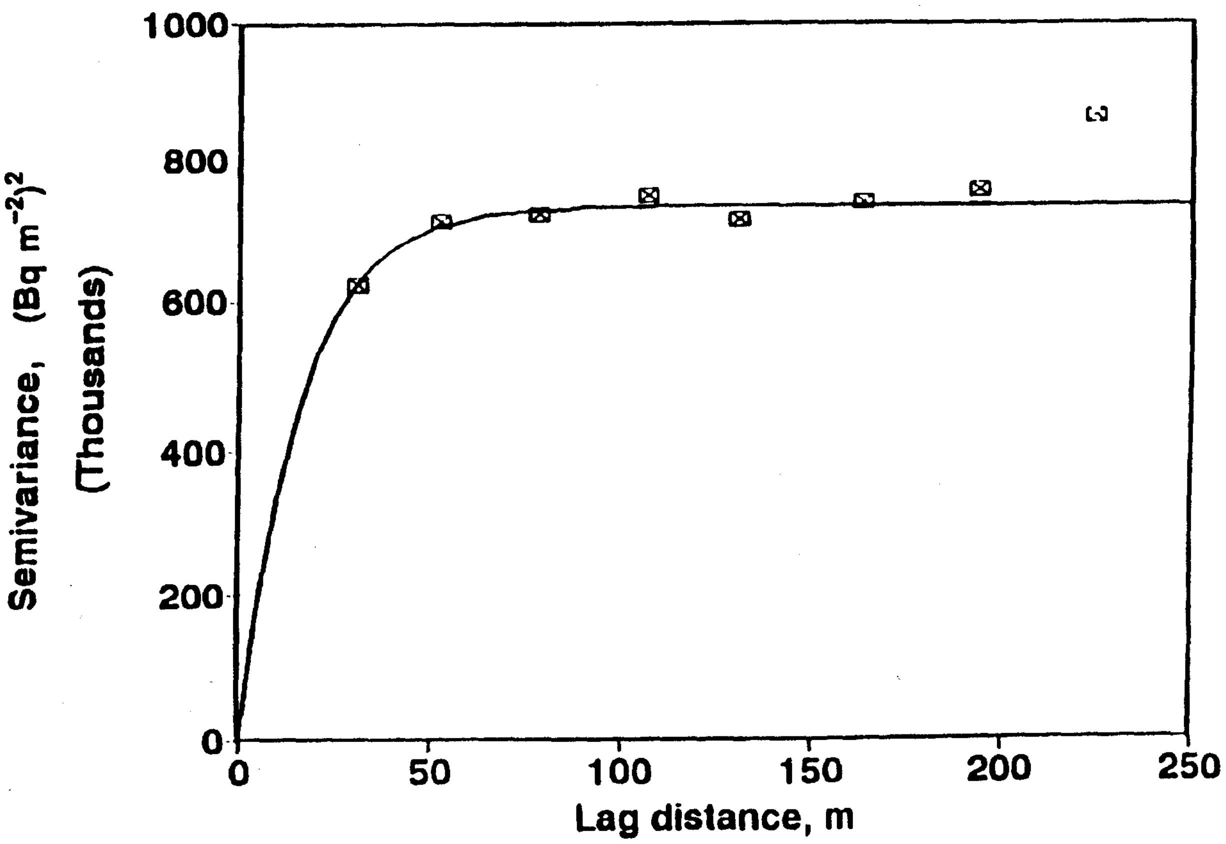
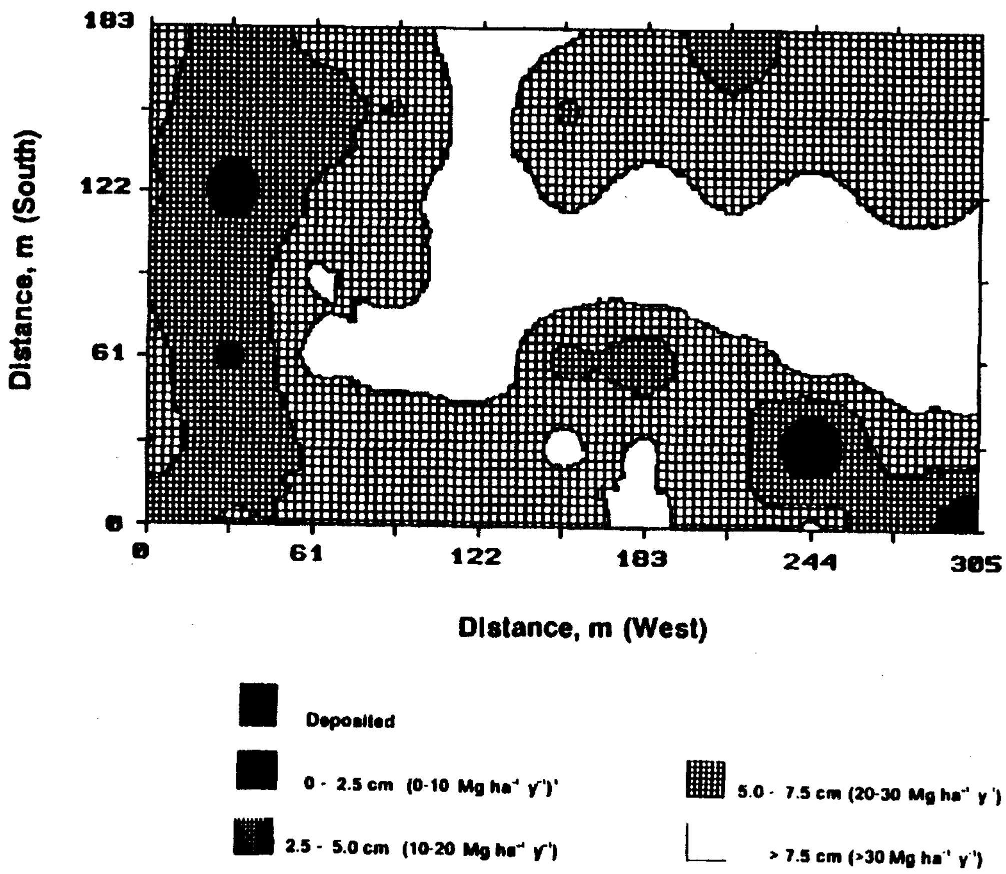
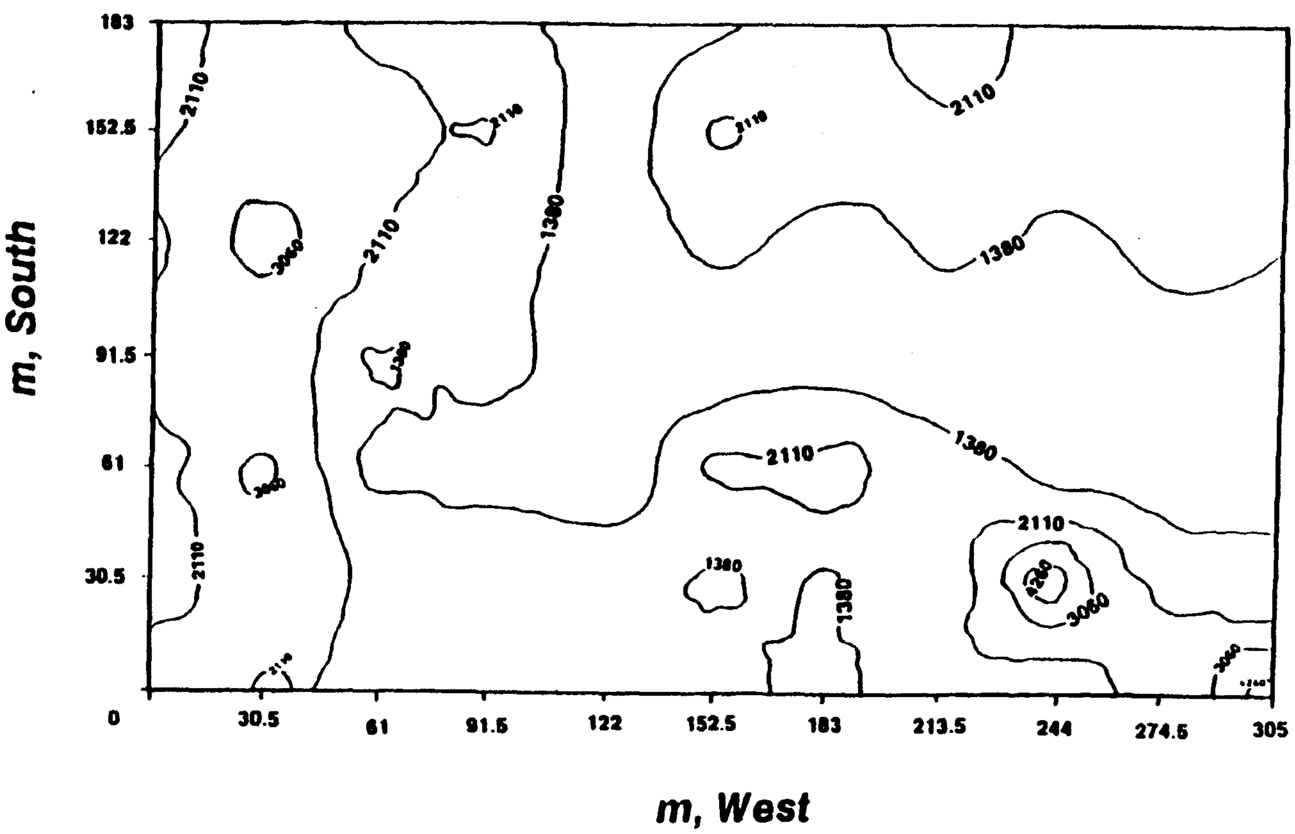


Figure 3. Distribution of the depth of soil lost by erosion estimated using the parabolic method.



[1] Equivalent annual soil erosion rate.

Figure 4. Erosion patterns based upon the spatial variability of ^{137}Cs activity.



Units are in Bq m^{-2}.

Long-Term Applications of Manure and Fertilizer in Irrigated Corn

Gregory D. Binford and Rex A. Nielsen

Objectives:

1 Evaluate the effects of 51 years of manure applications on yields of irrigated corn with and without applications of inorganic fertilizers.

Procedure:

This is a long-term continuous corn study that was initiated as part of a rotation study in 1912. In 1942 all rotations except the continuous corn were discontinued. At this time, a second replication was added to the continuous corn rotation and the plots were divided into two treatments (0 and 12 tons/acre of beef manure); these same treatments have been applied every year since 1942. In 1953 the main plots were split into six subplots (18 ft wide by 41 ft long) that continue to receive annual applications of the following treatments: 0, 40, 80, 120, 160 lb N/acre, and 120 lb N/acre plus 40 lb P_2O_5/acre. The plots are furrow irrigated every year.

In 1992, fertilizer (ammonium nitrate for N treatments, 0-45-0 for P_2O_5 treatments) and manure treatments were applied in mid-April and immediately incorporated. Corn was planted on May 1. Lack of soil moisture caused large variations in the number of days to emergence; final harvest populations were uniform among plots but variations in growth stage were present throughout the season because of the emergence problems. Soil samples were taken from the 24-inch layer of soil (two 12-inch increments) when corn plants were about 9 inches tall. These samples were analyzed for nitrate, exchangeable ammonium, total carbon, and total nitrogen. Leaf punches were taken from the ear leaf of 30 plants in each plot at silking and early dent. These punches were analyzed for percent nitrogen and carbon. Ear-leaf chlorophyll measurements were taken with a hand-held SPAD 502 chlorophyll meter at various times during the reproductive growth stages. The initial chlorophyll readings were taken on July 30. Samples of the lower stalk (6- to 14-inch segment above the ground) were taken on October 27. Yields were determined by hand harvesting 20-ft sections of the center three rows on each plot. A light frost (32$F) that caused damage to the upper corn leaves occurred on September 28. A freeze (23 $F) that killed the corn plants occurred on October 7; the corn was in the full dent stage when the freeze occurred.

Results:

Grain yields are shown in Table 1. When no fertilizer was applied, yields on nonmanured plots were about 35% of the yields on manured plots. Grain yields increased significantly with increasing rate of nitrogen fertilizer when no manure was applied, however, application of nitrogen fertilizer had no effect on grain yields when 12 tons/acre of manure was applied. Consequently, there was a highly significant interaction between rates of fertilizer and manure application on grain yields. Plots that have received no manure and no P fertilizer for 80 years seemed to yield slightly less than plots that have received annual applications of 40 lb P_2O_5/acre and(or) manure; however, there was no statistically significant difference in yields between the 120 lb N/acre treatment and the 120 lb N/acre + 40 lb P_2O_5/acre treatment.

Ear-leaf chlorophyll readings decreased linearly with time on the extremely N deficient plots (Fig. 1). Linear regression indicated that the average decline in chlorophyll readings on the 0 and 40 lb N/acre treatments was 0.46 units per day. Chlorophyll readings showed consistent trends with time, except for an unexplained increase in mid-September on the nonmanured 80 and

120 lb N/acre treatments. The chlorophyll readings indicated that the 0 and 40 lb N/acre nonmanured plots were already deficient in N when the initial readings were taken (visual observation of the plants at this time showed strong N deficiency symptoms). The chlorophyll readings indicate that the 80 lb N/acre plot did not become N deficient until later in the season.

Table 2 shows total N, total C, nitrate, and exchangeable ammonium concentrations in late-spring soil samples; leaf punch N concentrations at silking; and stalk nitrate concentrations at maturity. Late-spring soil nitrate concentrations, leaf punch N concentrations, and stalk nitrate concentrations all indicate that the manured plots had more N than needed for optimal yields. The late-spring soil nitrate concentration for the 80 lb N/acre, nonmanured treatment is well above the "critical concentration" that has been developed in other states, however, the grain yields are obviously below optimal. This could be explained by losses of N after soil sampling due to application of excess irrigation water. This plot is located on a University production field and is at the upper end of the field.

Table 1. Grain yields and analysis of variance information.

	Grain Yields		ANOVA	
	No	12 t/ac		
N Rate	Manure	Manure	Source	P > F
lb/acre	---- bu/acre ----			
0	65.0	178.4	Manure rate (M)	0.097
40	109.5	181.4	Fertilizer rate (F)	0.002
80	155.3	175.8	M*F	0.001
120	168.1	178.0		
160	162.4	164.8	Contrast	
120†	178.2	177.5	0 P vs. 40 P	0.631

† 120 lb N/acre plus 40 lb P_2O_5/acre.

Table 2. Late-spring total nitrogen, total carbon, soil nitrate, and exchangeable ammonium in the surface 12-inch layer of soil; leaf punch nitrogen at silking; and concentrations of nitrate in the lower portion of cornstalks at maturity.

N Rate	Manure rate	Total N	Total C	Soil Nitrate	Soil Ammonium	Leaf Punch N	Stalk Nitrate
(lb/acre)	(T/ac)	(%)	(%)	(ppm N)	(ppm N)	(%)	(ppm N)
0	0	0.067	0.69	4.1	2.1	1.83	6
40	0	0.072	0.69	15.0	2.1	2.80	6
80	0	0.077	0.73	30.1	3.3	3.39	636
120	0	0.080	0.74	32.9	6.6	3.49	150
160	0	0.084	0.80	28.4	5.0	3.69	979
120†	0	0.082	0.77	31.4	8.3	3.58	957
0	12	0.131	1.23	29.2	2.2	3.89	1393
40	12	0.149	1.42	31.3	2.1	3.86	3723
80	12	0.150	1.37	29.7	2.5	3.84	2924
120	12	0.151	1.38	61.1	2.6	3.86	1717
160	12	NA‡	NA‡	52.6	2.8	3.90	1651
120†	12	0.152	1.37	70.7	6.4	3.90	2273

† 120 lb N/acre plus 40 lb P_2O_5/acre.
‡ Samples have to be rerun in the laboratory.

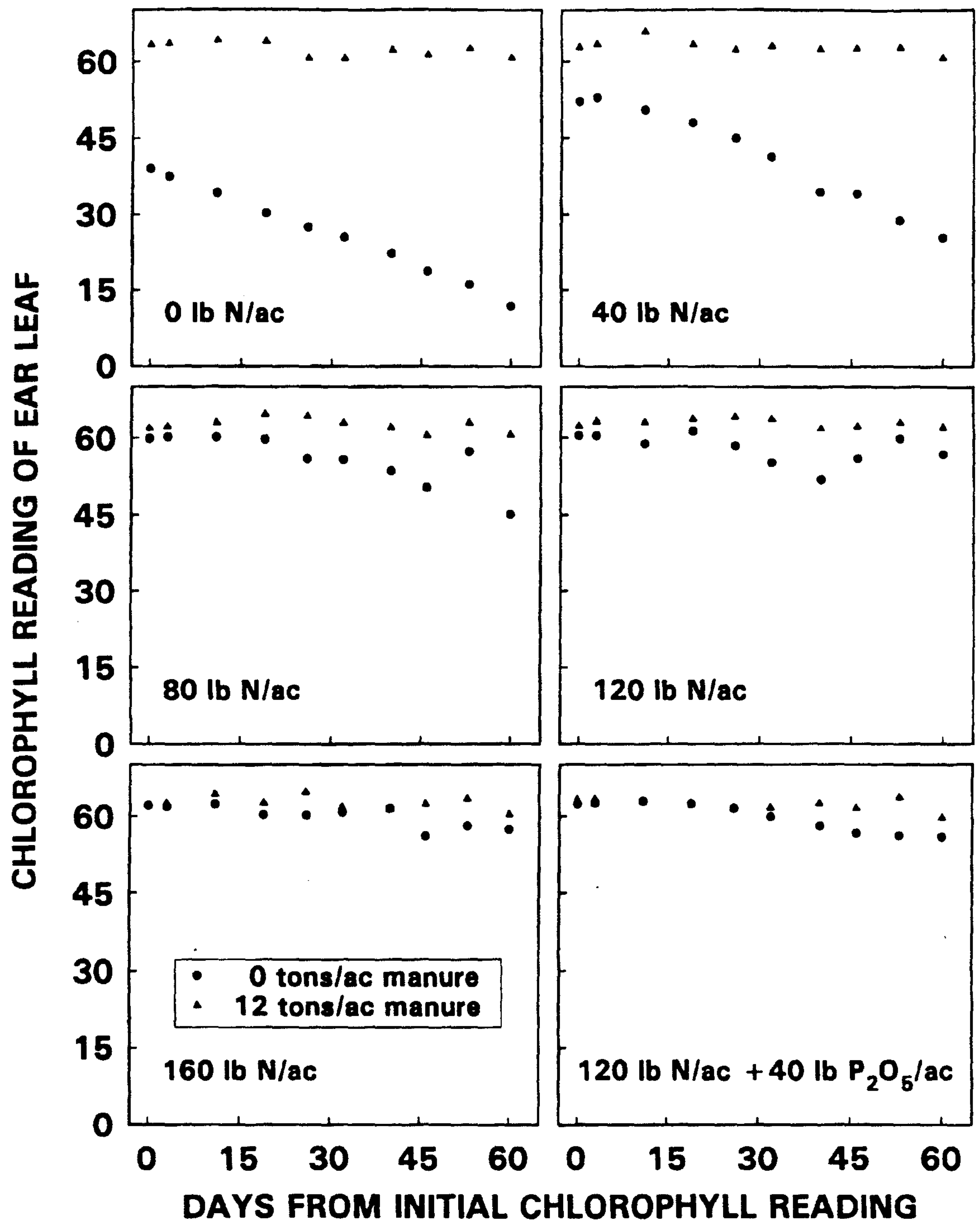


Figure 1. Change in leaf chlorophyll reading with time. Initial readings were taken approximately five days before 50% of the plants were silked.

Evaluation of Tillage, Rotation, Nitrogen and Cover Crop Effects on Nitrogen Cycling

K. Anabayan, D.T. Walters and D.H. Sander

Objectives

To determine the effect of tillage and rotation with soybean (*Glycine max*) on:

1 Grain and stover yield of corn (*Zea mays*) under increasing N rates.

2 Dry matter yield and N uptake of winter rye (*Secale cereale*) planted as cover crop following soybean and its effect on residual soil nitrate and soil cover.

3 The interaction between and relative contribution of N from different N sources (corn, soybean and rye residues, fertilizer N and soil N) to the nutrition of associated crops.

Procedures

This experiment was established in 1988 at the Agricultural Research and Development Center, Mead NE as a randomized complete block split-split plot design under irrigation. The treatments consist of (i) Two tillage systems, a spring disk (DK) and no-till (NT) with a cultivation for weed control as main plots, (ii) Three rotation systems, continuous corn (CC), corn following soybean (CB) or soybean following corn (BC), and corn after soybean/rye (CBR) as subplots and (iii) Five nitrogen rates viz., 0, 50, 100, 150, 300 kg N ha^{-1} applied as pre-plant as sub-subplots. The soil type is Sharpsburg silty clay loam (fine montmorillonitic mesic Typic Argiudoll).

Corn (Pioneer 3189, 118d RM) and soybean (Century 84) were planted at a row spacing of 0.75m (30") on May 11 and May 25, 1992, respectively. Corn planting rate was 72,000 seeds ha^{-1}. Corn was cultivated at the V8 stage and soybean at the V5-V6 stage on July 1, 1992. Winter rye was drilled into existing soybean stubble following soybean harvested on October 16, 1991 at a rate of 67 kg ha^{-1}. The dry yield of rye was estimated in the spring of 1992 by hand harvesting an area of $0.093m^2$ (1 ft^2) at five random locations within each plot. Residual soil nitrate nitrogen (RSN) was determined prior to tillage operations by soil sampling each tillage/rotation plot where N had been applied at the rate of 0, 100 and 300 kg ha^{-1} the previous year. Soil was sampled to depth of 1.5m at 30cm increments. Prior to tillage, rye was killed with glyphosate.

Corn grain and stover were hand harvested from a 1.22m (40') and 0.61m (20') row length respectively at physiological maturity on October 9, 1992 and yields estimated on a hectare basis. Soybeans were combine harvested from 21.3m (70 ft.) of row. Both grain and stover were sub sampled for moisture and total N analysis. Residue cover was measured prior to tillage, after planting and after cultivation by taking a 100 point line intersect count in each plot.

Results

A severe frost in early spring of 1992 drastically reduced the growth and the yield of rye, producing a maximum above-ground rye dry matter yield of only 361 kg ha^{-1}. This led to recycling of only 12 kg N ha^{-1} on the average to the succeeding corn crop through rye residues (Table 1).

Rotation and N rate significantly influenced the grain yield of corn in 1992 (Fig.1 & Tables 2 & 3). Corn rotated with soybean (w/o rye) resulted in a 28% increase in grain yield over continuous corn. Grain yield of corn under CBR was reduced by 9.3% compared to Corn-Soybean system without rye (CB). There was no difference in the total residual nitrate-N (RSN) between rye and no rye rotation systems at the time of planting, the yield reduction may be due to an unknown allelopathic effect caused by rye. Maximum corn grain yield in 1992 was achieved with approximately 100 kg N ha^{-1} regardless of rotation. Rotation of soybean (w/o rye) led to a 30% and 17% increase in N uptake in the grain and stover, respectively, over CC. Barren stalks were also reduced by approximately 5% under rotation (Table 2).

The primary effect of tillage was an increase stover yield and N uptake at the higher N rates under NT. An average grain yield of 2.8 Mg ha^{-1} (47 bu/ac) was obtained from soybean. Neither tillage nor N rate influenced the grain yield of soybean.

Presence of rye resulted in a significant reduction in RSN at 0-30cm depth and this was equivalent to 47% rye N uptake. BRC and BC accumulated less RSN at 100 kg N ha^{-1} between 60-150cm depth when compared to CC (Table 4 & Fig 2). RSN was reduced 21% due to rye in BRC over BC under disk. Overall, the greatest accumulation of RSN occurred in the CBR rotation under DK system (Fig 3). This may be attributed to the recycling of 42 kg N ha^{-1} through 1991 rye residue and consistantly poorer fertilizer N use efficiency following soybean under disk when compared to NT. After three years of fertilizer N application, RSN levels have continued to rise at a faster rate under DK and N removal in grain and stover have also been lower under DK than NT. However, continuous corn exhibited 40% increase in RSN accumulation in the profile when compared to previous year.

Table 6 shows the change in RSN from the spring of 1991 to the spring of 1992. These changes reflect the effects of the 1991 crop and the rye cover crop N uptake given in Table 1. Across all treatments, there was a net gain of approximately 56 kg NO_3-N/ha-1.5m, most of which occurred below the 0.6m depth. It is interesting to note that when soybean followed corn (CB-BC & CB-BCR in Table 6), the net gain in NO_3-N was appreciably lower than when corn was the 1991 crop. Also, the 1992 rye cover crop did result in a significant reduction in RSN between 1991-92. Corn following the 1990 bean/1991 rye crop displayed the greatest increase in RSN from 1991-92 (BRC-CBR in Table 6). This may be attributed to poor fertilizer use efficiency and the added availability of N mineralized from the high yield of the spring 1991 rye crop. We measured 35 to 76 kg N in aboveground rye drymatter in 1991. This suggests that the N from rye cover may contribute significant quantities of N to the following corn crop and that fertilizer N recommendations for corn following soybean/rye may need to be adjusted downward for N contributed from the mineralization of rye during the year. Lower RSN values from soil samples taken just prior to rye destruction would warrant a higher N fertilization rate using existing N recommendation algorithms. Preliminary analysis of the ^{15}N-labeled rye residue data (not shown) indicated greater percent N derived from rye residue in corn than that from soybean residue.

The measure of surface residue cover is an indication of the degree of susceptibility of the field to erosion. Figure 4 presents surface residue cover as a function of time for different rotation systems studied. Due to poor growth and yield of rye no additional surface residue cover over soybean residue (BC) was obtained in BRC system. But in 1991, inclusion of rye with soybean rotation gave 18% increased soil cover over soybean residue alone. DK tillage resulted in a significant decline in residue cover relative to NT. After cultivation, the soybean residue cover was 27% and 12% in DK and NT respectively. Despite a 33% increase in stover yield in CB and CBR systems over CC, no difference in surface residue cover among these systems was observed. Residue cover following soybean in the NT system was sufficiently high to meet erosion control standards until cultivation at which time crop canopy cover had reached approximately 60%.

Table 1. Main effect and 2-way interaction mean table for winter rye above ground dry matter yield (RDMY) and N uptake Mead, NE spring 1992.

Source		RDMY	N in RDMY
		(kg ha^{-1})	(kg ha^{-1})
Tillage			
Disk		295	10
No till		220	08
N Rate			
0		302	11
50		192	07
100		298	10
150		227	08
300		266	09
Tillage X N Rate			
Disk	0	361	12
	50	230	08
	100	330	11
	150	243	08
	300	316	11
No till	0	242	09
	50	162	06
	100	267	09
	150	213	08
	300	218	08

ANOVA

Source	df	------------------Prob > F------------------	
Tillage	1	NS	NS
N Rate	4	NS	NS
N lin	1	NS	NS
N Quad	1	NS	NS
Tillage X N Rate	4	NS	NS
(DK vs NT)*NL	1	NS	NS
(DK vs NT)*NQ	1	NS	NS

NS = Not significant at 0.05 probability level.

Table 2. Main effect and 2-way interaction means for corn grain and stover yield, grain and stover N content, grain and stover N uptake, plant population and barren stalks, NE 1992.

Sources			*Grain Yield Mg/ha	*Grain Yield (bu/a)	Stover Yield Mg/ha	Grain N %	Stover N %	Grain N Uptake kg/ha	Stover N Uptake kg/ha	Plant Popul. '000/ha	Barren Stalk %
Tillage											
	Disk		9.31	(169)	6.60	1.22	0.78	113	51	6.71	5
	No till		9.18	(166)	6.92	1.20	0.76	122	54	6.65	3
Rotation*											
	CB		10.71	(194)	6.98	1.22	0.77	130	54	6.77	2
	CBR		9.71	(176)	7.11	1.24	0.79	120	57	6.33	3
	CC		7.32	(133)	6.19	1.18	0.75	87	46	6.94	7
N Rate											
	0		8.21	(149)	6.08	0.95	0.49	80	30	6.72	5
	50		9.53	(173)	6.62	1.14	0.61	108	40	6.76	3
	100		9.95	(180)	7.03	1.29	0.83	128	58	6.79	4
	150		9.77	(177)	6.99	1.30	0.92	127	65	6.57	3
	300		8.76	(159)	7.07	1.38	0.99	119	69	6.57	6
Tillage x Rotation											
	Disk	CB	10.58	(192)	7.07	1.18	0.75	125	54	6.69	3
		CBR	9.85	(179)	7.04	1.23	0.78	122	55	6.36	3
		CC	7.49	(136)	5.67	1.24	0.80	93	44	7.09	9
	No till	CB	10.83	(196)	6.89	1.25	0.78	136	55	6.84	2
		CBR	9.56	(173)	7.17	1.24	0.81	119	59	6.29	2
		CC	7.15	(130)	6.71	1.12	0.70	82	48	6.79	6
Tillage x N Rate											
	Disk	0	8.6	(156)	6.16	0.95	0.50	82	31	6.49	5
		50	9.61	(174)	6.86	1.12	0.66	108	44	6.85	3
		100	9.99	(181)	6.77	1.33	0.84	132	57	6.84	5
		150	9.72	(176)	6.21	1.31	0.88	127	55	6.58	3
		300	8.60	(156)	6.97	1.38	1.00	117	68	6.80	7

Table 2 (Continued).

Sources		Mg/ha	$Grain Yield (bu/a)	Stover Yield Mg/ha	Grain N %	Stover N %	Grain N Uptake kg/ha	Stover N Uptake kg/ha	Plant Popul. '000/ha	Barren Stalk %
No till	0	7.81	(142)	6.0	0.96	0.48	78	29	6.95	5
	50	9.45	(171)	6.39	1.15	0.57	108	36	6.67	2
	100	9.90	(180)	7.29	1.25	0.82	124	59	6.74	2
	150	9.82	(178)	7.77	1.29	0.96	127	75	6.57	3
	300	8.92	(162)	7.18	1.37	0.98	123	70	6.35	4
Rotation x N Rate										
CB	0	10.16	(184)	6.62	1.04	0.46	105	30	6.93	3
	50	10.61	(192)	6.55	1.10	0.58	116	38	6.93	2
	100	11.19	(203)	6.94	1.28	0.86	148	60	6.80	3
	150	10.73	(195)	7.28	1.31	0.99	140	73	6.44	1
	300	10.83	(196)	7.50	1.36	0.95	147	71	6.80	2
CBR	0	9.06	(164)	6.72	0.98	0.51	89	35	6.50	3
	50	9.84	(178)	6.81	1.19	0.68	116	47	6.20	2
	100	10.43	(189)	7.73	1.30	0.90	135	68	6.37	1
	150	10.18	(185)	7.01	1.35	0.90	137	63	6.69	5
	300	9.02	(164)	7.27	1.37	0.98	124	71	5.98	3
CC	0	5.39	(98)	4.92	0.83	0.51	45	24	6.78	9
	50	8.10	(147)	6.50	1.13	0.59	92	36	7.15	4
	100	8.22	(149)	6.42	1.30	0.74	107	47	7.20	6
	150	8.41	(152)	6.68	1.24	0.87	105	58	6.63	5
	300	6.44	(117)	6.45	1.40	1.05	89	66	6.94	12

$ Grain yield as Mg/ha is for dry matter yield, bu/a adjusted to 15.5% moisture.
* First letter indicates 1992 crop.

TABLE 3. Analysis of variance table for variables listed in table 2, 1992 Mead, NE.

Sources	df	Grain Yield	Grain N	Grain N Uptake	Stover Yield	Stover N	Stover Uptake	N Popul.	Barren Stalks
		Prob > F							
Tillage	1	NS	NS	NS	NS	NS	NS	NS	NS
Rotation	2	***	NS	***	NS	NS	**	***	***
CB Vs CBR	1	*	NS	NS	NS	NS	NS	**	NS
(CB+CBR) Vs CC	1	***	NS	***	*	NS	**	**	***
N Rate	4	***	***	***	**	***	***	NS	NS
NL	1	NS	***	***	**	***	***	NS	NS
NQ	1	***	***	***	*	***	***	NS	NS
NC	1	NS	NS	*	NS	NS	NS	NS	NS
Tillage x Rotation	2	NS	**	NS	NS	NS	NS	NS	NS
(Disk Vs No till)* (CB Vs CBR)	1	NS	NS	NS	NS	NS	NS	NS	NS
(Disk Vs No till)* (CB+CBR VS CC)	1	NS	*	NS	NS	NS	NS	NS	NS
Tillage x N Rate	4	NS	NS	NS	*	NS	***	NS	NS
Disk vs No till * NL	1	NS	NS	NS	NS	NS	*	NS	NS
Disk vs No till * NQ	1	NS	NS	NS	*	NS	**	*	NS
Disk vs No till * NC	1	NS	NS	NS	NS	NS	NS	NS	NS
Rotation x N Rate	8	*	NS	NS	NS	*	NS	NS	NS
CB vs CBR * NL	1	NS	NS	NS	NS	NS	NS	NS	NS
CB vs CBR * NQ	1	NS	NS	NS	NS	NS	NS	NS	NS
CB vs CBR * NC	1	NS	NS	NS	NS	NS	NS	NS	NS
CB+CBR vs CC * NL	1	NS	NS	NS	NS	NS	NS	NS	NS
CB+CBR vs CC * NQ	1	**	NS	*	NS	**	NS	NS	*
CB+CBR vs CC * NC	1	NS	NS	NS	NS	NS	NS	NS	NS
Tillage x Rotation x N Rate	8	NS	NS	NS	NS	NS	NS	NS	NS

***, ** and * = Significance at .001, .01 and .05 probability level respectively.

Table 4. Main effect and 2-way interaction mean table for residual soil NO_3-N Mead, NE Spring 1992.

Source		Profile depth(cm)					
		0-30	30-60	60-90	90-120	120-150	Total
		NO_3-N(kg ha^{-1})					
Tillage							
Disk		17	19	38	51	44	168
No till		16	16	26	33	27	118
Rotation*							
	BRC	17	16	31	39	28	131
	BC	21	16	31	43	35	146
	CBR	17	25	47	52	37	178
	CB	15	19	31	41	37	144
	CC	13	11	18	36	39	118
N Rate							
	0	16	12	9	6	6	51
	100	16	14	20	31	28	109
	300	17	26	66	90	71	270
Tillage X Rotation							
Disk	BRC	16	15	32	41	32	136
	BC	20	17	41	50	44	172
	CBR	20	26	54	69	48	216
	CB	15	22	37	46	40	159
	CC	14	12	25	52	54	157
No till	BRC	17	16	31	38	24	125
	BC	22	14	22	35	26	119
	CBR	14	24	40	35	26	139
	CB	15	16	26	37	35	129
	CC	11	10	12	21	24	78
Tillage X N Rate							
Disk	0	19	12	10	7	6	54
	100	16	15	28	44	39	143
	300	16	28	75	103	86	308
No till	0	14	13	8	6	7	47
	100	16	13	13	17	18	76
	300	17	23	58	77	57	231

Table 4 (continued).

Rotation X N Rate							
BRC	0	12	12	11	7	5	48
	100	22	15	16	20	17	90
	300	15	20	67	91	62	254
BC	0	21	14	10	7	7	59
	100	20	11	13	21	20	85
	300	22	22	71	100	78	294
CBR							
	0	19	14	8	5	5	51
	100	14	17	25	34	32	122
	300	17	45	108	117	73	361
CB							
	0	15	12	9	7	6	49
	100	13	14	24	32	32	114
	300	18	31	61	85	74	270
CC	0	15	12	8	6	7	46
	100	11	11	23	47	42	135
	300	12	11	24	56	68	171

* First letter indicates 1991 crop.

Table 5. Analysis of variance table for residual soil NO3-N Mead, NE Spring 1992.

Source	df	Profile depth (cm)					
		0-30	30-60	60-90	90-120	120-150	TOT
		Prob > F					
Tillage	1	NS	NS	NS	NS	*	NS
Rotation*	4	***	***	***	NS	NS	***
BRC vs BC	1	**	NS	NS	NS	NS	NS
CBR vs CB	1	NS	*	**	NS	NS	**
(BRC+BC)vs(CBR+CB)	1	*	**	*	NS	NS	**
BRC vs CC	1	*	NS	*	NS	*	NS
N Rate	2	NS	***	***	***	***	***
NL	1	NS	***	***	***	***	***
NQ	1	NS	NS	*	NS	NS	NS
Tillage X Rotation	4	NS	NS	NS	NS	NS	*
(Disk vs No till)							
*(BRC vs BC)	1	NS	NS	NS	NS	NS	NS
*(CBR vs CB)	1	NS	NS	NS	*	NS	*
*(BRC+BC vs CBR+CB)	1	NS	NS	NS	NS	NS	NS
*(BRC VS CC)	1	NS	NS	NS	*	NS	*
Tillage X N Rate	2	NS	NS	NS	NS	**	*
(Disk vs No till)							
*NL	1	NS	NS	NS	NS	**	*
*NQ	1	NS	NS	NS	NS	NS	NS
Rotation X N Rate	8	*	***	***	**	NS	**
(BRC vs BC)*NL	1	NS	NS	NS	NS	NS	NS
*NQ	1	*	NS	NS	NS	NS	NS
(CBR vs CB)*NL	1	NS	NS	**	NS	NS	*
*NQ	1	NS	NS	NS	NS	NS	NS
(BRC+BC)vs(CBR+CB)							
*NL	1	NS	**	NS	NS	NS	NS
*NQ	1	**	NS	NS	NS	NS	NS
(BRC+BC vs CC)*NL	1	NS	NS	***	***	NS	**
*NQ	1	NS	NS	*	**	*	**
Tillage X Rotation x N Rate	8	NS	NS	NS	NS	NS	NS

* First letter indicates 1991 crop.
***, **, * = significance at 0.001, 0.01, 0.05 probability level respectively

Table 6. Change in residual soil NO_3-N from spring 1991 to spring 1992 as influenced by tillage, rotation and N rate.

			profile depth (cm)					
			0-30	30-60	60-90	90-120	120-150	Total
			change in NO_3 -N(kg/ha)					
Tillage								
Disk			0	-7	11	36	31	71
No till			0	-4	10	19	16	41
Rotation*								
BRC-CBR			6	11	33	42	25	117
BC-CB			-7	-7	12	29	25	52
CB-BRC			-2	-19	-9	15	13	-2
CB-BC			2	-19	-9	19	20	13
CC-CC			-1	-7	4	23	27	46
N Rate								
0			-1	-3	-1	-1	-1	-7
100			0	-10	1	22	19	32
300			1	-4	29	61	49	136
Tillage X Rot								
Disk	BRC-CBR		10	11	37	61	38	157
	BC-CB		-7	1	19	36	27	76
	CB-BRC		-7	-35	-25	15	15	-37
	CB-BC		-3	-33	-16	12	27	-1
	CC-CC		0	-5	7	11	41	79
NT	BRC-CBR		3	11	28	23	14	79
	BC-CB		-7	-14	7	24	23	33
	CB-BRC		2	-4	8	15	11	32
	CB-BC		7	-6	-1	12	13	25
	CC-CC		-4	-8	1	11	13	13
Till x N Rate								
Disk	0		2	-3	0	1	-1	-1
	100		-2	-13	3	34	30	52
	300		0	-7	29	74	62	158
NT	0		-3	-2	-1	-2	1	-7
	100		1	-7	1	9	9	13
	300		2	-2	30	49	38	117
Rot x N Rate								
BRC-CBR		0	6	6	0	-2	-4	6
		100	4	-2	15	27	25	69
		300	8	30	82	100	55	275
BC-CB		0	-7	-12	-6	-2	0	-27
		100	-8	-13	4	24	22	29
		300	-4	5	40	66	53	160

Table 6 (continued).

CB-BRC	0	-6	- 2	2	2	- 2	- 6
	100	-1	-22	-21	6	6	-32
	300	-1	-34	- 8	36	36	29
CB-BC	0	3	0	1	2	0	6
	100	-3	-26	-24	7	9	-37
	300	6	-32	- 4	45	52	67
CC-CC	0	-1	- 2	0	0	2	- 1
	100	-1	- 4	14	39	34	82
	300	-3	-14	- 2	32	46	59
Avg. change in NO_3-N @ each depth		**0**	**- 6**	**10**	**27**	**22**	**53**

* First letter of sequence indicates crop from year preceding soil sampling date.

For example: BRC - CBR is bean/rye following corn in 1990 - corn following bean/rye in 1991.

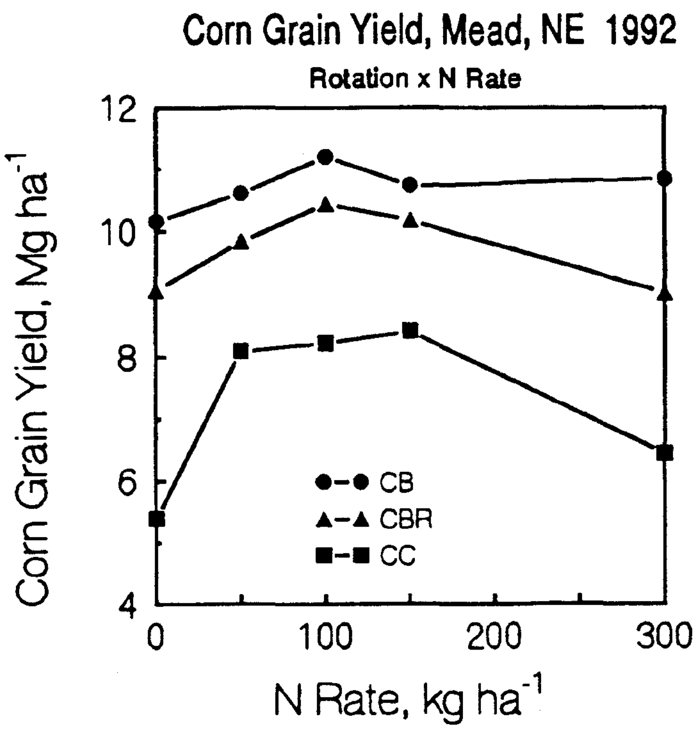


Figure 1. Corn grain yield as influenced by rotation and N rate, Mead, NE 1992.

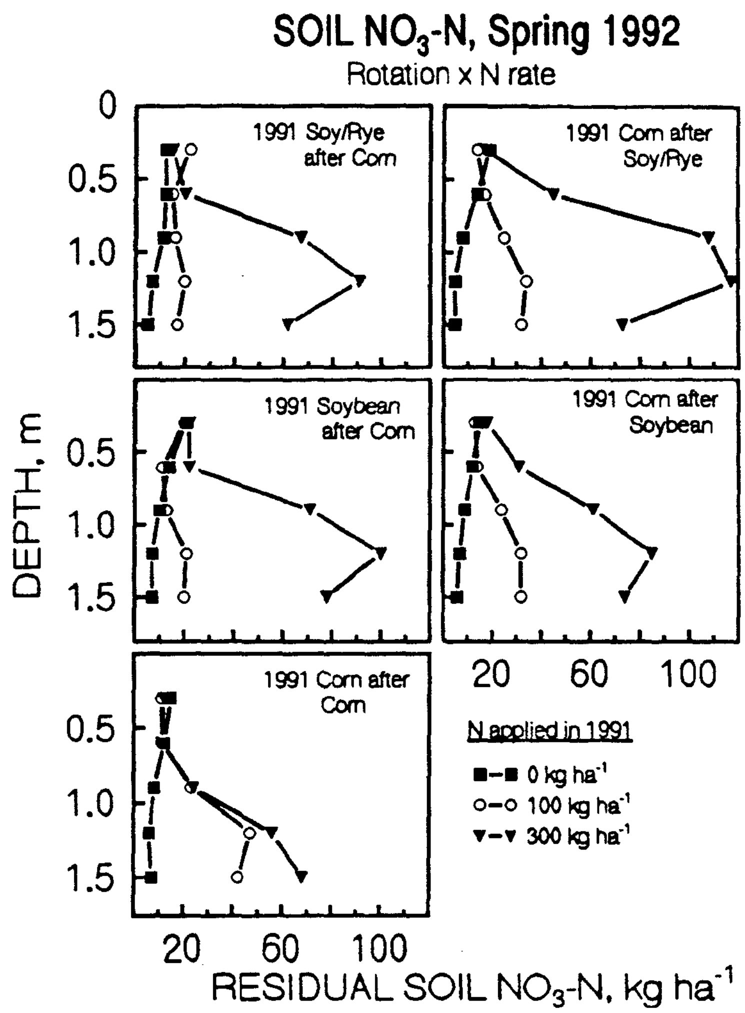


Figure 2. Residual soil nitrate-N to a depth of 1.5m as influenced by rotation and N-rate, spring 1992.

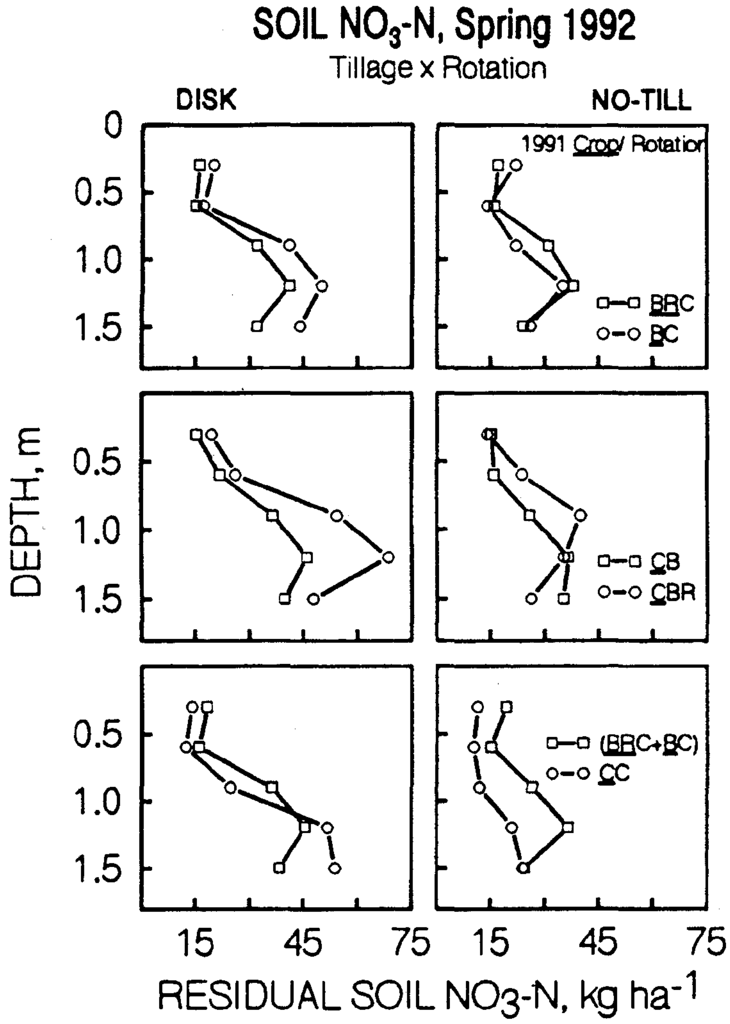


Figure 3. Residual soil nitrate-N to a depth of 1.5m as influenced by tillage and rotation, spring 1992.

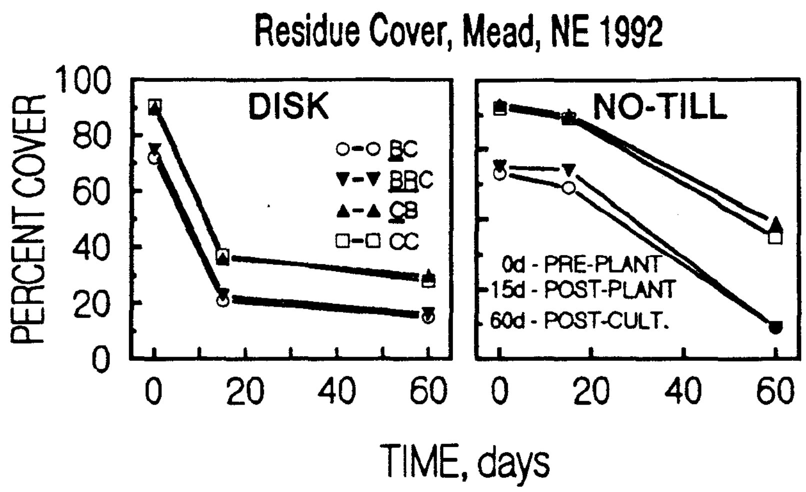


Figure 4. Residue cover at the soil surface as influenced by tillage and rotation, Mead 1992.