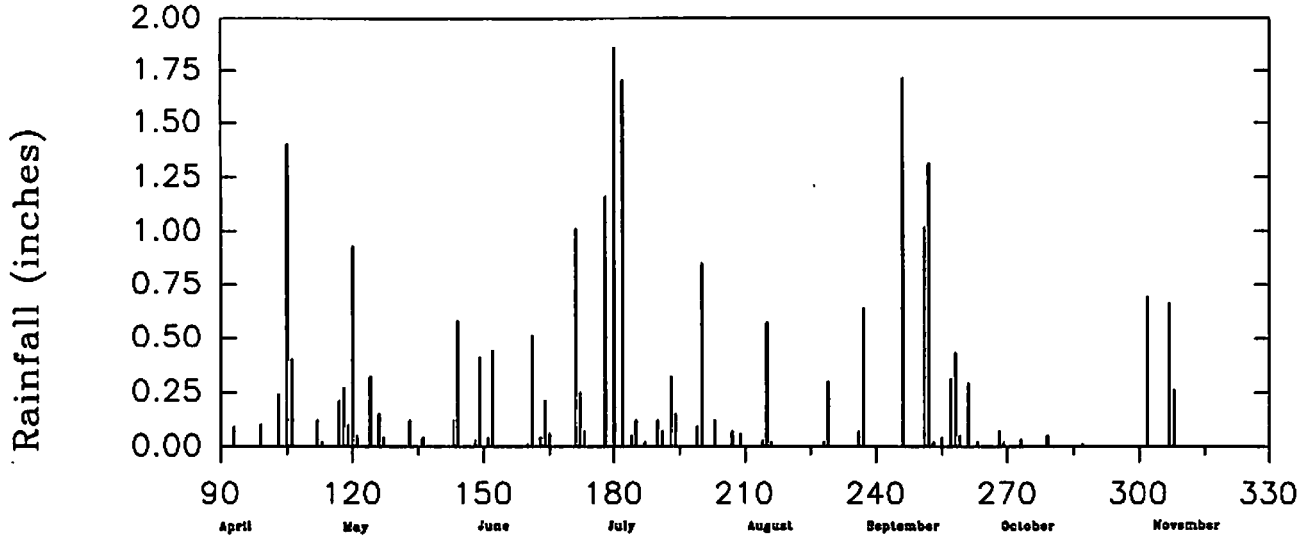
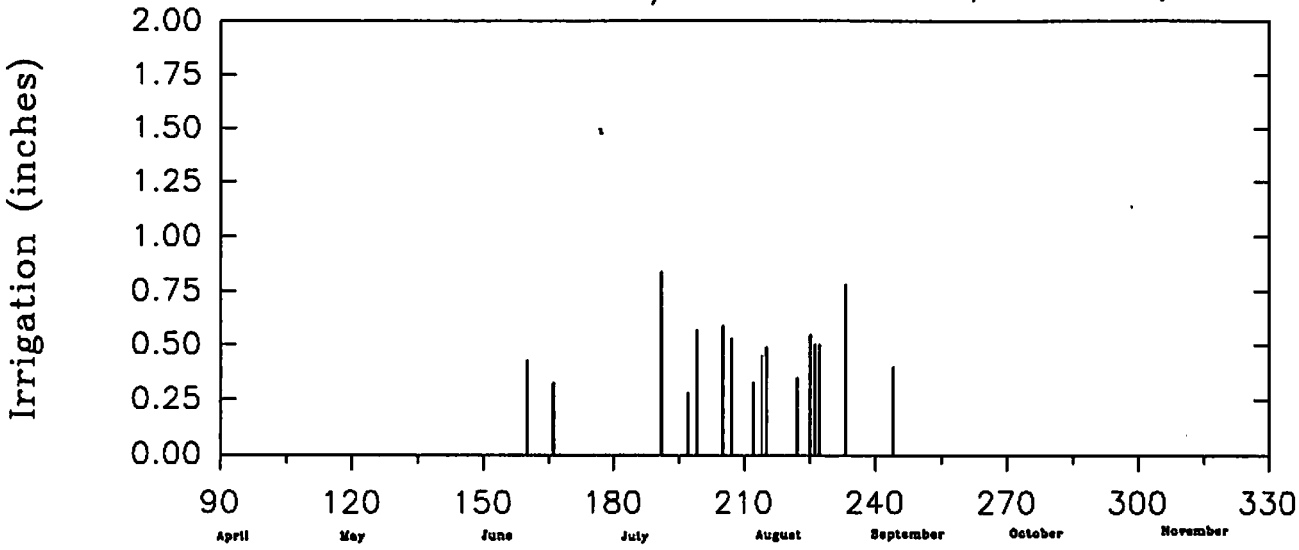
Fig 1. PRECIPITATION, STAPLES, MN., 1991



IRRIGATION ON CORN/ALFALFA STUDY, STAPLES,1991



IRRIGATION ON CORN/CORN STUDY, STAPLES, 1991

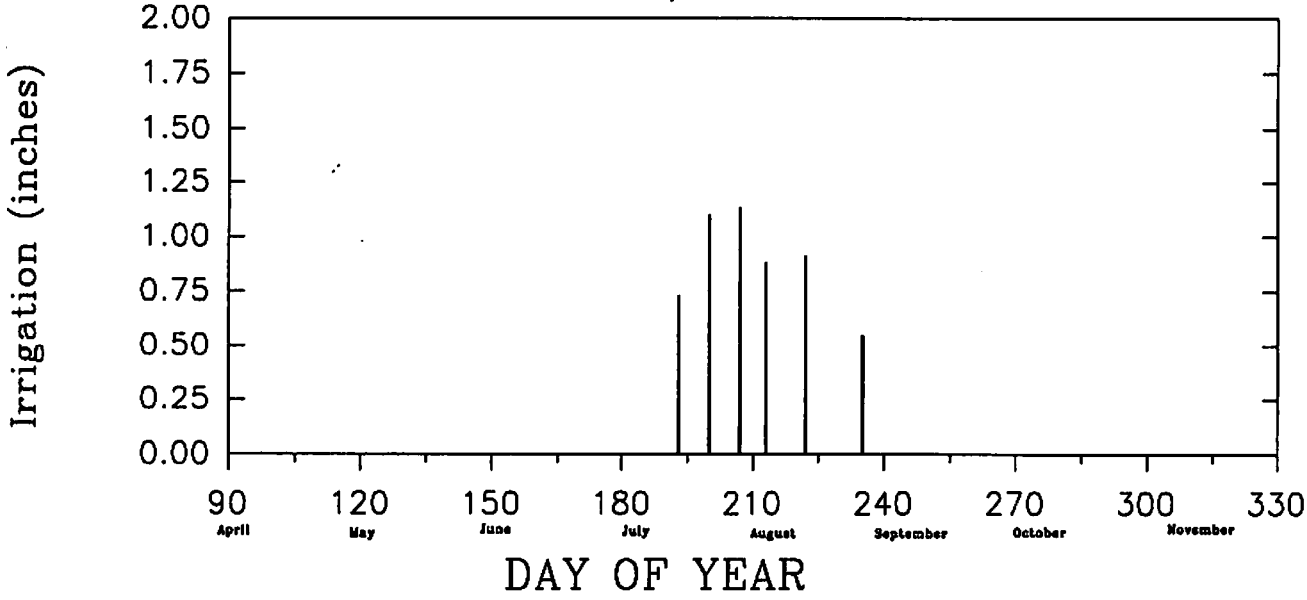


FIGURE 2.
SOIL WATER NITRATE IN CORN
FOLLOWING CORN AT STAPLES 1990

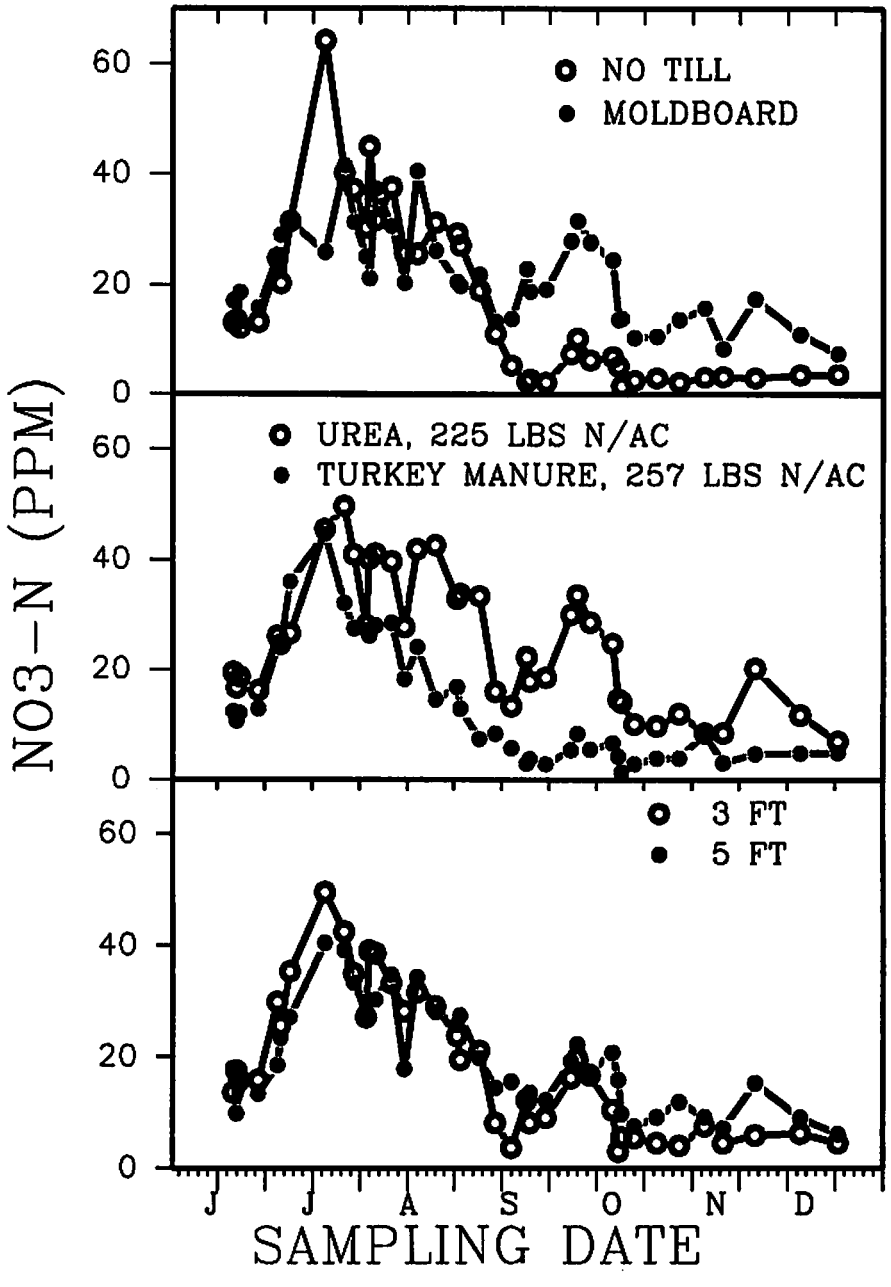


FIGURE 3.

SOIL WATER NITRATE BY DEPTH IN CORN FOLLOWING CORN

STAPLES 1990

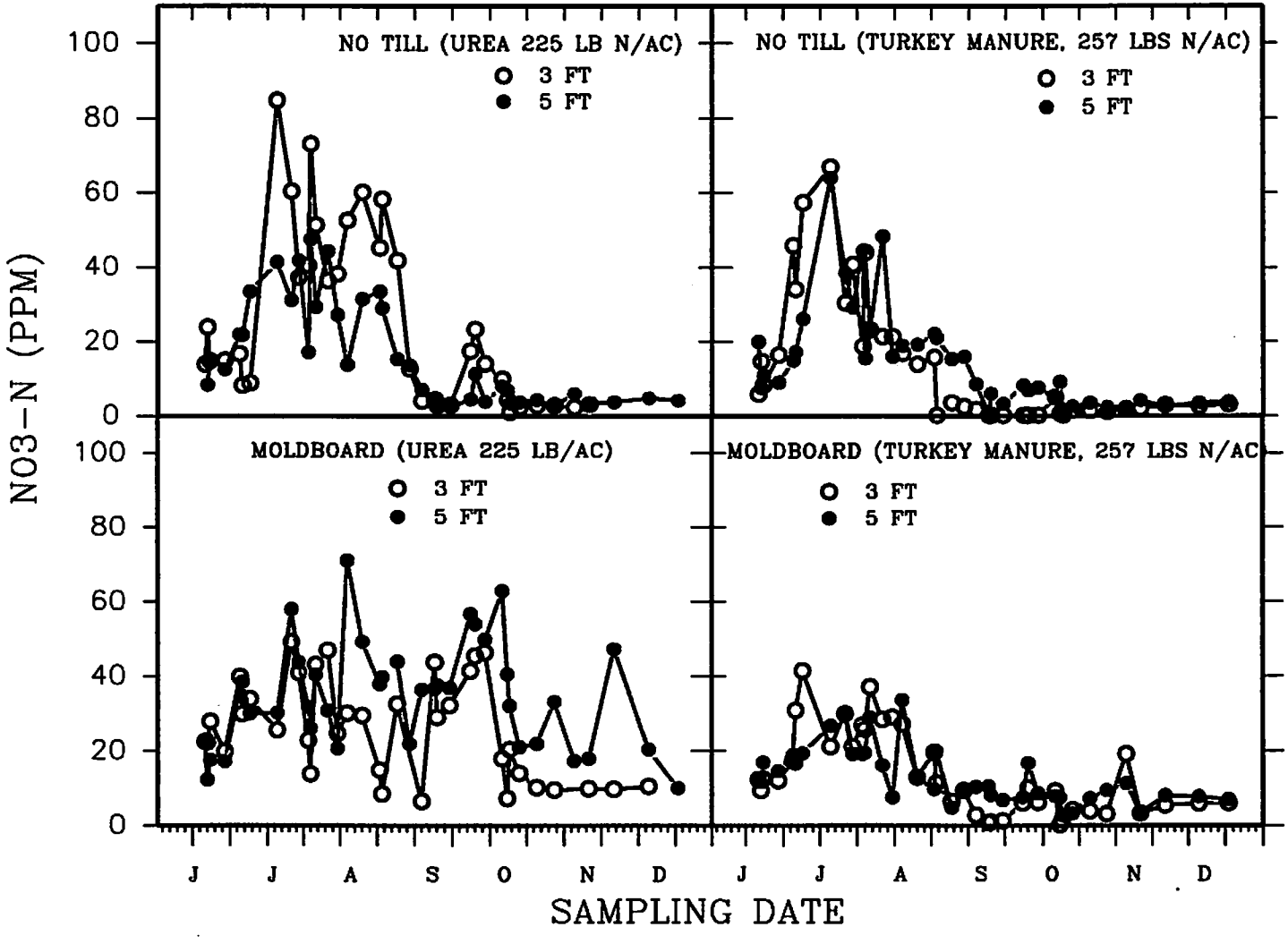


FIGURE 4.

SOIL WATER NITRATE IN 5th YEAR CORN FOLLOWING ALFALFA AT STAPLES 1991

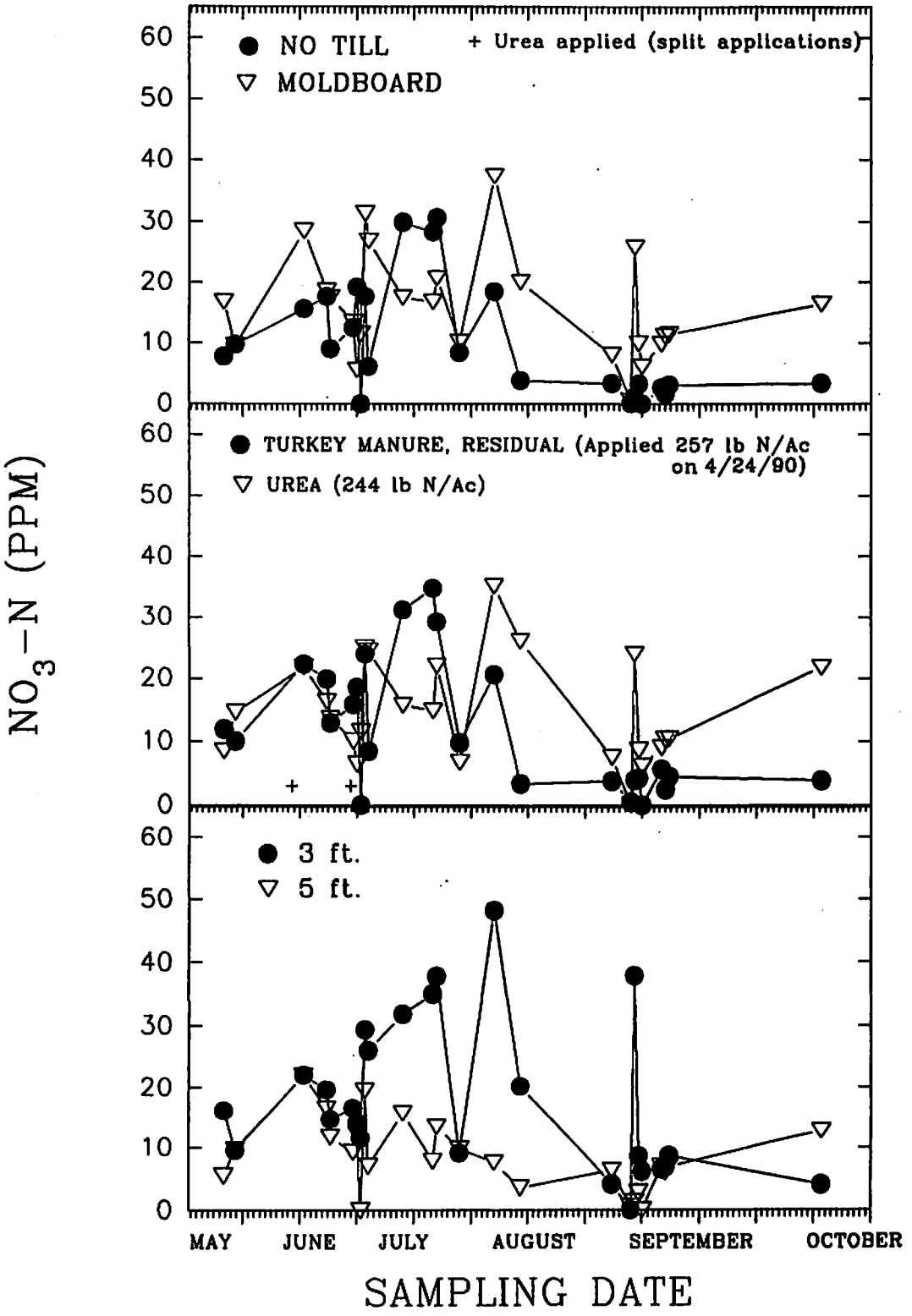
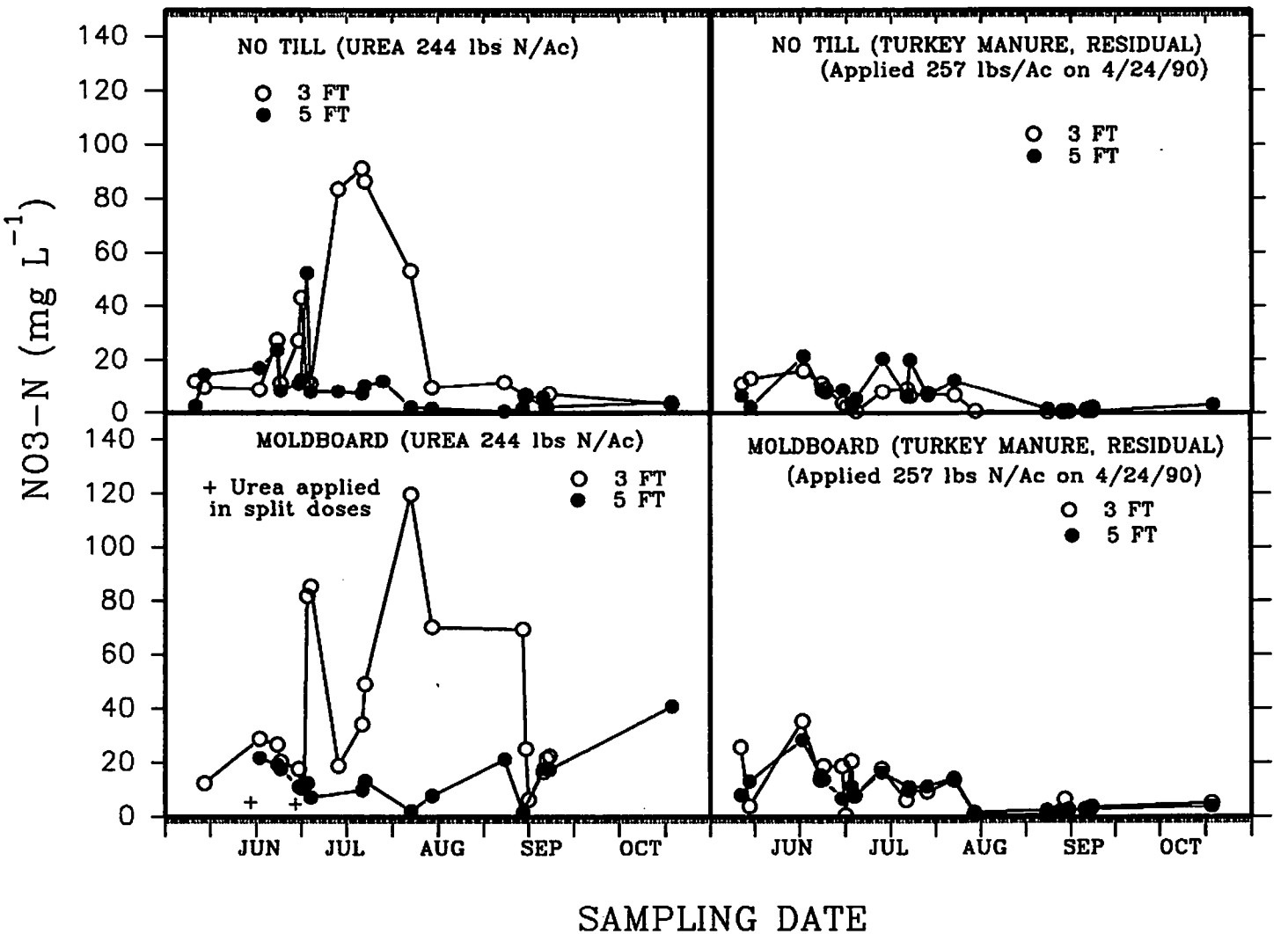


FIGURE 5.

SOIL WATER NITRATE IN FIFTH YEAR CORN FOLLOWING ALFALFA

STAPLES 1991



NITROGEN AND IRRIGATION MANAGEMENT EFFECTS ON CORN/POTATO YIELDS AND NITRATE LEACHING [1]

B.T. Sexton, J.F. Moncrief, C.J. Rosen, S.C. Gupta,
H.H. Cheng, J.A. Wright and M.J. Wiens.[2]

Test plots were located on a Verndale sandy loam (coarse loamy, mixed, frigid Udic argiboroll). Nitrogen sources included urea ($CO(NH_2)_2$) for corn, ammonium nitrate (NH_4NO_3) for potatoes, and turkey manure for both corn and potatoes. Four rates of commercial N fertilizer and two rates of turkey manure were used. The previous crop for potatoes was corn. Lupine, a legume, was the previous crop on the corn plots. All plots were moldboard plowed prior to planting. Corn responded up to 165 lb N/acre. Potatoes were still responding at the highest N rate, 425 lb estimated available N/acre from turkey manure. In all but two instances, NO_3-N leaching losses increased with N inputs. Due to early and late season rains, irrigation treatments differed little in water applied, crop yield or NO_3-N leached. Potatoes had more water percolation, but lower NO_3-N leaching compared to corn.

Introduction:

1991 was the first year of a three year effort to quantify water and NO_3-N movement under crops in the Central Sands of Minnesota. The test plots are located on the Staples Irrigation Center, Staples, Minnesota. Data from this experiment will be used to field validate computer models which will then be used to assess nitrogen and water Best Management Practices (BMPs) for the Central Sands.

Methods and Materials:

The test plots are located on a Verndale sandy loam. The area has a maximum slope of 2% with little or no runoff. The upper argillic horizon is compacted into a plow pan and has bulk densities up to 1.9 Mg/m^3. A typical soil profile from the plot area has the following description:

TABLE 1. TYPICAL VERNDALE SANDY LOAM PEDON DESCRIPTION

DEPTH		DESCRIPTION
0-10"	Ap	10YR 2/1; loamy sand; coarse, weak, subangular blocky structure; friable; abrupt boundary.
10-16"	Bt	10YR 4/4; sandy loam; med., mod, subangular blocky structure; friable to firm; clear boundary; <10% gravel.
16-21"	BC	10YR 4/6; loamy sand; coarse, weak, subangular blocky structure; friable; gradual boundary; <10% gravel.
21-32"	C1	2.5Y 6/6; sand; single grain; loose; gradual boundary; <10% gravel.
>32"	C2	2.5Y 6/4; sand; single grain; loose; some lamellae present at depths >48".

Soil tests were conducted in the spring, prior to manure spreading (see Table 2). Turkey manure was broadcast in the spring prior to tillage. Previous studies at Staples (Moncrief et. al., 1991) demonstrated the need to incorporate turkey manure for full nitrogen benefit. All plots were spring moldboard plowed. The rates of manure application were 10 and 16.6 tons/acre for corn, and 13.1 and 19.9 tons/acre for potatoes. Estimated available N from manure was determined by chemical analysis of KCl extraction and total N digestion (see Table 3). Thirty percent of total organic N was considered available for 1991. Estimated available N rates for turkey manure were then 228 and 367 lb N/acre for corn, and 282 and 425 lb N/acre for potatoes. These rates include 11 lb N/acre added as starter fertilizer for corn and 7 lb N/acre for both crops added as NO_3-N in irrigation water. Corn was planted on 8 May at a rate of 32,000 seeds/acre. Corn variety was Pioneer 3291. Russet Burbank potatoes were planted on 10 May at a 9 inch spacing.

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[1] *Support for this project was provided by the Legislative Commission on Minnesota Resources, Agricultural Utilization and Research Institute, and the Minnesota Dept. of Agric.. Their support is greatly appreciated.*

[2] *B.T. Sexton, Graduate Research Assistant, J.F. Moncrief and C.J. Rosen, Extension Specialists, S.C. Gupta and H.H. Cheng Professors of Soil Sci., Dept. Soil Sci., Univ. Minn, St. Paul, MN. J.A. Wright, Extension Irrigation Specialist, Dept. Ag. Eng. Univ. Minn., Morris, MN., M.J. Wiens is the Univ. Minn. Senior Plot Coordinator, Staples Irrigation Center, Staples, MN.*

TABLE 2. SOIL TEST RESULTS

CROP	P_2O_5	K_2O	S	Zn	Mg
CORN	143 lb/A	189 lb/A	12 lb/A	1.3 lb/A	259 lb/A
POTATOES	153 lb/A	240 lb/A			

TABLE 3. MANURE NITROGEN ANALYSIS ON DRY AND WET WEIGHT BASIS: Average water content was 78%, assuming 30% of organic N available and 80% of inorganic N available for the 1991 growing season. All numbers represent lb N/ton manure.

	total N	total mineral N	NH_4^+	NO_3^-	Est. avail. mineral N	total organic N	Est. avail. organic N	Total est. avail. N
dry wgt	83.8	24.7	20.9	3.8	19.8	59.1	17.7	37.5
wet wgt	47.1	13.9	11.7	2.1	11.1	33.2	9.9	21.0

TABLE 4. NUTRIENT ADDITIONS

CROP or treatment	ADDITION	RATE(S)	DATE	N lb/A	P_2O_5 lb/A	K_2O lb/A	S lb/A	Zn lb/A
CORN								
manure** plots only	turkey manure	10 ton/A 16.6 ton/A	2 May	210 349	171 284	178 295		
all plots	starter fert. 8-12-28-4-1	140 lb/A	8 May	11	17	39	5.6	1.4
commercial fert. plots only	urea $CO(NH_2)_2$ (46-0-0)	76,163,250 lb/A 76,163,250	29 May 13 Jun	36,74,118 36,74,118				
POTATOES								
manure plots only	turkey manure	13.1 ton/A 19.9 ton/A	2 May	275 418	224 340	233 353		
all plots	K, Mg, SO_4 (sulpomag)	340 lb/A	2 May			75	61	Mg 37
comm. fert. plots only	NH_4NO_3 35-0-0	77,154,231 lb/A	9 May	27,53,80				
all plots	0-46-0	108 lb/A	9 May		50			
all plots	0-0-61	258 lb/A	9 May			156		
comm. fert. plots only	NH_4NO_3 NH_4NO_3	77,154,231 lb/A 77,154,231	30 May 14 Jun	27,53,80 27,53,80				

** all manure application rates are on a wet weight basis

Commercial nitrogen fertilizer rates for corn were 18, 90, 165 and 254 lb N/acre from urea. Corn received 11 lb N/acre, from starter, and the remainder as two equal applications of urea. The first application was applied at the 4 to 6 leaf stage, on 29 May, and the second application at the 8 to 12 leaf stage, on 13 June (see Figure 1). NH_4NO_3 rates for potatoes were 7, 87, 167, and 247 lb N/acre. Potatoes received three equal applications of NH_4NO_3 at planting, on 9 May, emergence, on 30 May, and tuberization, on 14 June (see Figure 2). All fertilizer applications were incorporated by tillage or irrigation (see Table 4 for complete listing of fertilizer additions). All reported N rates include 7 lb N/acre applied as NO_3-N applied in irrigation water.

Two irrigation schedules were used for each crop (see Tables 5 and 6). The checkbook method (Wright

and Bergsrud, 1986) was used to calculate soil water deficits and schedule irrigations. A 20 inch rooting depth was used for both corn and potatoes, giving 2.33 inches of available water. The term "TRIGGER DEFICIT", used in Tables 5 and 6, refers to a water deficit, as determined from the checkbook method, which initiates irrigation.

Corn final stand was 31,065 plants/acre. Corn grain was harvested on 18 September. Potato vines were killed on 12 September and tubers harvested on 19 September.

Soil water content was determined prior to precipitation and irrigation events using tensiometers and soil water desorption curves. Water movement (PERCOLATION) was calculated by subtracting storable soil water (STORAGE), and estimated evapotranspiration (ET) from precipitation (PRECIP) and/or irrigation (IRRIG) amounts.

PERCOLATION = PRECIP + IRRIG - STORAGE - ET

Soil water nitrate concentrations were determined using two replicates of suction cup samplers placed in the row at a depth of 24 inches. One half bar suction was applied to the suction cup samplers on mornings when the soil water deficit was less than 0.2 inches, according to

TABLE 5. CORN IRRIGATION SCHEDULE

SCHEDULE	GROWTH STAGE	TRIGGER DEFICIT % , INCHES	INCHES OF IRRIG.
#1	all stages	0.75"	0.75"
#2	emergence-tasseling	60% , 1.40"	0.75"
#2	tasseling-1st dent	40% , 0.92"	0.92"
#2	1st dent-maturity	66% , 1.55"	0.75"

TABLE 6. POTATO IRRIGATION SCHEDULE

SCHEDULE	GROWTH STAGE	TRIGGER DEFICIT % , INCHES	INCHES OF IRRIG.
#1	all stages	0.7"	0.8"
#2	planting-tuberization	50% , 1.16"	1.16"
#2	tuberization-maturity	30% , 0.71"	0.75"

the checkbook method (Wright and Bergsrud, 1986). Soil water samples were collected the following morning. NO_3-N flux was calculated by multiplying water flux by soil water NO_3- concentration. The 254 lb N/acre, irrigation schedule two treatment corn NO_3-N fluxes are not included due to sampler tube malfunction.

Results and Discussion:

Total rainfall for the season 1 May to 20 September was 18.58 inches. Due to rainfall events early and late in the season, the two irrigation schedules differed little in total water inputs (see Table 7). Crop yields were not significantly affected by irrigation schedule (see Table 8). Timing of irrigations, however, were different (see Figures 1 and 2).

TABLE 7. TOTAL IRRIGATION INPUTS, PERCOLATION

CROP	IRRIG. SCHEDULE	INCHES OF IRRIGATION APPLIED	INCHES OF PERCOLATION
CORN	# 1	7.17 inches	7.2 inches
CORN	# 2	7.14 inches	7.0 inches
POTATO	# 1	7.95 inches	9.7 inches
POTATO	# 2	8.58 inches	9.8 inches

Figures 1 and 2 show individual rainfall, irrigation and calculated percolation events for the 1991 growing season for each crop irrigation schedule. Water percolation due to irrigation alone was

small, but instead, was related to rainfall events. During the irrigation season, more frequent irrigations to field capacity increases the probability of NO_3-N losses due to rainfall events following irrigations.

Corn responded up to 167 lb N/acre. Crop yields showed little difference between irrigation treatments (see Tables 8 and 9), but are presented separately due to differences in NO_3-N leaching (see Figures 3 and 4). For the growing season, manure leached less NO_3-N than comparable amounts of commercial fertilizers for both corn and potatoes.

TABLE 8. Effects of irrigation schedule, and N-rate on various crop yield parameters
Values are Pr > F; NS = nonsignificant; alpha = 0.1; culls = < 3 oz. potatoes

POTATOES	total yld	cull yld*	misshapen yld
irrig. schedule	NS	NS	NS
n-rate	.0043	.0668	.0035
n-rate*irrig	NS	NS	NS

CORN	grain yld	final stand
irrig. schedule	NS	NS
n-rate	.000	NS
n-rate*irrig	NS	NS

TABLE 9. POTATO HARVEST values are cwt/A **CORN HARVEST values are bu/A**

irrig sched.	n rate lb/A	total yld mean	total yld s.d.	cull yld mean	cull yld s.d.	mishp yld mean	mishp yld s.d.		irrig sched.	n rate lb/A	grain yld mean	grain yld s.d.
1	7	193.1	6.6	37.9	13.6	4.7	2.0		1	18	146.7	42.7
1	87	324.6	6.7	21.8	6.3	18.0	10.2		1	85	186.4	18.7
1	167	358.1	18.1	31.5	5.9	21.5	5.8		1	165	191.2	33.4
1	247	391.4	26.6	31.9	6.8	27.9	4.4		1	245	192.1	16.8
1	282*	388.3	23.1	30.6	6.0	30.0	12.1		1	228*	198.4	26.0
1	425*	416.1	64.3	32.3	7.4	39.2	32.8		1	367*	199.4	18.2
2	7	192.2	2.7	42.4	15.7	11.1	1.9		2	18	153.3	25.3
2	87	328.2	15.8	31.7	1.8	20.8	7.8		2	85	173.4	20.0
2	167	394.2	21.6	35.6	12.8	24.7	6.4		2	165	195.4	27.0
2	247	393.5	6.3	27.1	10.4	31.7	13.0		2	245	177.4	33.4
2	282*	429.6	15.6	36.0	4.8	43.4	12.6		2	228*	192.8	22.6
2	425*	445.3	38.9	32.8	6.3	42.9	23.0		2	367*	198.2	20.5

* estimated available N from turkey manure

Potatoes continued to respond through the highest N treatment, 425 lb estimated available N/acre from turkey manure. Irrigation treatments did not significantly affect crop yield but did affect NO_3-N leaching, especially in potatoes, with Schedule #2 showing slightly lower N loss due to leaching, (see Figures 3 and 4).

Over one half of NO_3-N leaching occurred following the rainfall events on the 29th of June and 1st of July. Nearly all of the precipitation from these two events percolated, since a 1.2 inch rainfall on the 27th of June brought the soil up to field capacity. Nitrate concentrations were also relatively high at this time, compared to water percolation events during the rest of the growing season. While some NO_3-N concentrations were higher, up to 240 ppm, these samples were taken during times of little or no water movement.

Figure 1 RAINFALL, IRRIGATION AND PERCOLATION FOR CORN

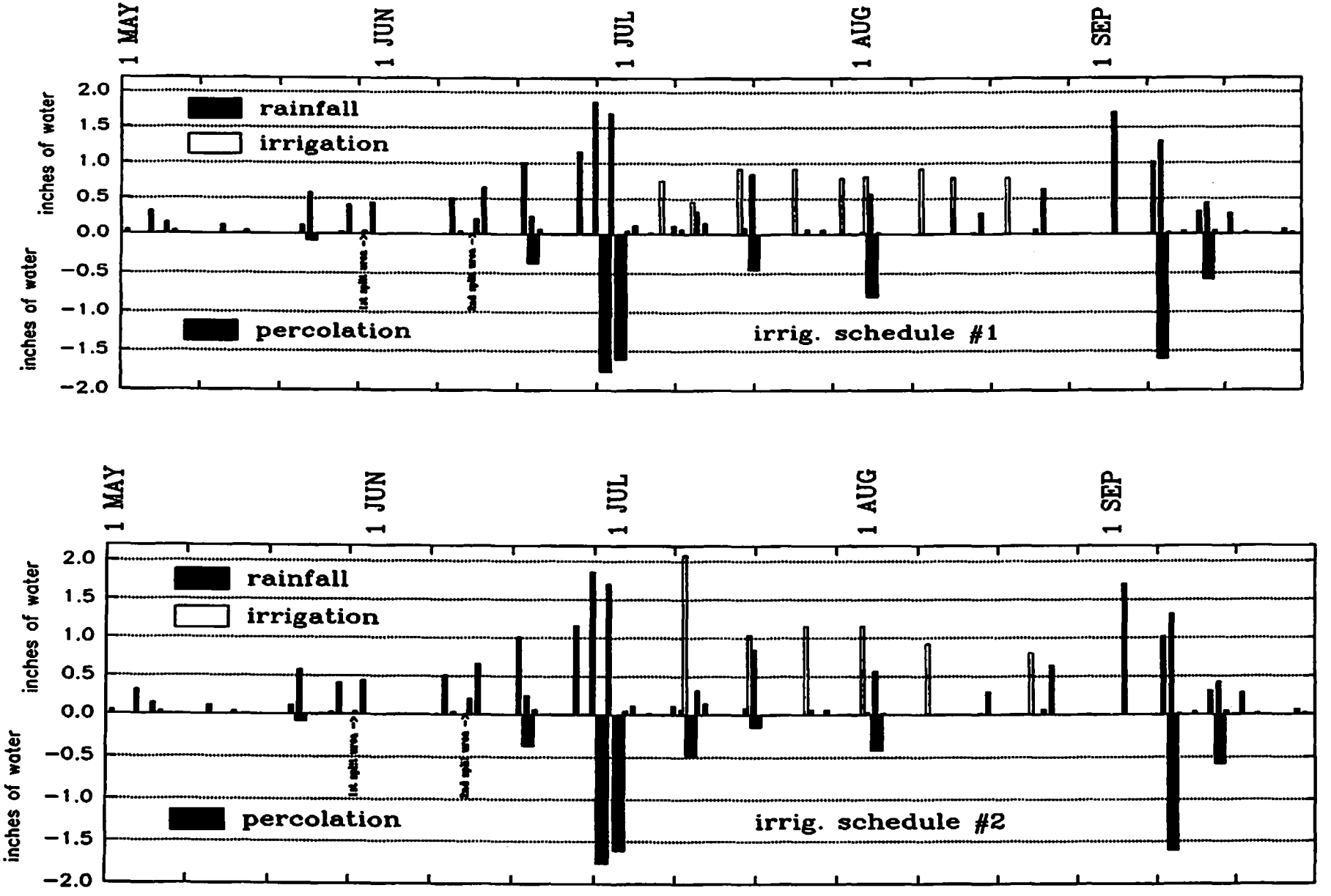


Figure 2 RAINFALL, IRRIGATION AND PERCOLATION FOR POTATOES

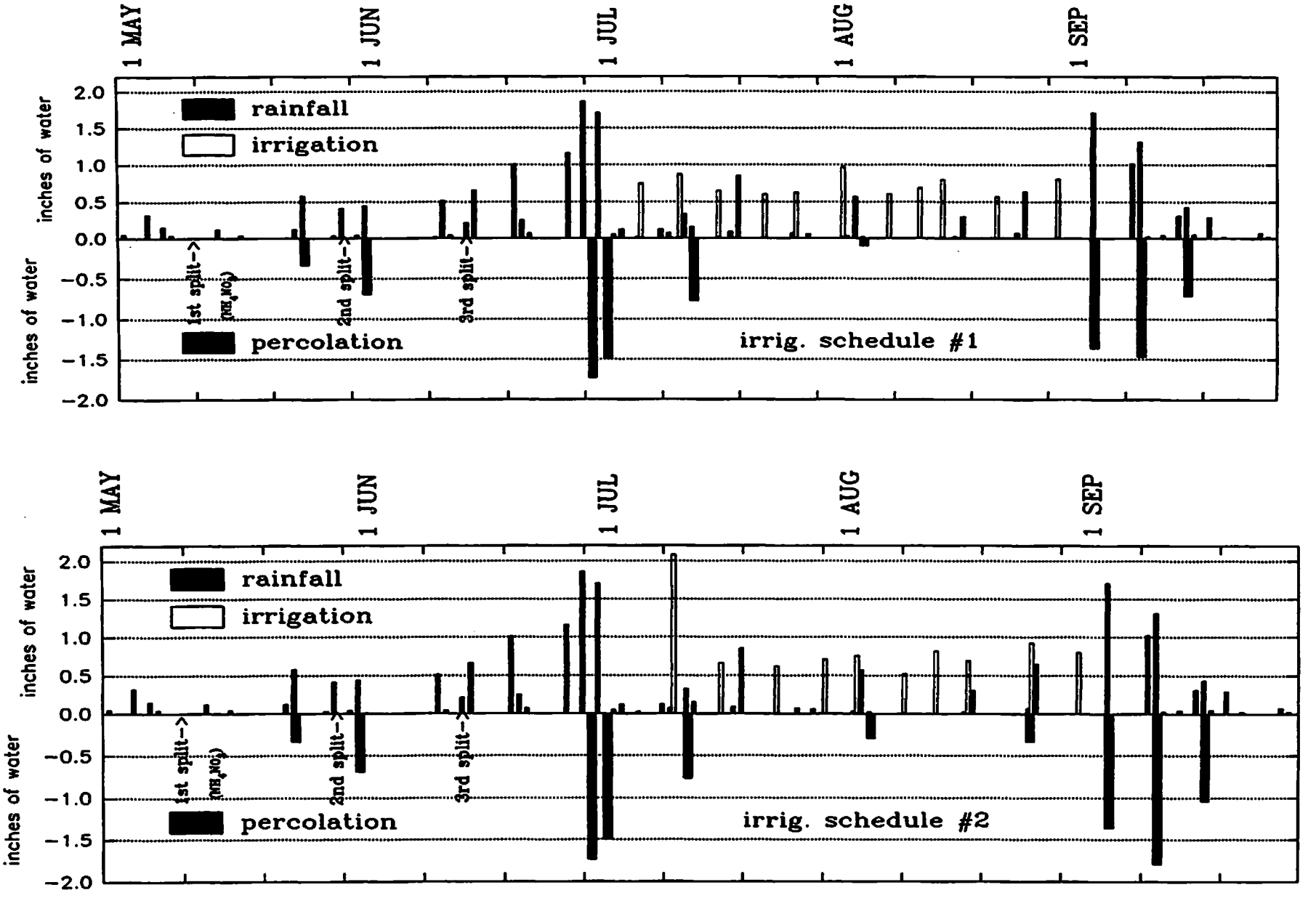
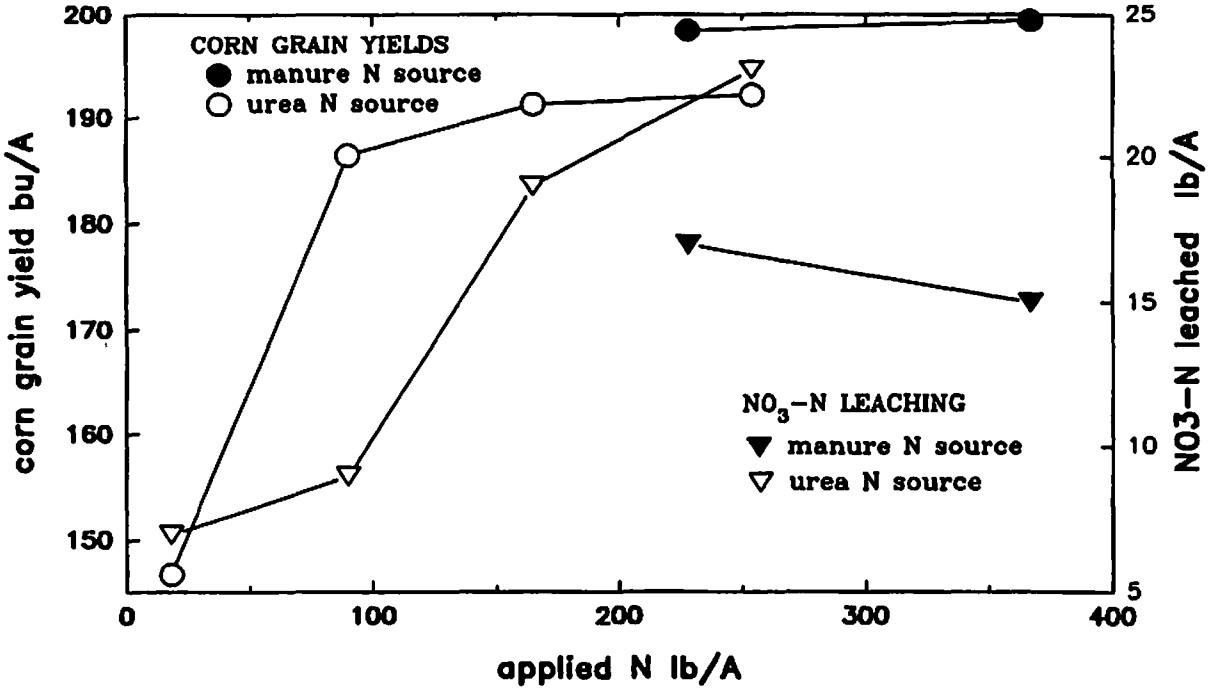


Figure 3 Corn grain yields and NO_3-N leaching

irrigation schedule #1



irrigation schedule #2

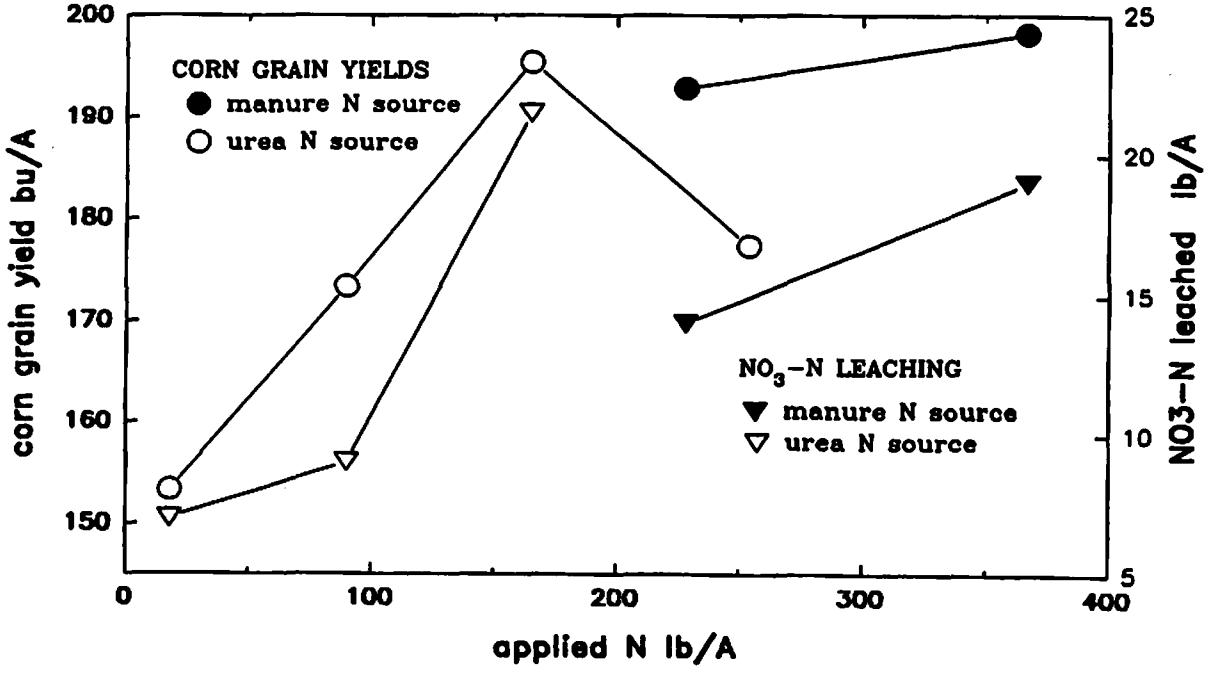
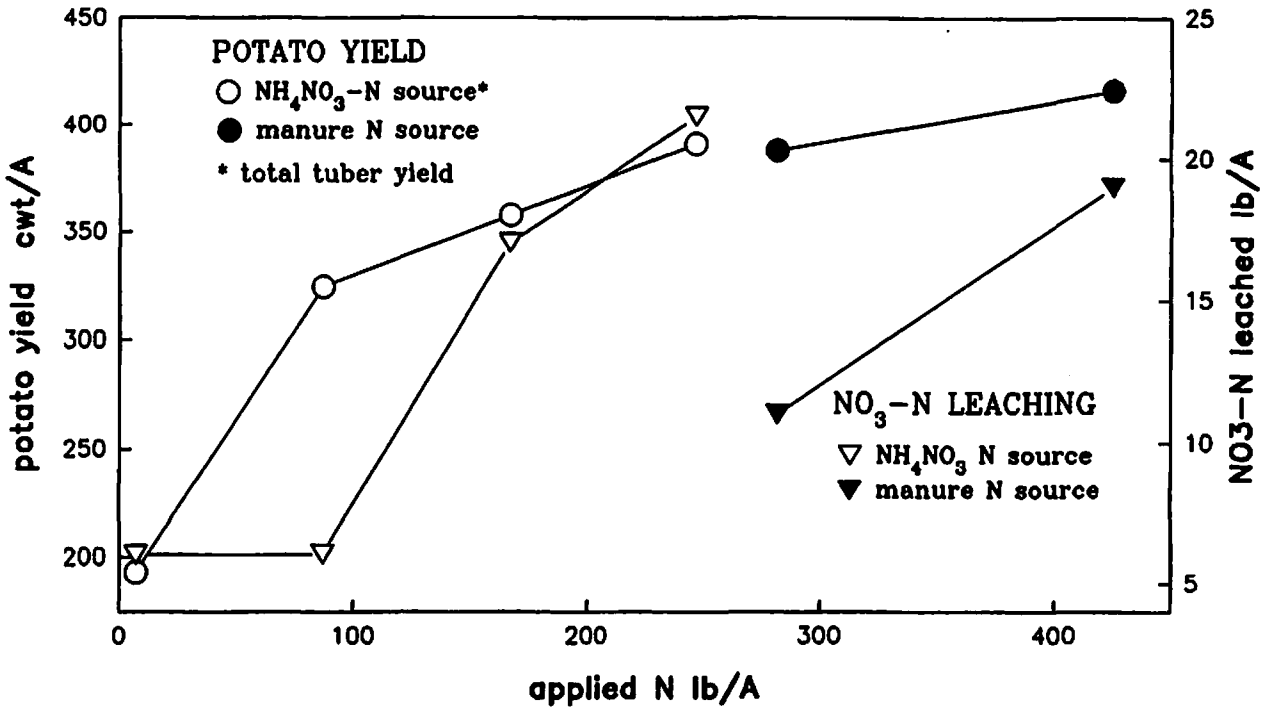
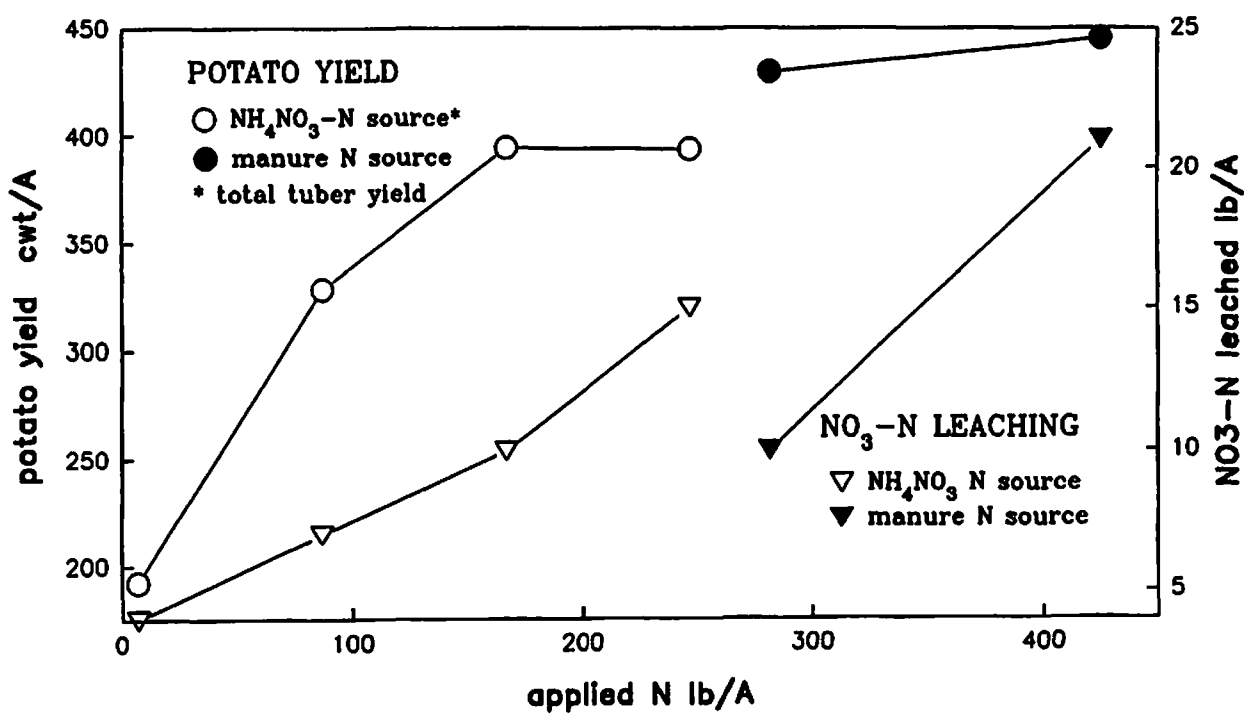


Figure 4 Potato tuber yields and NO_3-N leaching

irrigation schedule #1



irrigation schedule #2



CONCLUSIONS:

Corn grain yields were higher than expected for the 165 lb N/acre rate. University of Minnesota Extension N recommendation for 200 bushel/acre corn following corn is 220 lb N/acre (Rehm and Schmitt, 1989). The previous crop of lupine probably provided nitrogen to the corn crop. Potato yields were still increasing at the highest N rate, 425 lb estimated available N/acre from turkey manure. This affect may also have been due to the phosphorus and potassium additions from the manure.

Water percolation was lower under corn, but NO_3-N losses were higher compared to potatoes. The greater rooting depth of corn probably allowed more efficient use of water. The irrigation season for corn also ended 11 days prior to potatoes. The final irrigation on potatoes was shortly before a 1.7 inch rainfall in early September. Neither corn irrigation treatment showed water leaching from this event, while both potato irrigation treatments experienced over 1.3 inches of water percolating from this one event.

Lower N losses in potatoes was most likely due to potatoes still responding at the the highest N rate and the manner that water moves under the two crop. Warner and Young (1991) showed preferential flow to occur through the soil 4 inches on either side of a mature corn row. Cultivation with sweeps was used to incorporate the first application of urea applied to the corn. Such cultivation tends to push surface soil (and surface applied urea) towards the row, increasing the potential for NO_3-N leaching. The practice of hilling potatoes was shown by Saffigna et. al. (1976) to decrease water percolation through the sides of the hills, where commercial fertilizers were incorporated.

Irrigation scheduling is most critical following N application. Both irrigation schedules #2 (corn and potatoes) would decrease the probability of a leaching rain occurring during early growth stages. By not irrigating as often or to field capacity, the soil serves as a water storage buffer. Early growth stages are also the times when nitrogen applications are made. Manure tended to produce higher yields than comparable amounts of commercial fertilizer. The high organic content of manure serves as a slow release N source.

SOURCES:

Moncrief, J.F., M.J. Wiens, and J.J. Kuznia. 1991. "Tillage Effects on N Available to Irrigated Corn from Turkey Manure and Urea N Sources." *In* A Report on Field Research in Soils 1991 Misc. Pub. 71-1991. Minn Ag. Exp. Sta., U. MN, St. Paul, MN. p. 117-123.

Rehm, G. and M. Schmitt. 1989. Fertilizing Corn in Minnesota. AG-FO-3790 Minn. Extension Service, Univ. Minn. St. Paul, MN.

Saffigna, P.G., C.B. Tanner, and D.R. Keeney. 1976."Non-Uniform Infiltration Under Potato Canopies Caused by Interception, Stemflow, and Hilling". Agron. J. Mar-Apr 1976, vol. 68 p 337-342.

Warner, G.S. and R.A. Young 1991."Measurement of Preferential Flow Beneath Mature Corn" *In* Preferential Flow. Proceedings of 1991 ASAE convention. Chicago, IL p 150-159.

Wright, J.A. and F. Bergsrud. 1986. Irrigation Scheduling Checkbook Method. AG-FO 1322 Minn. Extension Service, Univ. Minn., St. Paul, MN.

CORN NITROGEN RATE STUDY

H. Meredith, Mel Wiens, and Andy Scobbie[1/]

ABSTRACT: A nitrogen rate study was initiated in 1990 on an irrigated sandy loam soil on the research area at the Staples Irrigation Center. The study is a multi-year ongoing research project to determine the optimum yield of irrigated corn in response to applied N, and intensive management.

Introduction: Production of high yields of corn on coarse textured soils with optimum use of supplemental moisture from irrigation is a common practice. These soils are subject to leaching of soluble constituents, especially nitrates. This study evaluates the response of corn to various rates of applied nitrogen.

Experimental: A Pioneer hybrid 3787 was seeded with a Duetz-Allis Model 385 four-row planter in 30-inch rows on April 23, 1991. The rate of planting was 32,000 seeds per acre. Nitrogen was applied in three equal applications beginning one month following planting, one month later, and the last increment was applied just prior to tassel. Nitrogen was applied at the 60, 90, 120, 150, 180, 210, and 240 pounds of N per acre.

Discussion: Maximum yield was achieved at the 180 pound N treatment. The most efficient response to N was at the 60-pound treatment (1.08 bu grain/lb N). AT the 180 pound N treatment, the increased yield was 0.2 bu grain/lb N. Corn at $2.50/bu and N at $.22 provides a small profit for applied N at the 180-pound/A rate.

Table 1. N rates, corn yield, grain moisture, and ear leaf N values at silking.

N Treatment	Grain Yield[1/]	Grain Harvest Moisture	Ear Leaf N at Silking	Stover
lbs/A	bu/A (15.5% H_2O)	%	%	D.M./A
0	56.1	27.2	1.03	1.54
60	121.1	27.7	1.74	2.45
90	133.8	26.1	1.96	2.42
120	137.4	27.7	2.17	2.24
150	147.8	26.4	2.41	2.67
180	153.6	27.5	2.43	2.46
210	151.9	27.0	2.61	2.25
240	153.7	25.6	2.67	2.49

[1/] Average of four replications

[1/] Regional Manager, TVA; Research Plot Supervisor, Staples Irrigation Center; Assistant Scientist, University of Minnesota, respectively.

LUPIN BEAN FERTILITY STUDY

H. Meredith, Mel Wiens, Andy Scobbie, and Dan Schmitz[1/]

ABSTRACT: A fertility study initiated in 1984 to determine nutrient requirements of the lupin bean (Lupinus albus) continued in 1991. Disease was quite prevalent and yields were reduced. As has been noted since the inception of these studies, no nutrient response to applied nutrients was noted. Yields appear in three tables.

Table 1 represents "good yields" (over 60 bu/A), and Table 2 lists the poor yields (less than 60 bu/A). The 1991 yields appear in Table 3. Yields are based on 13.5% moisture and 60 pounds bushel weight.

It is interesting to note that all yields over 60 bu/A average 62.8 bu/A while all yields under 60 bu/A average only 41.3 bu/A. Yields averaged over 60 bu/A on five occasions while yields under 60 bu/A occurred eight times, but a substantial difference of 21.5 bu/A.

Table 1. Summary of "good" Lupin yields, 1984-1991, Staples Irrigation Center.

Fertilizer Treatment	Yield, bu/A 1985	1987	1988	1990	
None	71.4[2/]	61.8[4/]	61.9[4/]	61.9[3/]	68.7[4/]
S	71.2	62.8	67.2	61.2	64.0
S+K	63.8	61.9	61.1	57.1	59.8
S+K+P	68.8	61.8	57.2	61.2	67.0
S+K+P+Zn	64.1	56.3	58.0	60.3	67.2
S+K+P+Zn+B	64.9	60.8	55.3	56.2	67.2
Average	67.4	60.9	60.0	60.0	65.6

Table 2. Summary of "poor" Lupin yields, 1984-1991, Staples Irrigation Center.

Fertilizer Treatment	Yield, bu/A 1984	1986		1987	1988	1989	
None	39.1[1/]	40.6[3/]	32.0[4/]	57.2[3/]	47.6[3/]	37.3[3/]	31.9[4/]
S	43.2	44.0	31.7	54.2	58.7	40.1	33.0
S+K	40.5	40.6	43.3	49.9	50.9	31.9	27.3
S+K+P	39.4	39.2	40.2	56.6	42.3	40.6	33.9
S+K+P+Zn	39.4	41.8	37.4	47.2	42.8	35.6	27.7
S+K+P+Zn+B	41.5	33.8	32.8	54.8	52.0	35.9	29.5
Average	40.5	40.0	36.2	53.3	49.0	36.9	30.6

[1/] 30-inch row spacing
[2/] 6-inch drill rows 1985 forward
[3/] Old fertility site
[4/] New fertility site

Table 3. Lupin yields in response to fertility treatments, Staples Irrigation Center, 1991.

No.	Treatment/A	Yield, bu/A[1/] 1991
1	No Fertility	45.0
2	50 lbs S	48.1
	100 lbs S	48.6
3	300 lbs K_2O	44.7
4	100 lbs P_2O_5	43.9
5	10 lbs Zn	33.5
6	2 lbs B	44.9
Average		44.1

[1/] 6-inch drill rows 1985 forward

[1/] Regional Manager, TVA; Research Plot Supervisor, Staples, Irrigation Center; Technical Field Crew, Soils Department, University of Minnesota, respectively.

Summary and Conclusions:

The 1991 growing season provided near ideal early growing conditions with temperatures well above average. Lush foliage developed coupled with irrigation provided an ideal situation for a high incidence of disease. Yields were drastically reduced.

The experience of wide-spread disease has thrown a ray of caution on the lupin growing project. It is apparent that seed stocks introduced from various regions have infected the area. Prudence must prevail such that only disease-free seed stocks are planted and that lupins follow a cereal crop to provide a near disease-free media for lupin production.

The lupin plant mobilizes sparingly soluble nutrients from the soil. A nutrient response has not been achieved which distinctively points to a nutrient deficiency. In some years, a tendency to slightly increased lupin yields is achieved following the addition of sulfur. This has not been a consistent observation, however.

Lupins are sensitive to soluble salts and lupin yields have been observed to be lower where high rates of fertilizer salts are applied or where fertilizer salts are placed in close proximity of the seed. High yields are attainable without application of fertilizer as evidence from the yields from previous years, especially 1985.

Lupins benefit from characteristics that provide "good husbandry." That is, high quality seed, freedom from disease, excellent vigor, high germination, establishment of "perfect" population density, weed-free, adequate heat and moisture, etc.

Lupin production is commonly compared to soybean production. Where soybeans are produced successfully in the 40-50 bushel range, lupins must exceed this production considerably to be competitive. This can be achieved consistently only after high yielding disease tolerant strains are introduced. Progress is being made along these lines. The present day lupin varieties have the capability to produce over 70 bushels per acre.

The highest yields were attained in 1985. This was a near ideal growing season for lupins. The year was one of the cooler summers in some time. The temperature was near ideal throughout the flowering period for lupins. Irrigation provided ample moisture. Pod set was heavy and essentially no aborting of fertilized ovaries was observed. The filling period was slow and was extended well into late summer. The cool temperatures prolonged maturity. A late frost permitted harvesting in mid October. Harvest normally occurs in August or early September. Poor seed viability resulted in disappointing yields in 1986.

Weed competition, inadequate population density and more recently disease have been the primary factors contributing to poor yields.

Crop rotation is deemed essential for lupin production. Ideally, lupins should follow a cereal crop and lupins should not be grown for more than one year on a site. Selection of disease-free sites must be accepted as one of the key management concepts.

TRITICALE PRODUCTION

H. Meredith, Mel Wiens, Andy Scobbie, and Dan Schmitz[1/]

ABSTRACT: Winter and spring triticale varieties have been evaluated under irrigation at the Staples Irrigation Center for several years. Winter triticale varieties as winter wheat do not have the winter hardiness needed to survive harsh winter, especially when a consistent snow cover is absent. Spring triticale varieties have greater promise although yields on the irrigated sands have been disappointing, Table 1.

Table 1. Winter triticale trials at the Staples Irrigation Center, 1991.

Variety	Grain Yield bu/A	Straw Yield Tons/A
Winterfest	30.7	3.80
Gold Rush	29.4	3.86
Snowfield	32.6	3.85
Centennial	31.5	3.42
Exp. 93	29.4	4.27
Exp. 97	27.0	3.20
Exp. 113	34.9	4.14
Exp. 192	24.2	3.40
Mitzi	28.9	4.18
Rymin	37.3	3.91
Dacold (ND)	25.7	3.35
Ave.	30.1	

Yields have been disappointing generally. Rye is included with the triticale plots to give an indication of hardiness. A summary of yields and chemical analysis follow:

Table 2. Winter triticale yields, Staples Irrigation Center. 1988.

Variety	Crop	Yield bu/A	Test Wt. lbs/A	Straw Yield tons/A
Ind 6-6-2	Triticale	34.9	51.9	1.79
Ind 5-3-3	"	31.6	50.2	2.00
Mitzi	Rye	55.3	60.2	2.04
Iowa 2-19-4	Triticale	35.9	56.1	1.68
Rymin	Rye	61.1	61.0	2.09
Ind 3-2-2	Triticale	40.1	54.7	2.06
Ind 2-2-4	"	45.9	55.0	2.00

Table 3. Spring triticale yields, Staples Irrigation Center. 1990.

Varieties	Yield bu/A	Test Wt. lbs/A	Straw Yield tons/A
Wapati	43.4	56.0	2.67
Florico	40.8	57.0	2.53
Companion	39.6	53.9	2.63
Plains	46.5	54.3	2.63
Norico	45.0	58.7	2.66
Norita	39.2	54.1	2.31

[1/] Regional Manager, TVA; Research Plot Supervisor, Staples, Irrigation Center; Technical Field Crew, Soils Department, University of Minnesota, respectively.

Table 4. Winter triticale yields, Staples Irrigation Center, 1990.

Varieties	Yield bu/A	Test Wt. lbs/A	Straw Yield tons/A
Winteri	9.2	44.8	1.37
81 DED 1015	11.1	50.3	1.30
81 DED 1012	7.5	49.4	1.45
Ind 5-3-3	11.2	47.9	1.48
Ind 3-2-2	11.0	45.6	1.28

Table 5. Nutrient Content of Rye and Triticale Seed, Staples 1987

Variety	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%						ppm				
Ia 2-19-4	2.8	.17	.48	.63	.06	.18	40	53	58	1.4	1.2
Ind 2-2-4	2.4	.16	.45	.57	.07	.18	42	54	55	1.7	1.3
Mitzie	2.0	.14	.40	.58	.05	.15	51	40	39	2.3	1.4
Ind 6-6-2	2.5	.17	.51	.67	.07	.18	41	60	57	1.9	1.2
Mitzie	2.0	.14	.41	.58	.05	.15	52	34	40	2.3	1.4
Rymin	1.9	.14	.40	.58	.05	.15	51	36	37	2.2	1.2

Table 6. Nutrient Uptake in Grain of Triticale and Rye, Staples 1987

Variety	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	lbs/A										
Ia 2-19-4	55	3.5	10	13	1.2	3.7	.08	1.2	.12	.003	.002
Ind 2-2-4	64	4.4	12	16	2.0	4.8	.11	1.4	.15	.005	.003
Mitzie	76	5.6	16	22	2.0	5.9	.20	1.5	.15	.009	.005
Ind 6-6-2	51	3.4	10	14	1.3	3.6	.08	1.2	.11	.004	.002
Mitzie	67	4.8	14	20	1.7	5.2	.18	1.2	.14	.008	.005
Rymin	71	5.3	15	22	1.8	5.5	.19	1.3	.14	.008	.005

Table 7. Nutrient Composition of Straw of Triticale and Rye, Staples 1987

Variety	N	S	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
	%						ppm				
Ia 2-19-4	.42	.05	.06	1.3	.28	.07	.02	.34	.14	1.0	2.4
Ind 2-2-4	.56	.06	.11	1.5	.41	.10	.01	.50	.16	1.3	5.0
Mitzie	.41	.06	.09	1.2	.30	.07	.02	.42	.10	1.0	2.2
Ind 6-6-2	.43	.06	.08	1.4	.36	.08	.03	.50	.13	1.2	4.0
Mitzie	.46	.06	.12	1.3	.31	.08	.02	.33	.10	1.0	2.3
Rymin	.48	.05	.11	1.4	.30	.08	.02	.38	.10	1.1	2.3

Triticale is a cross between durum wheat and rye. The Latin names of wheat, Triticum Aestinum and rye, Secale cereale are combined in the term Triticale. A naturally occurring triticale was identified as early as 1875. A successful cross between wheat and rye was successfully made in 1890. Triticales are not hybrids. Triticale in essence is an "artificial " genus combining the desirable characteristics of wheat and rye into one new specie.

When a cross between rye and wheat is made, the progeny or F_1 plant is sterile because the difference in the chromosome number of wheat and rye. Wheat has 42 chromosomes and rye has 14. The trick is to treat the developing embryo with colchicine. All of the chromosomes are doubled and the resulting F_1 triticale plant

is fertile and has 56 chromosomes. Triticales are largely self fertilized and usually breed true from one generation to the next.

Winter hardiness continues to plague newer triticale varieties. Snow cover provides vital protection against the severe cold. Warming periods in early spring followed by a severe drop in temperature have resulted in severe injury to an otherwise promising crop.

WATER QUALITY STUDIES

H. Meredith and Mel Wiens[1/]

ABSTRACT: For the past several years, a limited quantity of irrigation water samples have been collected and analyzed. Samples were taken from pumping wells, streams, and dug pits. The purpose of this study is to monitor the contents of dissolved nutrients from the irrigation water and to use this information as a guide to measure the long-term effects of irrigation.

The primary nutrients of significance are calcium and magnesium. Sodium, of great concern in arid regions where irrigation is common, is uncommonly low in Minnesota water used for irrigation.

Table 1. Analysis of Irrigation Water in Proximity of Staples, MN - 1991

PPM or Mg/L

Sample #	Date	N	P	K	Ca	Mg	Na	S
1 Well B	7/24	3.2	.10	1.2	79.0	20.4	2.1	2.0
2 Well B	7/24	5.7	.07	1.2	70.4	18.8	2.0	2.4
3 2 Tower	7/24	17.0	T	1.3	78.1	23.6	2.6	8.8
4 Farm Shop	7/24	<0.1	T	1.1	41.0	16.3	12.3	1.3
5 Energy Well	7/24	5.6	.04	2.5	72.4	22.4	7.2	9.2
6 NW Pit	7/24	12.8	T	1.2	72.5	24.2	2.6	6.4
7 SW Pit	7/24	<0.1	.27	2.9	47.5	13.0	1.7	4.8
8 Well B	8/1	3.2	.08	1.3	80.0	20.3	2.1	1.9
9 Well C	8/1	5.2	.08	1.2	67.9	20.0	2.1	2.0
10 Well D	8/1	6.3	.09	1.3	61.9	20.0	2.1	2.0
11 2 Tower	8/1	18.1	.05	1.3	92.0	24.6	2.8	9.2
12 Energy Well	8/1	6.5	.05	2.7	76.5	23.5	7.2	9.8
13 NE Pit	8/1	15.2	.04	1.2	83.1	24.4	2.7	6.9
14 Well B	8/8	3.6	.09	1.0	71.3	20.2	2.0	2.0
15 Well C	8/8	2.3	.09	1.2	71.1	20.4	2.0	1.2
16 Well D	8/8	5.8	.08	1.1	68.5	19.1	2.0	2.5
17 2 Tower	8/8	11.2	.04	1.2	78.1	22.6	2.5	6.9
18 Energy Well	8/8	6.7	.06	2.5	77.6	23.2	7.0	10.0
19 NW Pit	8/8	14.9	.05	1.4	76.8	24.2	2.8	6.6
20 SW Pit	8/8	<0.1	.24	3.2	49.5	14.8	2.1	8.5
21 Well B	8/19	3.9	.10	1.2	63.6	19.9	2.1	2.1
22 Well D	8/19	4.8	.10	1.4	69.4	19.1	2.0	2.4
23 2 Tower	8/19	11.9	.05	1.3	79.0	23.4	2.6	6.8
24 TS, Sec 5,N Germ		<0.1	.09	3.2	51.8	24.4	46.1	<.01
24 TS, Sec 6,N Germ		<0.1	.15	3.4	51.7	24.5	46.9	<.01
26 Forest Dingman Pit	8/21	3.4	.08	1.2	60.4	16.9	5.8	5.1
27 A.Carow #1, Sec 24, 60'	9/1	15.4	.06	2.7	85.9	27.3	3.0	11.8
28 A.Carow #1, Sec 13, 160'	9/1	<0.1	.24	2.4	62.4	31.1	7.6	.16
29 N.Schmitz 1, 55	1976	8.7	.05	1.9	78.5	23.2	7.3	11.3
30 N.Schmitz 2, 52'	1977	7.7	.05	1.7	77.1	21.1	3.7	5.0
31 N.Schmitz 3, Pit	1977	14.0	.05	2.2	91.1	27.6	2.9	19.0
32 House Well, Hard		16.5	.04	2.1	40.8	24.2	5.1	3.6
33 D.Sommars, House Soft		16.5	.04	1.9	58.1	27.6	4.5	4.0
34 D Sommars, Irr. Well		19.4	.04	2.7	101.6	26.7	3.4	4.6

[1/] Regional Director, TVA; Research Plot Supervisor, Staples Irrigation Center, respectively.

Table 2. Analysis of Irrigation Water in Proximity of Staples, MN - 1991.

Sample #	Specific Conductivity, Mmhos/cm	Lbs Nutrients/Ac Inch of Water						$CaCO_3$ Eq.
		N	K	S	Ca	Mg	Na	
1	470	.72	.27	.45	17.8	4.6	.5	61
2	430	1.3	.27	.55	15.8	4.2	.5	55
3	570	3.8	.27	2.0	17.6	5.3	.6	63
4	340	T	.26	.29	11.5	3.7	2.8	48
5	490	1.3	.55	2.1	16.3	5.1	1.6	62
6	500	2.9	.27	1.4	16.4	5.5	.6	61
7	340	T	.65	1.1	10.7	2.9	.4	38
8	450	.72	.29	.43	18.1	4.6	.5	62
9	420	1.2	.26	.43	15.3	4.5	.5	55
10	410	1.4	.29	.44	14.0	4.5	.5	55
11	540	4.1	.30	2.1	20.8	5.6	.6	72
12	520	1.5	.60	2.2	17.3	5.3	1.6	66
13	530	3.4	.27	1.6	18.8	5.5	.6	68
14	440	.81	.23	.44	16.1	4.6	.5	57
15	410	.52	.27	.28	16.1	4.6	.5	57
16	410	1.3	.23	.57	15.5	4.3	.5	55
17	500	2.5	.26	1.6	17.6	5.1	.6	62
18	520	1.5	.57	2.3	17.5	5.2	1.6	65
19	530	3.4	.31	1.5	17.4	5.5	.5	64
20	350	T	.71	1.9	11.2	3.3	.5	40
21	420	.88	.28	.47	14.4	4.5	.5	52
22	390	1.1	.31	.55	15.7	4.5	.5	55
23	520	2.7	.30	1.54	17.8	5.3	.6	60
24	540	T	.72	T	11.7	5.5	10.4	70
25	540	T	.77	T	11.7	5.5	10.6	71
26	400	.77	.27	1.1	13.6	3.8	1.3	56
27	580	3.5	.62	2.7	19.4	6.2	.7	71
28	500	T	.55	.04	14.1	7.0	1.7	63
29	530	2.0	.42	2.6	17.7	5.2	1.7	66
30	480	2.7	.49	1.1	17.4	4.7	.8	62
31	560	3.2	.47	4.3	20.6	6.2	.7	75
32	400	3.7	.84	.81	9.2	5.5	1.2	43
33	510	3.7	.84	.90	13.1	6.2	1.0	99
34	460	4.4	.99	1.0	22.8	6.0	.8	80

Summary and Conclusions Typically, irrigation farmers apply up to 10 acre inches of water in a dry year. It will be noted that the highest nutrient content was from samples No. 34. Ten inches of irrigation water would supply 44 pounds of N and 800 pounds of lime equivalent per acre.

SOUTHERN EXPERIMENT STATION

WASECA, MINNESOTA

WEATHER DATA - 1991

Month	Period	Precipitation 1991	Precipitation Normal[1]	Avg. Air Temp. 1991	Avg. Air Temp. Normal[1]	Growing Degree Days 1991	Growing Degree Days Normal[1]
		------ inches -----		------- ° F ------			
January	1-31	0.57	0.84	8.8	10.0		
February	1-28	0.65	0.99	23.5	16.4		
March	1-31	3.33	1.99	33.0	27.6		
April	1-30	4.30	2.64	48.6	44.7		
May	1-10	2.89		46.2		19.5	
	11-20	1.95		63.8		147.5	
	21-31	2.92		71.9		239.5	
	Total	7.76	3.76	61.0	57.7	406.5	334
June	1-10	.84		70.9		208.5	
	11-20	2.65		72.9		227.5	
	21-30	.24		76.3		242.5	
	Total	3.73	4.48	73.4	67.1	678.5	518
July	1-10	.86		72.0		213.5	
	11-20	3.82		76.3		244.0	
	21-31	3.99		67.8		198.5	
	Total	8.67	4.02	71.9	71.2	656.0	641
August	1-10	5.60		67.1		168.5	
	11-20	.64		68.9		189.5	
	21-31	.05		75.3		268.0	
	Total	6.29	3.99	70.5	68.8	626.0	579
September	1-30	4.61	3.36	59.2	59.8	308.0	311
October	1-31	1.40	2.08	45.7	48.9		38
November	1-30	7.42	1.43	23.0	32.5		
December	1-31	1.73	1.02	20.9	18.0		
Year	Jan-Dec	50.46	30.60	45.1	43.6	2675.0[2]	2421
Growing Season	May-Sep	31.06	19.61	67.2	64.9	2675.0	2383

[1] 30-year normal from 1951 – 1980.
[2] 50 to 86 ° F base, May 1 until first fall frost.

Notes:
1) Highest annual and growing season precipitation on record.
2) November precipitation was a record high while average temperature was a record low.
3) Highest temperature on June 27 & 28 – 97°F.
4) Only 16 days of ≥90 ° F.
5) Highest 24-hour precipitation on August 8 - - - 5.30".
6) Last spring frost - - - April 24.
7) First fall frost - - - September 20.

1991 Soil Moisture
0-5' Profile, Webster Clay Loam
Continuous Corn
Southern Experiment Station, Waseca, MN 56093

Depth	4/17	5/2	5/14	5/31	6/17	7/3	7/15	8/1	8/15	8/30	9/17	10/1	10/15	10/31
	inches available water in zone													
0-6[1]	1.08	.87	.92	1.07	1.25	.78	.74	.75	.89	.25	.72	.91	.62	1.14
6-12	.97	.61	.75	1.02	.99	.47	.58	.46	.70	.07	.42	.68	.39	.83
12-18	.89	.92	.83	.98	.90	.76	.63	.66	.79	.36	.77	.88	.55	.92
18-24	.89	.84	.71	.77	.84	.77	.63	.59	.69	.47	.67	.72	.47	.78
24-36	2.11	2.43	1.92	1.86	2.06	1.75	1.80	1.40	1.93	1.45	1.38	1.75	2.01	1.85
36-48	2.92	3.28	2.79	2.68	2.41	2.39	2.42	2.23	2.73	2.27	2.14	2.26	2.47	2.76
48-60	2.56	2.60	2.46	1.90	2.10	1.91	2.06	1.57	2.16	1.78	1.62	1.81	1.99	2.18
Total available water in 0-5' profile (inches)	11.43	11.56	10.38	10.29	10.55	8.85	8.87	7.66	9.90	6.66	7.71	9.01	8.49	10.47
% of Capacity[2]	100	100	94	93	95	80	80	69	90	60	70	82	77	95

[1] All values obtained by gravimetric sampling using Waseca D_b and WP constants.

[2] Assuming 11.05" field moist capacity.

Available soil moisture in the five-foot profile was plentiful throughout 1991. Above average rainfall resulted in a full soil moisture profile in June and no lower than 60% of a full profile at the height of evapotranspiration demand (July and August). Soil moisture conditions going in to 1992 are saturated with the profile being 95% full at the end of October.

NITROGEN LOSS TO TILE LINES AS AFFECTED BY TILLAGE[1]

Waseca, 1991

G. W. Randall and B. W. Anderson[2]

ABSTRACT: No tillage (NT) is thought to increase infiltration and, therefore, should increase the amount of water percolating through the soil compared to conventional tillage. This long-term study is being conducted to determine if greater amounts of NO_3-N and pesticides are being lost to tile drainage water with NT compared to moldboard plow (MP) tillage. Rainfall during 1991 was 19.9" above normal and tile flow was plentiful. The slightly higher tile drainage with NT was offset by higher NO_3-N concentrations with the MP system. Nitrate-N losses to the tile lines were 20% higher for the MP system. Corn yields, N uptake, and N removal in the grain were all significantly higher for MP compared to NT. Grain yield was 26% less with NT. Slightly higher amounts of NO_3 remained in the 8-foot soil profile in October with the MP system compared to NT.

Nitrogen losses to tile lines have been documented in a number of research studies including some conducted at Lamberton and Waseca, Minnesota. These studies primarily showed that N losses were a function of the N application rate and amount of precipitation. To some degree the time of application and crop grown have been shown to influence NO_3-N loss to tile lines. The purpose of this long-term study is to determine if tillage has an effect on N utilization, accumulation of NO_3-N in the soil profile, and the subsequent loss of NO_3-N to tile lines.

EXPERIMENTAL PROCEDURES

A study was initiated in 1975 on a Webster clay loam at Waseca to monitor the movement of N into a tile line installed in each of 12 plots measuring 45' x 50'. Each plot is enclosed with plastic sheeting to a 6' depth. Annual N rates of 0, 100, 200, and 300 lb N/A were applied from 1975-1979. No N was applied for the 1980 and 1981 crops. Residual N from N applied over the 5-year period (75-79) was utilized by the 1980 and 1981 corn crops. Soil samples to 10' and tile water samples taken in late 1981 showed little remaining evidence of the previous treatments.

In the fall of 1981, eight plots with the most uniform tile flow rates over the 1975-81 period were selected. Two tillage treatments (fall moldboard plow and no tillage) were replicated four times and randomized over the previous plot histories. Beginning in 1990, three replications and 6 plots were used. Corn was grown on these plots in 1982 through 1990. The stalks were chopped in October, 1990 and moldboard plots plowed.

On May 2, 180 lb N/A as ammonium nitrate was broadcast applied to the surface of all plots. The moldboard treatment was then field cultivated. Corn (Dekalb 547) was planted on May 15 at a population of 27700 plants/A with a John Deere Max-Emerge planter equipped with ripple coulters. Starter fertilizer was not used because of the high soil tests. Force was applied at 1 lb (ai)/A to control rootworms. Weeds were controlled with a preemergence application of Lasso (3-1/2 lb/A) and Bladex (3 lb/A) applied May 21. Weed and insect control were excellent. Percent surface residue was measured on May 3 and averaged 9 and 86% for the MP and NT systems, respectively.

The leaf opposite and below the ear was taken from 10 randomly selected plants per plot at silking (MP = July 22 and NT = July 24) and was analyzed for N. Silage yields were taken at physiological maturity by hand harvesting 40' of row from each plot.

Grain yields were taken by combine from 2 - 45' rows. Tile lines flowed from March 21 to August 21, Sept. 14 to 26 and November 16 to December 21. When tile lines were flowing, flow rates were measured daily and samples taken on a daily basis for the first week and then on a M-W-F basis thereafter for NO_3 analysis. All analyses were done by the Research Analytical Lab.

Soil NO_3-N in the 0-8' profile was determined from two cores/plot taken in 1-foot increments on October 18, 1991.

RESULTS

Yields, N uptake by the whole plant (silage), and N removal in the grain were all significantly higher for the moldboard plow (MP) system compared to no tillage (NT) (Table 1). This was the sixth year of ten where MP yields were significantly higher. Neither leaf N nor grain N concentration was affected by tillage (P = 90% level). Final population was slightly higher with NT.

Precipitation during the growing season was 11.4" above normal. Consequently, tile flow was substantially higher than in previous years and averaged about 19% higher with NT compared to MP tillage (Table 2). Flow-weighted NO_3-N concentration for the season averaged 53% higher with MP tillage. Thus, NO_3-N losses via the drainage water were 23% higher for MP tillage. On an annual basis these NO_3-N losses were the equivalent of 56% to 69% of the fertilizer N added. This figure is erroneous, however, because some of the NO_3 lost, especially early in the season, would have come from the residual NO_3 remaining in the soil after the 1990 crop. Much of that residual NO_3 was probably due to carryover of unused fertilizer N in the drier years and soil mineralization especially with MP tillage.

[1] Funding provided by the North Central Regional Research Committee (NC-201) and the Southern Experiment Station.

[2] Professor and Asst. Scientist, Southern Experiment Station, Univ. of Minnesota.

Table 1. Influence of tillage system on corn production and N utilization at Waseca in 1991.

Tillage system	Final population	Leaf N	Silage Yield	Silage N uptake	Grain Yield	Grain N	Grain N removal
	x10^{-3}	%	T DM/A	lb N/A	bu/A	%	lb N/A
Moldboard Plow	25.4	2.79	6.51	136.5	162.9	1.34	103.5
No Tillage	26.6	2.61	5.24	97.7	120.6	1.18	67.1
Signif. Level (%):[1]	96	79	92	92	99	87	97
CV (%) :	1.0	4.6	8.0	12.	3.1	6.6	9.8

[1] Probability level of significance.

Table 2. Influence of tillage system on tile flow, flow-weighted NO_3-N concentration and NO_3-N loss in 1991.

Month	Tile Flow		NO_3-N Concentration	NO_3-N Loss
	acre-in		ppm	lb/A
			Moldboard plow	
March	0.36		25.3	2.22
April	3.01		25.4	16.28
May	8.70		25.2	48.21
June	2.45		27.1	14.02
July	3.06		22.8	15.49
August	2.20		19.8	9.74
September	0.52		18.3	2.15
November	2.89		18.1	11.62
December	1.00		19.6	4.14
Total	24.19	Avg. =	23.5	123. 87
			No tillage	
March	0.51		18.4	2.09
April	3.51		16.1	12.59
May	9.04		16.6	31.87
June	3.48		19.7	14.98
July	4.03		18.6	16.65
August	2.84		15.5	9.63
September	0.70		12.3	1.94
November	3.20		11.4	8.13
December	1.38		10.2	3.08
Total	28.69	Avg. =	15.4	100.96

Residual NO_3-N in the soil profile at the end of the 1991 growing season showed about 30 lb/A more N remaining with the MP system (Table 3). The largest differences between the two tillage systems occurred in the 3 to 7' zone where more NO_3 accumulated with MP. These results are similar to previous years except that the greatest difference between the two systems usually occurred in the top 1 to 2 feet.

Table 3. Influence of tillage systems on residual NO_3-N in the soil profile in Oct., 1991.

Profile depth	Tillage System: Mb. Plow	Tillage System: No Tillage
feet	NO_3-N (lb/A)	
0-1	18.8	16.7
1-2	10.0	9.7
2-3	12.1	13.5
3-4	24.3	18.9
4-5	31.2	24.8
5-6	34.8	26.0
6-7	33.1	22.1
7-8	22.4	24.4
Total (lb NO_3-N/A 0-8')	186.7	156.1

TEN-YEAR SUMMARY

The cumulative totals for the 10-year period (1982-1991) are shown in Table 4. Corn yields over this period averaged 17.2 bu/A better with moldboard plow tillage. Approximately 20% more N has been removed in the grain with moldboard plow tillage. This has been due to both higher yields and slightly higher grain N concentrations with the moldboard tillage system some years. As a result an equivalent of 52 and 43% of the applied N has been removed in the grain by the MP and NT systems, respectively. Even though total water flow through the tile lines was 11% higher with NT compared to MP tillage, 3% more NO_3-N was lost via the tile lines with MP. This was due to higher NO_3-N concentrations, expecially in the last two years. This small difference is considered to be insignificant when considering tile flow variability among the plots. The equivalent of 20 to 21% of the fertilizer N applied to these plots has been lost to tile drainage over this 10-year period.

Table 4. Cumulative effects of the two tillage systems over the 10-year period.

	Tillage System	
Parameter	Mb. plow	No tillage
Fert. N applied (lb/A)	1800	1800
Corn grain removed (bu/A)	1395	1223
N removed in grain (lb/A)	929	775
N removed in grain as a percent of applied N (%)	52	43
Tile flow (acre inches)	104.6	116.3
Nitrate-N lost in tile (lb/A)	372.7	361.0
N lost via tile lines as a percent of applied N (%)	21	20

NITRATE LOSSES TO TILE DRAINAGE AS AFFECTED BY NITROGEN FERTILIZATION OF CORN IN A CORN-SOYBEAN ROTATION[1]

Waseca, 1991

Gyles W. Randall, Gary L. Malzer and Brian W. Anderson[2]

ABSTRACT: A study to determine the influence of time of N application and N-Serve on the uptake of N by corn and the loss of NO_3 to tile drainage was continued in 1991. Results from this fifth year showed significant yield improvement over the control with all N treatments, and significant differences among the four primary application time/method treatments. Corn yields and N efficiency were lowest with the fall N without N-Serve treatment, highest with the spring N treatments, and intermediate with the fall N plus N-Serve treatment. Tile lines flowed from late March through mid December. Tile flow averaged 17.10" for corn and 14.77" for soybean. Highest NO_3-N losses in the corn plots occurred with the fall application of N regardless of N-Serve while the highest losses under soybean occurred with fall application of N without N-Serve and split application to the previous corn crop. Nitrate-N concentrations and losses from continuous fallow plots that did not receive fertilizer N or a planted crop for five years were 60% higher than from the fertilized corn. This was due to high levels of NO_3 throughout the 8-foot profile as a result of soil mineralization and no crop uptake.

Nitrogen (N) losses to tile drainage water have been directly linked to N additions, crop grown, and soil organic matter level. Research has been conducted on NO_3 losses to tile water in Minnesota since 1972. This research has focused primarily on the effects of rates and timing of fertilizer N application and tillage in a continuous corn system. The purpose of this study is to determine the influence of time of N application and the use of a nitrification inhibitor on NO_3 movement and accumulation in the soil, NO_3 losses via tile drainage, and yield and N uptake by corn grown in a rotation with soybean.

EXPERIMENTAL PROCEDURES

Thirty-six individual tile line plots were installed on a poorly drained Webster clay loam at the Southern Experiment Station in 1976. Each 20 x 30' plot is completely surrounded by plastic sheeting to a depth of 6' to prevent lateral flow and contains a tile line (4' deep) 5 feet from one end. All tiles drain to collection pits where flow rates can be measured and water samples collected for analyses. After completing a research project in 1983 using this tile facility, the plots were cropped to corn with a blanket N rate in 1984 and 1985 to establish uniformity.

Beginning in 1986 corn was planted on one-half of the experimental site while soybean was planted on the other half. Thirty two plots (16 with corn and 16 with soybean) with the most uniform drainage were selected from the 36 for the primary study. The experimental design consists of a 4 x 4 Latin square where the rows and columns were based on the previous (1977-83) tile flow rates from each plot. The four basic N treatments (see Table 1) are applied to the corn phase each year with the residual effects measured in the soybean phase. Three additional N treatments were replicated four times around the edge of the core 16-tile-plot area and were planted to corn. These three treatments were analyzed along with the other four as a completely randomized design.

Anhydrous ammonia was applied at a rate of 135 lb/A for all N treatments while N-Serve was applied at 0.5 lb/A. Fall treatments were applied on October 26. Average soil temperature at the 4" depth on that date was 47°F with an average of 48°F over the following 10-day period. Spring preplant treatments were applied on May 21. The sidedress portion (60%) of the split treatments was applied at the V-9 stage on July 8.

The soybean area that was planted to corn in 1991 was field cultivated once before planting. The corn area (1990), however, was fall chiseled and field cultivated once prior to planting soybean. Surface residue accumulation estimated by the line-transect method on May 3 showed an average of 52 and 48% for the areas that were planted to corn and soybean, respectively, in 1990. Because of high soil P and K tests, no broadcast nor starter fertilizer was used.

Corn (Pioneer 3751) was planted at 30,200 plants/acre on May 29 with a JD Max-Emerge planter equipped with waffle coulters. A corn rootworm insecticide was not used. Weeds were chemically controlled with a preemergence application of Lasso (3.5 lb/A) plus Bladex (3 lb/A).

Soybeans (Hardin) were planted in 30" rows at 9 beans per foot of row on May 29. Weeds were chemically controlled with a post emergence application of Pursuit (4 oz/A) at the 1st trifoliate stage.

Two plots within each of the corn and soybean areas were not planted and were fallowed all summer. These four fallow plot areas were located on those tile plots that showed greatest water flow variability (1977-83). The purposes of these plots were to simply check the NO_3-N concentrations in the tile water in a fallow system and to utilize all 36 of the tiled plots, even though these four historically showed the highest flow variability.

Stand counts were taken at the V-5 stage and plots were thinned to a uniform population. Eight randomly selected plants were removed from the center rows at silk initiation (July 30) and were chopped, dried, weighed and ground for total dry matter accumulation and analyzed for total N concentration. Stover and grain samples were taken at physiological maturity by hand harvesting 30' of row for stover yields and 60'

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of row for grain yields and moisture. Chemical analyses of whole plant, stover and grain samples were performed by the Research Analytical Laboratory, University of Minnesota. Tile line flow rates were determined daily and were recorded when flow exceeded 10 ml/minute (0.01"/day). Samples were collected for NO_3-N analysis on an every-other-day basis. Periodic samples were collected for alachlor (Lasso), cyanazine (Bladex), and imazethapyr (Pursuit) analyses.

Soil samples for NO_3-N analysis were taken in 1-foot increments to a depth of 8 feet from the fallow plots and selected corn and soybean plots on April 15. The same technique was used to sample all fallow and corn plots and selected soybean plots on October 21.

RESULTS AND DISCUSSION

Plant

Whole plant N concentration at the silking stage was highly affected by the N treatments (Table 1). This is in contrast to 1990 probably because of the high amount of rainfall during the 1991 growing season (11.4" above normal). Very low plant N concentrations were found with the fall applications with a slight but non-significant improvement when N-Serve was applied. Plant N concentrations at silking were increased significantly by all spring and split applications over the fall applications. Dry matter accumulation at silking was not improved over the control by fall application without N-Serve. Spring applications resulted in highest DM accumulation at silking. Stover N concentration was increased significantly over the control by all spring applications but not by either of the fall applied treatments. Dry matter yield of the stover at physiological maturity (PM) was increased by all of the N treatments over the control. However, spring applications were clearly superior to fall N without N-Serve while fall N plus N-Serve showed an intermediate stover DM yield. Final population was not significantly different among the N treatments.

Table 1. Influence of time of N application and N-Serve on whole plant N, stover yield, and final population of corn following soybeans.

N application		Whole Plant Silk Stage		Stover		Final
Time	N-Serve	N	DM	N	Yield	Population
		%	g/plt	%	TDM/A	ppA x 10^3
Primary trts						
Fall (Oct.)	No	1.01	86	.32	1.90	28.0
Fall (Oct.)	Yes	1.11	99	.37	2.17	27.9
Spr. (April)	No	1.59	107	.43	2.30	28.2
Split[1]	No	1.30	103	.43	2.30	28.4
Additional trts						
Check	-	1.02	76	.34	1.49	28.4
Spr. (April)	Yes	1.53	114	.46	2.34	28.2
Split[1]	Yes	1.63	97	.46	2.21	27.4
		Statistical Analysis				
Latin square (Primary Trts)						
Signif. Level (%) :		99	97	90	99	42
BLSD (.05) :		0.16	13	-	0.22	-
CV (%) :		7.8	7.3	15.	5.8	1.6
Completely randomized (7 trts)						
Signif. Level (%) :		99	99	99	99	95
BLSD (.05) :		.14	11	.08	.27	0.7
CV (%) :		7.9	8.2	13.	9.1	1.4

[1] 40% preplant + 60% sidedress.

Grain and silage yields were increased significantly over the check (0 lb N/A) by all of the N treatments (Table 2). However, grain and silage yields with fall applied N without N-Serve were clearly inferior to the spring N applications and fall N with N-Serve. Although not statistically significant (P = 95% level), spring applications of N gave consistently higher grain and silage yields. Grain moisture at harvest was significantly higher (P = 99% level) for the check compared to the N treatments with no significant difference (P = 95% level) among the four primary time/method treatments. Grain N concentration and N removal in the grain were increased over the 0-lb N check by all of the N treatments and was significantly higher with the spring applications compared to fall application regardless whether N-Serve was used. Total N uptake was increased over the control by 23.6 lb/A (43%) for the fall N without N-Serve, 40.5 lb/A (74%) for the fall N with N-Serve, and over 65 lb/A (121%) with the four spring N treatments. In summary, all plant yield and N efficiency parameters were significantly improved by the spring N treatments, regardless of method or N-Serve, compared to fall applications.

Total N removal in the grain ranged from 65.8 to 108.2 lb/A for the six N treatments (Table 2). Based on these removal amounts, N efficiency (N removed by a treatment - N removed in the check ÷ 135 lb N/A) ranged from 16 to 48% for the six N treatments. Efficiency of the spring treatments ranged from 42 to 48% and was substantially higher than the 16 and 26% with the fall treatments without and with N-Serve, respectively. Nitrogen efficiency based on total plant uptake ranged from 17 to 56% for the six N treatments. Again, N efficiency with the spring N treatments (49 to 56%) was clearly higher than from the fall treatments (17 to 30%) regardless if N-Serve was used.

Table 2. Corn grain and silage production as influenced by time of N application and N-Serve.

N application		Grain					Total N
Time	N-Serve	Yield	H_2O	N	N removal	Silage	uptake
		bu/A	%	%	lb/A	TDM/A	lb/A
Primary trts							
Fall (Oct.)	No	122.5	22.8	1.14	65.8	5.21	78.0
Fall (Oct.)	Yes	143.4	21.8	1.16	79.0	6.00	94.9
Spr. (April)	No	151.2	19.3	1.40	100.8	6.41	120.5
Split[1]	No	152.8	20.3	1.42	103.0	6.47	122.7
Additional trts							
Check	-	93.2	25.4	1.00	44.0	4.02	54.4
Spr. (April)	Yes	154.5	21.0	1.48	108.2	6.57	129.9
Split[1]	Yes	151.3	20.7	1.40	100.2	6.35	120.2
			Statistical Analysis				
Latin square (Primary trts)							
Signif. Level (%) :		99	92	99	99	99	99
BLSD (.05) :		16.0	-	0.08	13.9	0.43	12.9
CV (%) :		6.3	7.6	3.7	9.3	4.2	7.3
Completely randomized (7 trts)							
Signif. Level (%) :		99	99	99	99	99	99
BLSD (.05) :		12.6	1.8	.08	10.4	.45	12.5
CV (%) :		6.8	6.1	5.0	9.1	5.7	9.0

[1] 40% preplant + 60% sidedress

Table 3. Influence of time of N application and N-Serve on time of N uptake.

N application		Fodder N Yield at[1]		Grain N Yield at PM			
Time	N-Serve	Silk	PM	Total	OLD[2]	NEW[3]	NEW[3]
		lb N/A					%
Primary trts							
Fall (Oct)	No	53.7	12.2	65.8	14.5	24.5	36
Fall (Oct)	Yes	68.0	16.0	79.0	52.0	26.9	34
Spr (April)	No	105.7	19.8	100.8	86.0	14.8	13
Split[4]	No	83.5	19.7	103.0	63.8	39.2	38
Additional trts							
Check	-	48.1	10.4	44.0	37.7	6.3	14
Spr (April)	Yes	108.1	21.7	108.2	86.4	21.8	20
Split[4]	Yes	95.8	20.0	100.2	75.8	24.4	24
			Statistical Analysis				
Latin square (Primary trts)							
Signif. Level (%):		99	99	99	99	88	92
BLSD (.05) :		13.6	4.2	13.9	13.1	-	-
CV (%) :		10.	14.	9.3	13.	44.	40.
Completely randomized (7 trts)							
Signif. Level (%):		99	99	99	99	95	94
BLSD (.05) :		9.8	3.8	10.4	11.2	21.9	-
CV (%) :		9.1	16.	9.1	13.	56.	53.

[1] Silk = Silk stage, PM = physiological maturity.

[2] OLD N = N in stover at silk – N in stover at PM; the difference is assumed to be translocated to the grain.

[3] NEW N = Total N in grain – Old N; the difference is assumed to be absorbed from the soil and/or translocated from the roots after silking.

[4] 40% preplant + 60% sidedress.

Total N uptake by the plants receiving fertilizer N prior to silking (Fodder N yield at silking) divided by total N uptake at PM shows that from 62 to 87% of the N was accumulated by the plants prior to silking (Table 3). NEW N in the grain (assumed to be taken up by the plant after silking and translocated to the grain) ranged from 14% in the check treatment to between 13 and 38% for all treatments receiving fertilizer N. Under the 1991 conditions there was no clear effect of time/method of N application on post-silk (NEW N) N uptake into the grain.

The General Linear Model program in SAS was used to "contrast" the four primary treatments and determine if significant differences existed. The significance levels shown in Table 4 show consistent yield and N efficiency differences among the N-Serve treatments with fall-applied N. Spring application of N showed significant advantages over fall-applied N for all plant parameters except plant population. With the exception of whole plant N concentration at silking, there was no difference between the spring preplant and split application of N.

Table 4. Significance levels for differences among the four primary treatments as determined by contrast statistics.

Parameter	Contrast: Fall w/o N-Serve vs Fall w/N-Serve	Fall vs Spring	Spring preplant vs Split
	Significance Level (%)		
DM Yield at Silking	99	99	57
Plant N Conc. at Silking	87	99	99
Stover N Conc. at PM	79	99	0
Grain N Conc. at PM	43	99	32
Grain Moisture	65	99	68
Grain Yield	99	99	17
Stover Yield	92	98	1
Silage Yield	99	99	19
Final Population	40	85	40
Grain N Removal	97	99	30
Silage N Uptake	98	99	25

Water

Weather conditions during the 1991 growing season were slightly warmer than normal but were 11.4" wetter than normal. Rainfall during May through August totaled 10.20" above normal. This resulted in tile flow from March 25 through December 6. Tile drainage volumes shown in Table 5 indicate highest flows in May and July. Drainage from the 16 corn plots averaged 17.10" with a 1.78" range among the four time/method treatments. Soybeans showed slightly less tile drainage compared to corn with an average of 14.77" from the 16 plots and a range of 2.91" among the four time/methods. Ideally, drainage should be uniform among the time/method treatments; however, normal soil and drainage variability exists in these plots and results in these unfortunate differences.

Monthly flow-weighted NO_3-N concentrations in the corn plots averaged less than 15 mg/L in April but increased up to 34 mg/L in June with the fall N treatment without N-Serve (Table 6). Nitrate-N concentrations in the tile water with the fall N plus N-Serve and the spring N treatments peaked in June but at lower concentrations of 27 and 16 mg/L, respectively. Nitrate-N concentrations continued to decline after June until reaching levels as low as 6.6 mg/L in December. The fall N treatments tended to give slightly lower NO_3-N concentrations in the tile water in September thru December than the spring treatments. Flow-weighted NO_3-N concentration for the season averaged about 19.0 mg/L for the fall treatments, 15.1 mg/L for the spring treatment and 14.1 mg/L for the split treatment. An opposite trend occurred under soybean where N had been applied in either October, 1989 or spring 1990 for the 1990 corn crop. In this case, flow-weighted monthly NO_3-N concentration started above 20 mg/L in March and slowly declined through the season. The NO_3-N concentration associated with the fall N plus N-Serve treatment was generally lower than the spring treatments and was consistently lower than the fall N without N-Serve treatment. Highest and lowest flow-weighted annual NO_3-N concentrations were associated with the split-applied treatment and fall N plus N-Serve treatment, respectively, when applied to corn the previous year. Nitrate-N concentrations under a 5-yr continuous fallow system (no fertilizer N applied) were approximately 3 to 4X as high as from corn or soybean early in the season but dropped to 2 to 3X as high later in the season.

Under corn, substantially higher NO_3-N losses occurred with the fall treatments compared to the spring treatments (Table 7). This was due to higher NO_3-N concentrations. Little difference was observed between the NO_3-N losses from the spring and split treatments. Nitrate-N losses under soybean were highest for the fall N without N-Serve and the split application treatments that were applied for the 1990 corn crop. This was due primarily to higher NO_3-N concentrations with these two treatments and higher flow rates with the fall treatment. Very high NO_3-N losses occurred under the fallow system where the mineralization of the soil organic matter was the nitrate source. This emphasizes the importance of growing a crop to absorb N released from these high organic matter soils.

Table 5. Tile water discharge from the corn, soybean, and fallow plots in 1991.

N application		Month									Year
Time	N-Serve	March	April	May	June	July	Aug.	Sept.	Nov.	Dec.	Total
		acre-inches									
		CORN									
Fall (Oct.)	No	0.00	2.03	6.22	0.83	4.94	1.43	0.40	1.49	0.19	17.53
Fall (Oct.)	Yes	0.00	2.02	6.05	0.88	4.78	1.25	0.15	1.36	0.21	16.70
Spr. (April)	No	0.00	1.88	5.24	1.13	4.79	1.62	0.22	1.22	0.10	16.20
Split	No	0.00	2.09	5.96	0.99	5.65	1.75	0.11	1.23	0.20	17.98
		SOYBEANS									
Fall (Oct.)[1]	No	0.22	1.95	6.74	0.72	4.23	1.61	0.00	0.92	0.09	16.26
Fall (Oct.)[1]	Yes	0.16	2.34	5.96	0.69	3.98	1.24	0.00	1.31	0.06	15.74
Spr. (April)[1]	No	0.18	1.82	5.32	0.65	3.75	1.22	0.00	0.68	0.10	13.72
Split[1]	No	0.32	1.93	5.23	0.50	3.49	1.06	0.00	0.78	0.04	13.35
		FALLOW									
NONE		-	1.40	4.72	0.74	2.67	0.98	0.28	1.16	0.13	12.08

[1] N applied for the 1990 corn crop.

Table 6. Flow-weighted NO_3-N concentrations for each month from the corn, soybean, and fallow plots in 1991.

N application		Month									Year
Time	N-Serve	March	April	May	June	July	Aug.	Sept.	Nov.	Dec.	Avg.
		mg NO_3-N/L									
		CORN									
Fall (Oct.)	No	-	15.8	22.9	33.6	24.4	13.8	7.1	14.3	6.6	18.9
Fall (Oct.)	Yes	-	15.7	20.4	27.4	22.5	14.4	7.3	11.5	9.2	19.0
Spr. (April)	No	-	13.9	16.5	16.8	14.0	9.4	13.0	10.9	13.6	15.1
Split	No	-	14.1	16.5	16.3	14.0	10.7	13.0	13.2	8.4	14.1
		SOYBEANS									
Fall (Oct.)[1]	No	21.5	23.4	18.9	18.2	14.8	13.4	-	14.3	13.6	17.7
Fall (Oct.)[1]	Yes	21.4	17.1	15.7	16.0	14.4	11.8	-	11.5	11.7	14.9
Spr. (April)[1]	No	22.8	19.4	17.5	17.2	13.7	11.4	-	10.9	9.5	16.2
Split[1]	No	19.5	21.0	20.7	19.7	17.7	14.3	-	13.2	15.6	19.0
		FALLOW									
NONE		-	60.6	46.8	41.9	33.0	34.3	12.2	35.2	29.8	37.9

[1] N applied for the 1990 corn crop.

Table 7. Nitrate-N loss for each month from the corn, soybean and fallow plots in 1991.

N application		Month									Year
Time	N-Serve	March	April	May	June	July	Aug.	Sept.	Nov.	Dec.	Total
		lb NO_3-N/A									
		CORN									
Fall (Oct.)	No	-	6.69	30.94	5.58	24.65	3.93	0.66	2.16	0.28	74.89
Fall (Oct.)	Yes	-	7.18	28.32	5.19	24.13	3.84	0.22	2.53	0.40	71.81
Spr. (April)	No	-	6.84	21.59	4.54	15.60	3.47	0.35	2.77	0.31	55.47
Split	No	-	6.71	22.27	3.69	17.37	4.00	0.19	2.64	0.46	57.33
		SOYBEANS									
Fall (Oct.)[1]	No	1.05	10.71	28.83	2.97	13.68	4.79	0.01	2.95	0.29	65.28
Fall (Oct.)[1]	Yes	.79	8.87	21.03	2.46	12.99	3.33	0.00	3.38	0.15	53.00
Spr. (April)[1]	No	.92	8.36	21.60	2.59	11.71	3.10	0.00	1.69	0.23	50.20
Split[1]	No	1.50	9.06	24.42	2.26	13.92	3.51	0.01	2.45	0.15	57.28
		FALLOW									
NONE			15.78	44.88	7.51	18.44	6.60	1.19	8.32	0.90	103.62

[1] N applied for the 1990 corn crop.

Nitrate-N losses to the tile drainage water were normalized to tile water flow to minimize the influence of water flow volume among the N treatments on the interpretation of the data (Table 8). Normalized values for corn were highest for the two fall treatments with no difference between them. In the year following corn and its associated treatments, normalized losses ranked in the order split > fall w/o N-Serve > spring preplant > fall w/N-Serve. Apparently, sufficient N was not utilized by the corn and remained in the soil profile following the split application; thus, higher NO_3 losses in the succeeding year. Normalized NO_3-N losses for the corn-soybean system were highest for the fall application without N-Serve and lowest for the spring application. Additional years with adequate drainage losses are necessary to determine if these findings are consistent over time.

Table 8. "Flow-normalized" NO_3-N losses to tile drainage in a corn-soybean sequence in 1991.

Crop[1] System	Time/Method of N Application: Fall No N-Serve	Fall N-Serve	Spring No N-Serve	Split
	NO_3-N Lost (lb/A/inch of drainage)			
Corn	4.27	4.30	3.42	3.19
Soybean	4.01	3.39	3.71	4.39
C-Sb System	4.12	3.88	3.57	3.70

[1] Continuous fallow (5 years without fertilizer N) = 8.58

Soil

Nitrate-N remaining in the 0-8' soil profile in mid-April was high in the fallow plots (226 lb/A) compared to those where either soybean or corn were grown in 1990 (Table 9). This value is considerably less than the 377 lb/A that was measured in late October 1990. The reason for the 150 lb/A change over the winter months is not known but may have been largely due to immobilization coupled with some sampling error. Soybean that had not received fall-applied N averaged 99 lb/A with 67 lb/A remaining in the top 5'. Very low amounts of residual NO_3-N remained in the 0-8' profile when corn receiving no N fertilizer was the previous crop (55 lb/A). Residual NO_3-N remaining from the 1990 crop was increased by 30 to 60 lb/A with the previous fall, spring preplant, and split applications. Distribution of NO_3 within the profile was markedly different among the crop/fallow systems. In the fallow plots NO_3-N concentration increased with depth to 4 feet and then remained consistently high. With soybean and corn that received 0 lb N/A, NO_3-N concentrations were highest in the surface foot, decreased in the 1-2' layer, and then remained consistent throughout the rest of the profile. Corn that received the 135-lb N rate in 1990 showed a relatively uniform distribution of NO_3 throughout the profile.

Table 9. Nitrate-N in the soil profile in April, 1991 as influenced by previous crop and N treatment for corn in 1990.

Profile depth	1990 Crop: Fallow	Soybean	Corn[1]: 0 lb N	Fall	Preplant	Split
feet	lb/A[2]					
0-1	14.3	17.8	11.1	11.1	14.3	15.6
1-2	21.2	11.8	6.2	7.0	11.5	11.3
2-3	24.1	13.3	7.3	10.1	14.8	14.6
3-4	35.5	11.0	4.8	9.7	16.0	12.5
4-5	38.9	13.3	5.4	12.7	15.9	12.0
5-6	32.2	11.9	6.0	13.4	15.2	13.1
6-7	32.2	9.7	8.0	10.5	13.3	11.5
7-8	27.8	10.4	6.1	8.4	9.6	10.0
Total in						
0-5' profile	134.0	67.2	34.8	50.6	72.5	66.0
0-8' profile	226.2	99.2	54.9	82.9	110.6	100.6

[1] These fall, spring preplant and split treatments all received N-Serve.
[2] Average of 4 replications.

A comparison of the residual NO_3 amounts found in April, 1991 (Table 9) with those amounts found in the same plots in October, 1990, shows the spring NO_3 levels to be approximately 40% less for the fallow plots, 19% less with the corn that did not receive fertilizer N, and about 26% less with the corn that received 135 lb N/A in 1990.

Residual NO_3-N remaining in the 0 to 5' profile after the 1991 season shows low amounts of NO_3 and markedly less than after the 1990 season (Table 10). This was not surprising considering the high amount of rainfall and subsequent leaching in 1991. Residual NO_3 in the fallow plots was reduced 39% in the 0-5' profile and 25% in the 0-8' profile in this one-year period. The low amounts of NO_3 found in all of the corn plots showed no large differences among time/method of application or between the N-Serve treatments. The spring preplant application of N with N-Serve, however, did show slightly higher amounts of residual NO_3 in the top four feet. Residual NO_3-N levels for the fallow plots were higher in October than in April (Table 9). This is puzzling and cannot be explained considering that over 100 lb NO_3-N/A was lost in the drainage water and that NO_3-N concentration in the water decreased throughout the season.

Table 10. Residual NO_3-N remaining in the 0-8' soil profile after harvest as influenced by time of N application and N-Serve.

Profile depth	Fallow	Check	Application Time					
			N-Serve			No N-Serve		
			Fall	Preplant	Split	Fall	Preplant	Split
feet	lb NO_3-N/A[1]							
0-1	43.9	11.7	16.3	21.1	22.3	14.7	17.7	21.5
1-2	22.8	3.5	5.1	11.3	7.2	5.5	5.9	6.0
2-3	23.3	3.3	3.8	8.5	5.4	4.3	4.3	5.5
3-4	29.5	4.2	6.4	12.7	9.5	7.8	7.9	9.2
4-5	42.5	6.1	12.3	12.6	12.2	12.1	12.3	11.8
5-6	48.3	7.4	12.6	12.5	11.3	14.1	12.5	12.1
6-7	42.7	6.9	13.3	11.3	11.2	14.0	11.6	12.6
7-8	31.2	9.2	12.8	10.2	10.2	16.0	10.8	12.4
Total in								
0-5' profile	162	29	44	66	57	44	48	54
0-8' profile	284	52	83	100	89	89	83	91

[1] Avg. of 4 replications

CONCLUSIONS

The warm and wet conditions resulted in good corn production and excellent tile drainage. Corn production was greatly improved by the various N treatments over the control. Fall-applied N, especially without N-Serve, gave lower corn yields and showed poorer N efficiency compared to the spring applications. Crop production differences were not apparent between the spring preplant and split applications. Tile flow data indicated only small differences among the four N treatments with respect to amount of drainage but did show markedly elevated NO_3-N concentrations and losses with the fall applications (regardless of N-Serve use) compared to the spring applications. Nitrate-N concentrations and losses in the drainage water in the "residual" year with soybeans were significant and were highest with the previous fall N without N-Serve treatment and the split application treatment. Residual soil NO_3 at the end of the season was low except in the fallow plots. These data again indicate the importance of growing a crop to utilize the N mineralized from these high organic matter soils.

IMPACT OF RESIDUAL SOIL NITRATE ON CORN PRODUCTION[1/]

Waseca, 1991

Gyles W. Randall, Brian W. Anderson, and Michael Schmitt[2/]

ABSTRACT: A study was conducted to determine the impact of residual nitrate (NO_3) on corn production in 1991. High amounts of residual NO_3 carried over from 1990 to late April 1991. Between late-April and early June, approximately 38% of the residual NO_3 was lost from the 0-3' profile, probably due to the excessive 9.71" of rain during this period. Low amounts of NO_3 remained in the 0-5' soil profile after harvest regardless of the 1990 or 1991 N rate applied. Corn production was not affected by any of the 1990 N treatments but was increased significantly by the 1991 N rate (75 lb N/A) applied to all 1990 plots. No interaction between 1990 and 1991 N rate was found. Under these wet conditions, residual NO_3 was not found to be a reliable source of N. This illustrates the difficulty in developing a good soil NO_3 test under humid conditions.

Carryover of residual nitrate (NO_3) from one season into the next can reduce fertilizer N rate recommendations in the second year if accurately determined with a soil NO_3 test. This is especially true in the more arid areas of the Corn Belt and Great Plains where the soil NO_3 test has been used for years. The purpose of this study was to determine the carryover of nitrate from N applied to corn in June 1990 and to measure the effect of that residual NO_3 on corn production in 1991.

EXPERIMENTAL PROCEDURES

Corn was planted in 1990 following alfalfa (1987-89) on a Nicollet clay loam at the Southern Experiment Station, Waseca. Anhydrous ammonia was sidedress-applied at rates of 0, 60, 90, 120 and 180 lb N/A in June 1990 as part of a study to evaluate soil N tests. Yield responses to the applied fertilizer N were not found but significant differences in residual soil NO_3-N were found (Table 1). The amount of NO_3-N in the 0-5' soil profile ranged from 125 lb/A in the control (0 lb N/A) to 293 lb/A with the 180 lb N/A rate.

Table 1. Residual soil NO_3-N in October, 1990 as influenced by N rates applied to corn in June 1990.

	N rate (lb/A)				
Depth	0	60	90	120	180
feet	ppm NO_3-N				
0-1	15.7	19.0	19.8	22.5	43.9
1-2	3.3	5.0	4.5	5.0	5.9
2-3	2.1	7.0	5.0	6.5	7.9
3-4	5.2	7.2	7.7	6.8	8.9
4-5	5.0	5.2	7.8	6.6	6.7
	lb NO_3-N/A				
0-1'	63	76	79	90	176
0-5'	125	174	179	190	293

With this large difference in residual soil NO_3, each 1990 plot was split in 1991. Urea was applied in April at a rate of 75 lb N/A to one-half of each plot with the remaining half not receiving N. Soil samples were taken preplant (April 22) to a depth of 5' and to a depth of 3' at the V4 stage (corn 6 to 12" high) on June 6 from the plots that only received N in 1990. All samples were analyzed for nitrate and ammonium. In October soil samples were taken after harvest to a depth of 5' from the 0 and 75-lb N rates (1991) that received 0, 90 and 180 lb N/A in 1990 and analyzed for nitrate.

Corn (Pioneer 3751) was planted on May 3 at 30,600 plants/A. No starter fertilizer was applied. Force was used to control corn rootworms. Weeds were controlled with a preemergence application of Lasso (3.5 lb/A) plus Bladex (3.0 lb/A) on May 14. Each plot (4 rows or 10' wide X 25' long) was hand harvested in late September. Both silage and grain yields were taken from the center two rows each 20' long.

RESULTS

Residual soil NO_3 found in the 0-5' profile in April, 1991 was approximately 10% lower than in October 1990 (Table 2). Largest over-winter decline (28%) was found with the 180-lb N rate. The most striking finding was the substantial movement of NO_3 out of the 0-1' layer and into the 1-2' and 2-3' layers during this 6-month period.

Soil samples taken on June 6 revealed very low NO_3-N concentrations in the 0-1' layer with little accumulation in the 0-3' layer (Table 3). During this 45-day period, in which 9.71" of rain occurred, NO_3-N amounts in the 0-3' layer declined by 14% in the 0 lb N/A plots and an average of 38% in the plots that received fertilizer N in 1990. It is likely that a combination of denitrification and leaching occurred to cause this loss of NO_3.

[1/] Funding provided by the National Fertilizer and Environmental Research Center - TVA and Southern Experiment Station.

[2/] Professor and Asst. Scientist, Southern Experiment Station, and Asst. Prof. Dept. of Soil Science, Univ. of Minnesota.

Table 2. Residual soil NO_3-N on April 22, 1991 as influenced by N rates applied to corn in June 1990.

Depth	N rate (lb/A) 0	60	90	120	180
feet	ppm NO_3-N				
0-1	5.5	6.0	8.7	9.3	9.6
1-2	8.0	10.5	12.3	11.7	14.0
2-3	4.6	8.3	9.1	10.5	11.5
3-4	4.2	7.8	8.7	9.9	9.4
4-5	4.5	6.6	6.7	7.3	8.4
	lb NO_3-N/A				
0-1'	22	24	35	37	38
0-3'	72	99	120	126	140
0-5'	106	157	182	195	211

Table 3. Soil NO_3-N on June 6, 1991 as influenced by N rates applied in June 1990.

Depth	N rate (lb/A) 0	60	90	120	180
feet	ppm				
0-1	4.3	4.1	4.9	5.7	5.1
1-2	5.0	6.1	5.4	6.6	5.7
2-3	6.3	7.1	7.6	7.5	9.0
	lb NO_3-N/A				
0-1'	17	16	20	23	20
0-3'	62	69	71	79	79

Table 4. Soil NO_3-N on October 11, 1991 as influenced by N rates applied in June 1990 and April 1991.

	June 1990			June '90 + April '91		
	N Rate (lb/A)					
Depth	0	90	180	0 + 75	90 + 75	180 + 75
feet	ppm NO_3-N					
0-1	5.2	5.9	7.0	5.3	5.6	6.1
1-2	2.8	2.5	3.1	2.6	2.7	3.2
2-3	2.4	2.2	3.0	1.9	1.9	2.3
3-4	3.8	3.5	4.5	4.6	3.4	4.6
4-5	4.6	6.7	5.7	5.6	4.9	5.7
	lb NO_3-N/A					
0-1'	21	23	28	21	22	24
0-3'	42	42	52	39	40	46
0-5'	75	83	92	80	74	88

Post-harvest samples showed very low concentrations of NO_3-N throughout the 0-5' profile regardless of 1990 or 1991 N rate applied (Table 4). Crop uptake and the very wet conditions during the year probably accounted for this lack of residual NO_3 in 1991.

Yields and N concentrations in the corn grain and stover in 1991 were not influenced by the 1990 N treatments (Table 5). Nitrogen uptake in the grain and silage was also not affected by the 1990 N rates. Corn production, however, was excellent in all of the plots, probably due to alfalfa in the rotation (1987-89).

Corn grain, stover and silage yields were increased by the 75-lb N treatment (1991) to all of the 1990 N treatments (Table 5). Grain moisture at harvest was also decreased while grain and stover N concentrations were not affected by the 1991 treatment. No interaction between the 1990 and 1991 N treatments was found for any plant parameter.

Table 5. Corn grain and silage yield, N concentration and N uptake as influenced by 1990 (residual) and 1991 N rates.

N Rate		Grain				Stover		Silage	
1990	1991	Yield	H_2O	N Conc.	N uptake	N	Yield	Yield	N uptake
lb/A	lb/A	bu/A	%	%	lb/A	%	TDM/A	TDM/A	lb/A
0	0	165.6	34.1	1.25	98.2	.68	2.02	6.38	125.5
60	0	164.0	34.4	1.24	96.8	.67	2.14	6.45	125.1
90	0	166.8	34.7	1.24	97.7	.61	2.14	6.52	123.7
120	0	169.6	34.9	1.21	97.3	.69	2.08	6.58	126.2
180	0	166.9	34.2	1.25	98.8	.63	2.25	6.67	127.3
0	75	193.2	31.6	1.24	113.4	.67	2.25	7.79	149.2
60	75	202.3	32.0	1.18	113.0	.58	2.68	8.18	146.1
90	75	200.2	31.5	1.12	105.0	.57	2.81	8.02	137.0
120	75	190.8	31.5	1.29	116.5	.65	2.85	7.90	153.8
180	75	206.2	31.4	1.25	122.2	.61	2.90	8.33	157.4
MAIN EFFECTS									
1990 N Rate (lb/A) - "Residual"									
	0	179.4	32.8	1.25	105.8	.67	2.35	7.08	137.3
	60	183.1	33.2	1.21	104.9	.62	2.48	7.32	135.6
	90	183.5	33.1	1.18	101.7	.59	2.44	7.27	130.4
	120	180.2	33.2	1.25	106.9	.67	2.46	7.24	140.0
	180	186.6	32.8	1.25	110.5	.62	2.58	7.50	142.3
Signif. Level (%):		42	32	56	61	72	79	60	69
1991 N Rate (lb/A)									
	0	166.6	34.4	1.24	97.8	.66	2.12	6.52	125.5
	75	198.5	31.6	1.22	114.2	.62	2.80	8.04	148.7
Signif. Level (%):		99	99	54	99	94	99	99	99
1990 N Rate x 1991 N Rate IA									
Signif. Level (%):		84	6	69	38	23	11	33	31
CV (%)	:	4.2	4.0	7.5	9.1	9.1	6.9	4.3	8.9

CONCLUSIONS

Even though substantial NO_3-N carried over into the 1991 season from 1990, it did not influence corn production in 1991 because most of it was lost from the 0-3' soil profile between late April and early June. Under these wet conditions residual NO_3 cannot be counted as a reliable N source. From this we can see the difficulty of obtaining accurate N rate recommendations from soil nitrate tests under high rainfall conditions.

DECLINE RATES OF SOIL TEST P AND K IN A CORN-SOYBEAN ROTATION[1]

1991

G. W. Randall and S. D. Evans[2]

ABSTRACT: Decline rates of soil test P and K are being measured following 12 years of various application rates of P and K at two locations. Soil test P declined by about 10% at Waseca and 14% at Morris. Soil test K increased by 30 and 35% at Waseca and Morris, respectively. Corn yields were increased 22 to 33% over the long-term control plots at the two sites when soil test Bray P_1 was greater than 24 lb/A. There appeared to be little effect of soil test K on corn yield at Waseca. Over the 5-year (1986-91) period soil test P declined by 1.1, 3.9 and 5.4 lb/A/yr when no fertilizer P was applied to soils testing 16, 48 and 89 lb/A initially at Waseca. Soil test K varied considerably from year to year and did not allow consistent decline rate calculations. At Morris soil P declined by 5.5 lb/A/yr when the initial Bray P_1 test was 67 lb/A.

With good fertilization practices over the last 20 to 30 years, many farmers throughout the Cornbelt have built their P and K soil tests to high and very high levels. Studies conducted over the last 12 years have not shown corn and soybean yield increases from additional broadcast P and K at these high to very high test levels. Consequently, a number of farmers have curtailed P and K fertilization on these high testing soils. Two commonly asked questions in this scenario are: (1) How fast will my soil test drop if I don't continue to add fertilizer P and K? and (2) At what test level should I begin to add P and K to maintain fertility at an optimum level for efficient and economical production? The purposes of this study are to determine (1) the decline rates of soil test P and K and (2) the optimum soil test level which should be maintained for economical corn and soybean production.

EXPERIMENTAL PROCEDURES

High rates of P and K were applied over a 12-year period (1973-84) in studies at the Southern Experiment Station at Waseca (Table 2) and the West Central Experiment Station at Morris (Table 3). These rates created a wide range of soil test values upon which we can evaluate the decline rates of soil test P and K when no additional fertilizer is added. Treatments 2, 3, and 4 have not received additional P since 1984 while treatments 6 and 7 at Waseca have not received K. The K treatments were not included at Morris because of very high native soil test K levels. Treatment 5, which had a moderately high level of fertilization prior to 1985, continues to receive P and K, and thus, serves as the high fertility control.

Table 1. Experimental procedures for corn on the high P and K rate study at the two branch stations in 1991.

Variable	Location: Morris	Location: Waseca
Planting date	4/25	5/14
Row spacing	30"	30"
Planting rate (plants/A)	27,500	30,200
Variety	Pioneer 3788	Pioneer 3578
Herbicide	3# Lasso + 2.2# Bladex/A (Bdct)	3.5# Lasso + 3# Bladex/A (Bdct)
Harvest date	9/18	10/10
Soil type	Aastad clay loam	Webster clay loam

The P and K materials (0-46-0 and 0-0-60) were broadcast on the soil surface and incorporated by chisel plowing the corn residue in the fall of 1990. Specific experimental procedures used for corn at the two locations are presented in Table 1. Management practices providing for optimum yields were employed at each location. Starter fertilizer was not used.

RESULTS AND DISCUSSION

Total phosphate (P_2O_5) and potash (K_2O) applied over the 12-year period ranged from 0 to 1200 lb/A (Tables 2 and 3). These application rates plus the 1985-86 rates resulted in highly significant differences in soil test P at both locations and soil test K at Waseca. At Waseca soil test P ranged from 10 to 95 lb/A (Table 2). Soil test P declined about 10% compared to 1990, but soil test K increased by 30% even though K was not applied. Corn yields were increased significantly by P but plateaued at soil P levels higher than 25 lb/A.

[1] Funding provided by the TVA-National Fertilizer Development Center.

[2] Soil scientists and professors at the Southern Experiment Station (Waseca) and West Central Experiment Station (Morris), respectively.

At Morris, Bray P_1 ranged from 12 to 71 lb/A while Olsen's $NaHCO_3$ test ranged from 11 to 62 lb P/A (Table 3). Soil test P values declined about 14% at Morris, while soil K values increased about 35%. Grain yields were increased 26 to 38 bu/A, but this was statistically significant at only the 85% level due to high variability. Grain moisture was decreased significantly by the P treatments.

Table 2. Soil test values, grain moisture, and grain yield as influenced by 18 years' application of P and K at Waseca.

	P and K Treatments				Soil Test[2]			Corn	
	Total								
No.	1973-84		1985-90[1]		pH	P	K	Moisture	Yield
	- - - - - - - lb P_2O_5 + K_2O/A - - - - - - -					- - - - lb/A - - - -		%	bu/A
2	0	+ 1200	0	+ 100	6.8	10	315	22.3	133.2
3	600	+ 1200	0	+ 100	6.6	25	295	22.3	176.7
4	1200	+ 1200	0	+ 100	6.8	60	299	21.7	165.2
5	600	+ 1200	100	+ 100	6.9	85	317	22.3	190.4
6	1200	+ 0	100	+ 0	7.0	95	225	21.0	175.5
7	1200	+ 600	100	+ 0	6.9	87	221	21.1	165.4
Signif. Level (%):					36	99	99	46	97
BLSD (.05) :					-	12	40	-	34.3
CV (%) :					3.8	12.	8.0	5.5	10.

[1] Treatments applied each fall. P was discontinued for treatments 6 & 7 in 1988.
[2] Samples were taken in October before 1991 treatments were applied.

Table 3. Soil test values, grain moisture, and grain yield as influenced by 18 years' application of P and K at Morris.

	P and K Treatments			Soil Test[2]				Corn	
	Total								
No.	1973-84		1985-90[1]		pH	P_1	P_{ol}	K	Moisture	Yield
	- - - - lb P_2O_5 + K_2O/A - - - - -					- - - - - - - lb/A - - - - - - -			%	bu/A
2	0	+ 1200	0	+ 100	7.9	12	11	564	24.9	150.4
3	600	+ 1200	0	+ 100	7.9	24	22	463	23.8	176.2
4	1200	+ 1200	0	+ 100	7.9	46	39	503	22.8	188.7
5	600	+ 1200	100	+ 100	7.8	71	62	498	22.8	181.5
Signif. Level (%):					66	99	99	99	95	85
BLSD (.05) :					-	8.7	6.6	27	1.8	-
CV (%) :					0.8	29.	26.	6.3	4.3	13.

[1] Treatments applied each fall.
[2] Samples were taken in October before 1991 treatments were applied.

FIVE-YEAR SOIL TEST DECLINE RATES

Regression analysis was used to assess the average decline rates for Bray P_1 and exchangeable soil test K at Waseca and Bray P_1 at Morris. Soil test data from each of the plots in treatments 2, 3 and 4, which have not received fertilizer P since 1984, were included for the 5-year period (1986-1991) for both sites. Similarly, soil test data for each of the plots in treatments 6 and 7, which have not received fertilizer K since 1984, were included for the 5-year period at Waseca. Both soil test P and K were included from all plots in treatment 5, which received 100 lb P_2O_5/A + 100 lb K_2O/A annually.

Soil Bray P_1 change over the 5-year period at Waseca is shown by each of the lines in Fig.1. Average soil P test for each of the treatments in any particular year is shown by the appropriate symbol. Coefficients of determination (R^2) indicate highly significant relationships (99% level) for the treatments where fertilizer P was not applied and a significant (95% level) relationship where P was applied (Table 4). Soil test P was shown to decline by 1.1 lb/A/yr when the initial soil test was 16 lb/A. At initial soil test values of 48 and 89 lb/A, soil Bray P_1 declined by 3.9 and 5.4 lb/A/yr, respectively, in this corn-soybean rotation. Annual additions of 100 lb P_2O_5/A increased the soil test an average of 4.6 lb/A/yr when the initial test was 61 lb/A.

No relationship was found between the exchangeable soil K test and time (years after 1986) when 100 lb K_2O/A was applied annually (trt 5) or with treatment 6 (Fig. 2). Soil test K was extremely variable over this period as shown by the symbols in Fig. 2. Very high K levels were found in 1988, 1989 and 1991 while K tests were much lower in 1987 and 1990. The relationship between soil K test and time was significant for treatment 7 and indicated a 11.0 lb/A/yr decline in soil K when the initial test was 254 lb/A.

At Morris, soil test P variability was high and decline rates could not be calculated from the regression equations, which were not significant, for treatments 2 and 3. However, soil P did decline by 5.5 lb/A/yr when P was not added to the plots that initially tested 67 lb P/A. This decline rate was almost identical to the rate found at Waseca where soil P test was also very high.

Table 4. Linear regression equation and coefficient of determination (R^2) for the various P and K treatments at Waseca and Morris.

Location	Nutrient	Treatment	Regression Equation[1/]	R^2
Waseca	P	2	ST = 15.8 - 1.13 X	39.4**
"	P	3	ST = 47.8 - 3.90 X	50.8**
"	P	4	ST = 88.8 - 5.43 X	80.8**
"	P	5	ST = 61.3 + 4.62 X	25.7*
"	K	5	ST = 284.0 + 2.45 X	1.1^{NS}
"	K	6	ST = 242.0 - 7.47 X	14.6^{NS}
"	K	7	ST = 253.6 - 11.09 X	25.9*
Morris	P	2	ST = 9.7 + 0.32 X	2.4^{NS}
"	P	3	ST = 34.9 - 1.59 X	3.1^{NS}
"	P	4	ST = 67.3 - 5.54 X	35.4**
"	P	5	ST = 34.3 + 5.58 X	15.4+

[1/] ST = Soil Test (lb/A), X = Years

CONCLUSIONS

Long term (12-yr) additions to these two soils created a wide range in soil test P levels. Corn yields were optimized over the no P treatments at soil test P levels of 25 lb/A at Waseca. Yields were not affected by K at Waseca. At Morris, corn yields were improved about 30 bu/A with the higher soil test P levels. Soil test P declined by about 10% at Waseca and 14% at Morris. Soil test K was increased by about 30% and 35% at Waseca and Morris, respectively, in 1991. Over the 5-year period (1986-91), soil Bray P_1 tests declined by 1.1, 3.9 and 5.4 lb/A/yr when no fertilizer P was applied to these soils initially testing 16, 48 and 89 lb/A, respectively, at Waseca. When 100 lb P_2O_5/A was added annually, soil Bray P_1 increased by 4.6 lb/A/yr when the initial test was 61 lb/A. At Morris, soil test P was more variable, but soil P declined by 5.5 lb/A/yr when the initial Bray P_1 was 67 lb/A.

Because of extremely high soil test K variability from year to year, it was difficult to show a consistent soil test change over time. One relationship, however, did show a 11.0 lb/A/yr decline in soil K when the initial test was 254 lb/A. This information on soil test decline rates when fertilizer is not applied should be very helpful to farmers who are considering omitting fertilizer P for a few years when their soils test high in P.

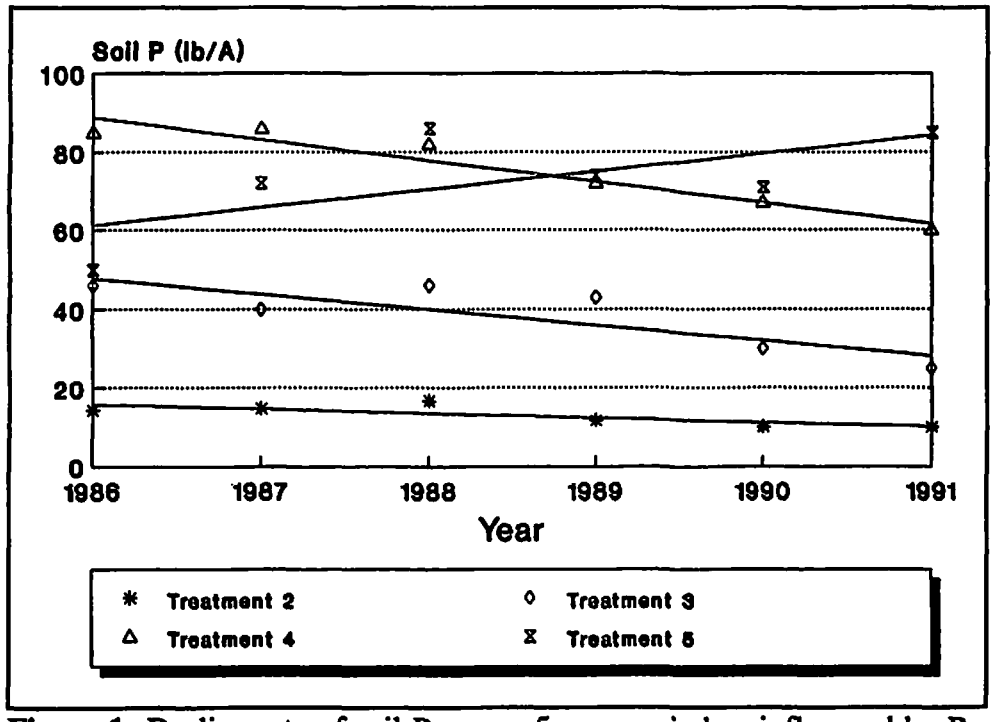

Figure 1. Decline rate of soil P over a 5-year period as influenced by P treatment at Waseca

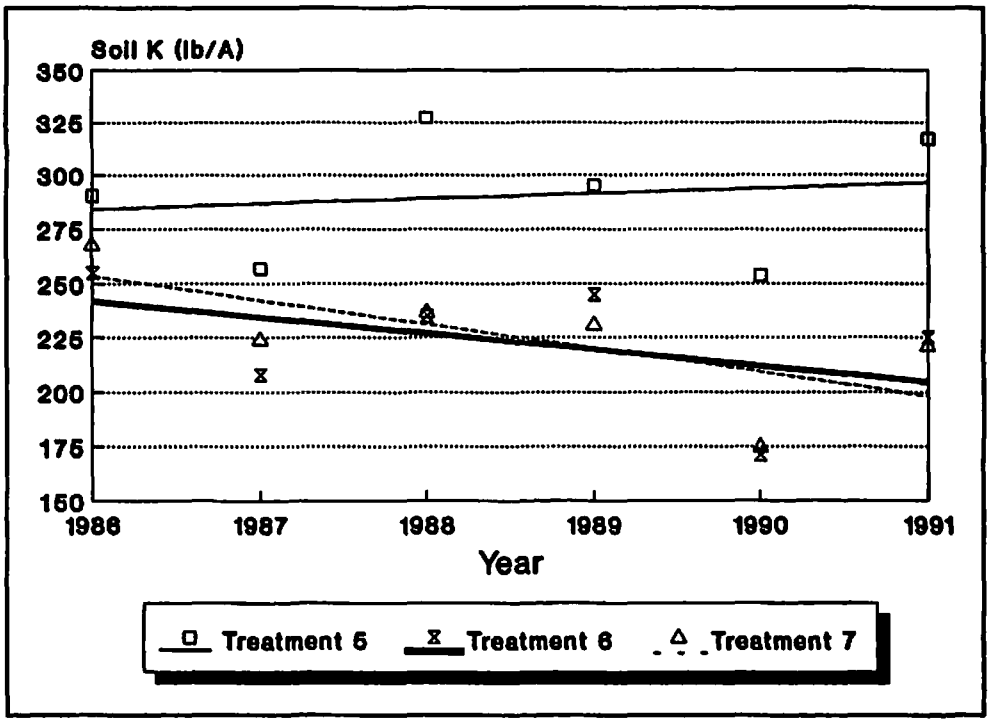

Figure 2. Decline rate of soil K over a 5-year period as influenced by K treatment at Waseca

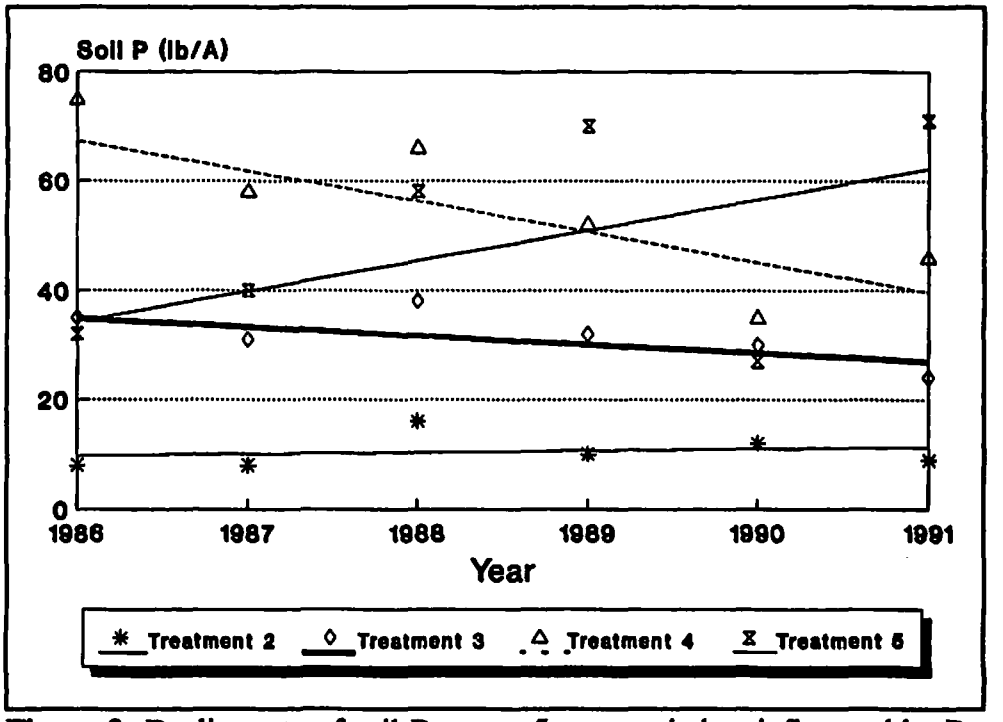

Figure 3. Decline rate of soil P over a 5-year period as influenced by P treatment at Morris

NITRATE AND PESTICIDE LOSSES TO TILE DRAINAGE, RESIDUAL SOIL N, AND N UPTAKE AS AFFECTED BY CROPPING SYSTEMS[1]

Lamberton, 1991

G. W. Randall, D. Fuchs, W. W. Nelson, D. D. Buhler,
M. P. Russelle, and J. L. Anderson

ABSTRACT: Four cropping systems (continuous corn, a corn-soybean sequence, alfalfa, and CRP) were established in 1988 to determine biomass yields, N uptake, residual soil NO_3 and NO_3 and pesticide losses to tile drainage water as influenced by cropping system. Corn and alfalfa yields in this fourth year of the study were excellent while soybean yields were average. Nitrogen removed by the corn, soybean, and alfalfa crops totaled 128, 202 and 339 lb/A, respectively. Residual soil NO_3-N remaining in the 0-5' profile in October totaled 84, 86, 56, 16 and 13 lb/A for the continuous corn, corn-soybean, soybean-corn, alfalfa and CRP systems, respectively. Available water in the 0-5' profile in late October with the row-crop systems ranged between 4.0 and 4.4 inches while the perennial crops only had 1.1" (alfalfa) and 2.2" (CRP). Tile water drainage from the row-crop system ranged from 7.0 to 10.8 acre-inches while only 1.6 to 1.7 acre-inches drained from the perennial crops. Flow-weighted NO_3-N concentrations ranged from 29 to 39 mg/L for the 3½ month drainage period with the corn and soybean systems but averaged only 4 mg/L with the alfalfa and CRP systems. Nitrate-N losses ranged from only 1.5 lb/A with the alfalfa and CRP systems to 72 lb/A with the corn-soybean rotation. Alachlor, cyanazine, Accent and Pursuit were not detected in any of the tile water samples.

Nitrate and pesticide losses to tile drainage water have been monitored in the last few years for continuous corn systems at the Lamberton and Waseca branch experiment stations. However, very little information exists on the N and pesticide losses from other cropping systems, especially those involving alfalfa or CRP grass:legume plantings. The purpose of this study was to determine the effect of four cropping systems on the:

1) above-ground biomass yields, N concentrations in the biomass, and N removal,
2) residual NH_4 and NO_3 in the 0 to 10' soil profile after harvest, and
3) NO_3 and pesticide losses in the tile drainage water.

Background

Fifteen tile drainage plots each measuring 45' x 50' surrounded with plastic sheeting to a depth of 6' were installed in 1972 at the Southwest Experiment Station at Lamberton. Nitrogen rates from 18 to 400 lb N/A were applied annually to corn from 1973 through 1979 on this Nicollet clay loam. Since 1979, continuous corn without N in 1980-1985 and with only 50 lb N/A in 1986-87 was grown to "erase" the effects of the previous treatments.

Experimental Procedures

Four cropping systems (continuous corn, corn-soybean sequence, continuous alfalfa, and continuous CRP (Conservation Reserve Program) species) were established on these drainage plots in the spring of 1988. Each cropping system was randomly assigned to the drainage plots in a randomized, complete-block design with three replications. The detailed experimental procedures are shown in Table 1.

Soil samples taken from the 0 to 8" layer in 1988 indicate high soil test P&K values. Consequently, no broadcast nor starter fertilizer was used for the corn, soybeans or CRP systems. Potassium was broadcast at a rate of 120 lb K_2O/A following the first cutting of alfalfa. Samples taken to a 5-foot depth in late-April were used to determine the N fertilizer rates needed for corn (Table 3). The 122-lb N rate used for continuous corn and the 109-lb N rate for corn after soybeans was based on the NO_3 concentration in the 0 to 24" and 24 to 48" layers and a yield goal of 140 bu/A. Due to a miscalculation, the 109-lb rate was used instead of the 135-lb rate suggested by the soil test.

Results and Discussion

Weather

Climatic conditions during the 1991 growing season were slightly wetter than normal (Table 2). Rainfall over the 7-month growing season was 3.9" above normal with greatest departure from normal in June and September. Monthly temperature averages were markedly above normal for April-June while the 7-month seasonal average was 1° F above normal. These conditions resulted in excellent corn and alfalfa yields and good soybean yield.

Spring Soil Nitrate

Residual NO_3 in the 0 to 5-foot soil profile in late-April was moderately low for both the corn-soybean and soybean-corn systems and high for the continuous corn system (Table 3). Nitrate-N distribution was relatively uniform throughout the profile for all systems, which is in contrast

[1] Funding provided by the North Central Regional Research Comm. (NC-201), Southwest Experiment Station, Southern Experiment Station, and Center for Agricultural Impacts on Water Quality.

to 1990 when most of the NO_3 was in the top two feet. Residual soil NO_3 decreased by 18 to 52% in the cropping systems between the October '90 sampling and the April '91 sampling. These changes between fall and spring sampling suggest sizeable over-winter "losses" of NO_3 probably through immobilization and perhaps leaching, and indicate that late-fall soil sampling to determine fertilizer N needs may not lead to sound fertilizer recommendations.

Crop Yields

Crop yields shown in Table 4 were above the yield goal for corn and were very good for alfalfa. Corn yields and N uptake by the corn were 16 and 10% higher, respectively, for the corn-soybean system compared to continuous corn. Nitrogen concentrations in the grain and stover were slightly higher for continuous corn, probably due to the lower yield. Nitrogen removal by the soybeans and alfalfa far exceeded that by corn. The CRP plots, which were dominated by alfalfa in 1989 and showed a 50:50 split between grass and alfalfa in 1990, had a 90:10 ratio between grass and alfalfa yield in 1991. The wetter conditions in 1990 and 1991 apparently led to the reestablishment of the grass species.

Fall Soil Nitrate

Soil NO_3 levels throughout the 10-foot profile were markedly lower for those cropping systems dominated by alfalfa and CRP compared to the corn and soybean systems (Table 5). Ranking from highest to lowest was: CC = C-Sb > Sb-C > A = CRP. Nitrate-N concentrations were highest in the 0-1' profile, usually lowest between 1 and 3' and were somewhat higher again below 3'. Distribution below 3' was very uniform for the CC and Sb-C systems but declined below 5' with the C-Sb system. The alfalfa and CRP systems exhibited very low NO_3-N concentrations down to 7 feet. From 7 to 10 feet, NO_3-N concentrations, although still low, more than doubled. Amounts of soil NO_3 in the top five feet in October ranged from -36% (continuous corn) to +17% (C-Sb) higher than in April. Absolute differences between the dates of sampling were -47, +17, and -25 lb NO_3-N/A for the CC, C-Sb and Sb-C systems, respectively. Even though 122 lb N/A was applied to the CC systems, soil NO_3-N decreased significantly. This was probably due to the wetter than normal conditions coupled with the high yield.

Soil Moisture

Soil moisture in the 0 to 5' profile in October was affected substantially by the cropping system (Table 6). This was especially true for alfalfa and CRP where soil water levels were considerably below those of the corn and soybean systems. Available water in the top five feet was below normal for the row crop systems and was close to deficit levels with the alfalfa and CRP cropping systems.

Tile Flow

Tile line discharge occurred from March 26 through July 5 for the corn and soybean systems, from March 26 through June 28 for CRP and from April 15 through June 30 for alfalfa. Discharge averaged 8.8" for the systems containing corn and soybean; this was 5.3x higher than the 1.7" for the alfalfa and CRP systems (Table 7). Flow-weighted NO_3-N concentrations for the season were highest for the CC and Sb-C (corn in 1990) systems and were approximately 10x higher than the alfalfa and CRP systems. The C-Sb system (soybean in 1990) showed average $NO_3$0-N concentrations about 9 to 10 mg/L less than those systems planted to corn in 1990. Temporal changes in NO_3-N concentration did not occur over the April-July flow period. Losses of NO_3-N in the tile drainage for the 1991 season were 48 and 41 times higher for the corn-soybean sequences and CC systems, respectively, compared to the two perennial crop systems. Losses averaged 72 lb/A for the two corn-soybean sequences, 62 lb/A for the CC system and only 1.5 lb/A for the alfalfa and CRP systems. These data indicate that N removal (alfalfa) and N cycling (CRP) along with high ET demand of the perennial crop are resulting in minimal NO_3 loss. Thus, we can speculate that NO_3 loss from native prairies to ground water prior to the adoption of cropping and tillage practices in southern Minnesota would have been extremely small.

Water samples were collected weekly throughout the 3½ month flow period and were submitted for pesticide analyses. No alachlor (Lasso) was found in any of the 128 samples collected from the corn and soybean systems. Cyanazine (Bladex) was not found in the 65 samples collected from the CC and Sb-C systems that received cyanazine in 1990 or in the 24 samples collected after May 9 (date Bladex applied) from the C-Sb system that received cyanazine in 1991. Detectable concentrations of Accent and Pursuit were not found in 25 samples collected from the C-Sb and Sb-C systems to which these herbicides had been applied in 1988-90. Detection limits were 0.10 ppb for all four herbicides. These data indicate very little need for concern regarding the leaching of these herbicides to tile discharge water in these high organic matter, fine-textured soils in southern Minnesota.

Conclusions

The slightly wetter than normal conditions in 1991 resulted in excellent corn and alfalfa yields and average soybean yield in this fourth year of the study. Nitrogen removal by soybean and alfalfa was 1.5x and 2.6x as high, respectively, as with corn. After two moist years, the grass species again dominated the CRP system. Over winter "loss" of soil NO_3 averaged 36% for the two cropping systems that received fertilizer N in 1990, indicating that spring soil sampling may be preferable to fall sampling to determine fertilizer N rate recommendations. Residual soil NO_3 in the fall, although not as high as in previous years, was approximately 3x higher with the row crop systems compared to the perennial crop systems. Tile flow occurred over a 3½-month period from late March through early July. Drainage averaged 8.8 acre-inches from the row crop systems and 1.7 acre-inches from the perennial crop systems. Nitrate-N concentrations also were 8 to 10x higher with the row-crop systems. Nitrate-N losses to the drainage water averaged 72 lb/A from the two row crop systems receiving fertilizer N in 1990, 62 lb/A in the C-Sb system, and only 1.5 lb/A in the alfalfa and CRP systems. Tile water samples analyzed for alachlor, cyanazine, Accent, and Pursuit showed no detectable amounts of any of these pesticides.

Table 1. Experimental procedures used in 1991 for the nitrate-pesticide movement study at Lamberton.

Cropping System	Procedures
Cont. Corn and Corn-"Sb"	
Hybrid	Pioneer 3615
Planting rate and date	27700 ppA on 5/10
Insecticide	Counter (1 lb/A), Pounce on 6/24
Herbicides	Lasso (4 lb/A) + Bladex (3½ lb/A)
Date	Both applied on 5/9 and incorporated 1X with field cultivator and 1x with a disk
N rate (Cont. corn only)	122 lb N/A as urea
Date	6/3 and cultivated in the same day
Cultivation date(s)	6/18
Harvest date	9/30
Fall tillage (kind and date)	Moldboard plow 10/28
Corn - "Sb"	
N rate	109 lb N/A as urea
Date	6/3
Soybeans	
Secondary tillage	Disked (5/9), Field cultivated (5/21)
Variety	Hardin
Planting rate and date	150,000 seeds/A on 5/22
Row width	30"
Herbicides	
Lasso	
Rate and date	4.0 lb/A on 5/21, incorporated with a field cultivator
Cultivation date(s)	6/27
Harvest date	10/7
Fall Tillage	None
Alfalfa	
Harvest date(s)	6/8, 7/12 and 8/27
Harvest area	3' x 20'
CRP	
Harvest date	9/18

Table 2. Growing season monthly air temperature averages and precipitation amounts during 1991 and the long-term normals for Lamberton.

	Avg. Temperature		Precipitation	
Month	1991	Normal	1991	Normal
	°F		inches	
April	59	46	4.33	2.73
May	61	59	4.06	3.16
June	72	68	6.69	3.55
July	72	73	1.37	3.88
Aug.	70	70	2.98	2.73
Sept.	58	60	5.64	3.34
Oct.	44	49	0.38	2.17
7-mo avg.	62	61	-	
Total	-	-	25.45	21.56

Table 3. Residual NO_3-N in the 0 to 5' soil profile of the cropping systems in April, 1991.

Depth	Cropping System in 1991		
	Cont. Corn	Corn-Sb	Soybean-C
feet	lb NO_3-N/A		
0 - 1	28.0	18.7	13.3
1 - 2	20.0	10.7	20.0
2 - 3	20.0	13.3	14.7
3 - 4	34.7	17.3	17.3
4 - 5	28.0	13.3	16.0
Total (0-5')			
Apr.'91	130.7	73.3	81.3
Oct. '90	160.1	151.1	138.7
% Change over winter	-18	-52	-41

Table 4. Crop yields, N concentration, and N uptake at Lamberton in 1991.

Cropping System	Yield	N Concentration	N Uptake
		%	lb/A
Cont. Corn			
Grain (bu/A)	146.7	1.59	110.4
Stover (lb DM/A)	2679.	.42	11.2
Total			121.6
Corn-Sb			
Grain (bu/A)	170.4	1.48	119.3
Stover (lb DM/A)	3635.	.41	15.1
Total			134.4
Soybean-C			
Seed (bu/A)	43.4	6.68	153.6
Stover (lb DM/A)	3840.	1.26	48.5
Total			202.2
Alfalfa			
1st Cut Forage (lb DM/A)	5191	3.19*	165.6
2nd Cut Forage (lb DM/A)	2828	3.09	87.4
3rd Cut Forage (lb DM/A)	2601	3.30	85.9
Total	5.31 T/A		338.9
CRP			
Grass (lb DM/A)	3214	2.32	74.5
Alfalfa (lb DM/A)	348	2.03	7.0
Total			81.5

* = Forage not analyzed, value is average of 2nd & 3rd cutting.

Table 5. Soil profile NO_3-N concentrations and amounts in October, 1991 as influenced by cropping system at Lamberton.

Depth	Cont. Corn Avg.	Cont. Corn SE	Cont. Corn Avg.	Corn-Sb Avg.	Corn-Sb SE	Corn-Sb Avg.
feet	------ ppm ------		lb/A	------ ppm ------		lb/A
0 - 1	6.9	0.75	27.5	5.9	2.61	23.6
1 - 2	2.8	0.52	11.3	4.8	3.25	19.2
2 - 3	2.9	0.27	11.7	4.5	2.97	18.0
3 - 4	4.2	0.94	16.7	3.4	0.99	13.7
4 - 5	4.2	1.02	16.7	2.8	0.20	11.2
5 - 6	3.8	0.86	15.3	2.2	0.20	8.9
6 - 7	3.5	0.82	14.1	1.8	0.32	7.1
7 - 8	4.0	1.40	16.1	1.8	0.46	7.1
8 - 9	3.7	1.21	14.9	2.0	0.46	8.0
9 - 10	5.1	2.28	20.5	2.2	0.43	8.9
Totals						
0 - 5			83.9			85.7
5 - 8			45.6			23.1
8 - 10			35.4			16.9
0 - 10			164.9			125.7

Depth	Soybean-C Avg.	Soybean-C SE	Soybean-C Avg.	Alfalfa Avg.	Alfalfa SE	Alfalfa Avg.
feet	------ ppm ------		lb/A	------ ppm ------		lb/A
0 - 1	4.3	0.50	17.3	1.2	0.20	4.9
1 - 2	1.5	0.12	6.1	0.8	0.17	3.1
2 - 3	1.6	0.18	6.5	0.7	0.22	2.7
3 - 4	3.0	0.23	12.1	0.6	0.15	2.4
4 - 5	3.4	0.44	13.7	0.6	0.19	2.5
5 - 6	2.7	0.24	10.9	0.6	0.25	2.4
6 - 7	2.5	0.22	10.1	0.9	0.35	3.6
7 - 8	3.2	0.22	12.9	1.8	0.40	7.2
8 - 9	4.0	0.17	15.9	2.2	0.27	8.9
9 - 10	4.3	0.29	17.3	2.4	0.38	9.7
Totals						
0 - 5			55.9			15.6
5 - 8			33.9			13.2
8 - 10			33.2			18.6
0 - 10			123.0			47.4

Depth	CRP Avg.	CRP SE	CRP Avg.
feet	---------- ppm ----------		lb/A
0 - 1	0.9	0.19	3.7
1 - 2	0.6	0.21	2.4
2 - 3	0.6	0.20	2.4
3 - 4	0.5	0.13	2.1
4 - 5	0.6	0.12	2.5
5 - 6	0.8	0.22	3.3
6 - 7	2.0	1.23	7.9
7 - 8	2.7	1.18	10.7
8 - 9	2.8	0.79	11.1
9 - 10	2.9	0.26	11.6
Totals			
0 - 5			13.2
5 - 8			21.9
8 - 10			22.6
0 - 10			57.7

Table 6. Gravimetric water content of the 0-10' profile and "available" water in the 0-5' profile as influenced by cropping system in October, 1991.

Profile depth	Cropping system				
	Cont. Corn	Corn-Sb	Soybean-C	Alfalfa	CRP
feet	Water Content (%)				
0 - 1	22.1	22.0	21.8	17.2	18.4
1 - 2	20.7	21.9	20.4	17.8	18.9
2 - 3	18.2	19.3	17.8	14.8	15.1
3 - 4	17.8	17.0	17.3	13.7	14.9
4 - 5	18.7	18.0	18.1	13.7	16.8
5 - 6	18.7	19.0	19.3	15.8	18.6
6 - 7	19.4	19.7	19.3	16.9	19.2
7 - 8	19.3	19.6	19.6	18.8	19.8
8 - 9	19.5	19.6	20.4	19.3	19.7
9 - 10	18.8	19.1	19.5	20.8	20.3
"Available" Water 0-5' (inches)	4.33	4.44	4.00	1.09	2.23

Table 7. Tile discharge, flow-weighted NO_3-N concentration, and NO_3-N loss via the tile lines as influenced by cropping system.

Month	Cont. Corn	Corn-Sb	Soybean-C	Alfalfa	CRP
	Tile Flow (acre-in)				
March	0.00	0.01	0.05	0.00	0.04
April	1.68	2.70	2.02	0.04	0.68
May	2.16	3.47	2.80	0.20	0.76
June	3.06	4.50	3.57	1.34	0.25
July	0.12	0.11	0.13	0.01	0.00
Total	7.02	10.79	8.57	1.59	1.73
	Flow-weighted NO_3-N Conc. (ppm)				
March	-	35.1	24.4	-	4.1
April	39.4	29.2	35.9	2.8	4.1
May	38.7	28.9	38.5	3.0	3.1
June	38.4	30.5	36.9	5.8	8.9
July	39.1	30.2	36.6	4.1	-
Season Avg.	39.1	29.0	37.5	4.1	3.9
	NO_3-N Loss (lb/A)				
March	0.0	0.1	0.3	0.00	0.04
April	15.3	17.2	16.6	0.02	0.49
May	19.2	22.0	24.4	0.09	0.44
June	26.6	30.6	30.0	1.36	0.52
July	1.1	0.8	1.1	0.01	0.00
Total	62.2	70.7	72.4	1.47	1.49

N CREDITS FOR MANURE AND ALFALFA

J.A. Lory, G.W. Randall, and M.P. Russelle[1]

ABSTACT: Farmers in southern Minnesota rarely obtain a yield response from fertilizer or manure N applications to first year corn following alfalfa and obtain limited yield response from N applications to second year corn following alfalfa. The overall objective of this series of experiments is to refine N credit methodology for alfalfa and manure. First year corn yields following alfalfa with no N applied were equivalent continuous corn yields at the optimum N rate. First year corn following alfalfa yielded an additional 18 bu/A in response to of 60 lb N/A at Waseca. Second year corn following alfalfa responded to fertilizer N applications of 60 lb N/A. The first year manure N credit for continuous corn closely matched the predicted manure N availability at Rosemount. In contrast, yield response was more limited to spring applied dairy manure to continuous corn at Waseca. There was no significant grain yield response to residual manure the second year after application to corn or alfalfa at both locations.

Many dairy farmers apply manure to alfalfa in the spring or fall before they plow down an old stand. This practice is not recommended because it creates an oversupply of N for the succeeding corn crop, potentially leading to losses of N from the soil profile. Portions of the manure and alfalfa N will not be available to corn until the second and third year after incorporation. Current N recommendations utilize estimated "N credits" to adjust fertilizer N rates downward to account for these sources of N. The first objective of this experiment is to compare the impact of over-application of fertilizer N and manure N on soil inorganic-N levels in both continuous corn and alfalfa-corn rotations. The second objective is to estimate first and second year N credits for 1)dairy manure applied in the spring to two previous crops (corn or alfalfa) and 2) alfalfa, using two methods of estimation (continuous-corn fertilizer response curve vs. corn following alfalfa fertilizer response curve).

The fertilizer and manure treatments in the study were initiated two different years (1990 and 1991) at two locations (Rosemount and Waseca) for a total of four site-years for each year of the experiment. The duration of the experiment is two years at each site. This report presents results based on the 1991 corn DM and N yields for all four sites. A previous report discussed the first year results of the study initiated in 1990.

Materials and Methods

Experimental plots were located on a Webster clay loam at the Southern Experiment Station, Waseca, MN, and on a Port Byron silt loam at Agronomy Hill, Rosemount Experiment Station, Rosemount, MN.

Plot history

Plots for all sites were established in spring of 1988 as a split-plot arrangement in a randomized block design with four replicates at each Waseca site, and three replicates at each Rosemount site. Establishment and previous management of the two sites where N treatments were initiated in 1990 were outlined in a previous report with the following exception. Plots designated for urea treatments in 1991 received 100 lb N/A in spring 1990 if corn was the previous crop and 0 lb N/A if alfalfa was the previous crop.

At the remaining two sites, alfalfa plots were seeded with variety DK120 (13 lb/A) with Nitragin inoculant in 1988. Weeds in alfalfa were controlled with 0.75 lb/A Treflan at Rosemount, and 1 gal/A Balan at Waseca. Plots were harvested once in the seeding year and on a 3-cut system in 1989 and 1990. The Rosemount seedling stand received 5 in. irrigation water in 1988 and alfalfa was seeded with a notill drill into the existing stand in spring 1990 to fill open patches in the stand from significant winter kill the previous winter. Corn plots at both sites were managed for corn grain production. Corn plots were chisel plowed and cultivated in spring at Rosemount and fall moldboard plowed and spring cultivated at Waseca in 1988, 1989, and 1990. Fertility levels of P and K were maintained at or above University Minnesota soil test recommendations. At Rosemount, 150, 120, and 100 lb N/A as urea was applied preplant incorporated in 1988, 1989, and 1990 respectively; at Waseca, 150 lb N/A as NH_4NO_3 was applied sidedress in 1988, 150 lb N/A as NH_4NO_3 was applied preplant in 1989, and 120 lb N/A as NH_4NO_3 was applied preplant in 1990.

Table 1. Nutrient content of applied dairy manure at Rosemount and Waseca, MN.

Location	Year Applied	DM	Total N	NH_4-N	P	K	S	Na	pH
		%	- - - - - - - -		lb / 1000 gal	- - - - - - - -			
Rosemount	1990	10.4	36.3	1.4	7.6	26.1	5.9	0.77	-
	1991	11.7	41.7	20.3	6.4	28.5	2.8	1.4	5.7
Waseca	1990	10.1	32.1	13.4	6.2	27.5	2.8	5.0	6.1
	1991	11.1	35.5	17.1	8.1	39.3	2.1	60.5	7.1

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Table 2. Effect of previous crop, dairy manure the second year after application, and urea on corn yield and N uptake at Rosemount, MN in 1991.

Cropping[1] sequence	N source	Rate		Grain Yield	Grain N uptake	Silage Yield	Silage N uptake
				bu/A	lb/A	T DM/A	lb/A
A-A-A-C-C		control		147	111	6.99	135
	Urea	60	lb/A	150	129	7.56	154
		100		174	148	8.36	182
		140		161	139	7.48	175
		180		176	152	8.48	204
			P>F	0.07	0.01	0.03	0.01
			MSD[2]	25	21	1.02	24
			CV (%)	6.6	7.1	5.9	6.7
	Manure[3]	3000	gal/A	164	125	7.62	151
		5000		167	134	7.61	164
		7000		168	135	7.83	164
			P>F	0.19	0.10	0.17	0.10
			MSD[2]	-	24	-	28
			CV (%)	7.0	8.6	5.4	8.6
A-C-C-C-C		control		131	93	5.75	108
	Urea	60	lb/A	164	127	7.12	149
		100		155	126	7.15	151
		140		167	143	7.81	179
		180		172	147	7.89	177
			P>F	0.08	0.06	0.05	0.02
			MSD[2]	32	39	1.34	43
			CV (%)	9.1	13.9	8.5	12.8
	Manure[3]	3000	gal/A	126	88	5.70	104
		7000		140	99	6.47	118
		11000		156	128	7.16	158
			P>F	0.14	0.06	0.02	0.02
			MSD[2]	-	-	0.64	26
			CV (%)	6.4	8.5	4.8	7.7

1 A = alfalfa, C = corn, and the 1991 crop is underlined
2 Minimum significant difference (0.10)
3 Manure applied spring 1990.

Procedures in 1991

At the two sites that received N treatments in 1990, all plots were spring moldboard plowed at Rosemount, and fall chisel plowed at Waseca. Five urea treatments (0, 60, 100, 140, 180 lb N/A) were applied in spring 1991 to the designated plots in each previous crop block and all plots were disked before planting corn. Plots receiving manure the previous year received no additional treatments.

At the two sites where treatments were initiated in 1991, 8 treatments were applied randomly to each previous crop block. Treatments in previous corn were 0 (control), 60, 100, 140, 180 lb N/A as urea, and 3330, 6660, 9990 gal/A dairy manure at Rosemount, and 3200, 6400, and 9990 gal/A dairy manure at Waseca. Treatments in previous alfalfa were 0 (control), 30, 60, 100, 140 lbs N/A as urea, and the same manure treatments as continuous corn. Liquid dairy manure was obtained from the Brand Farm in Farmington, MN, and from the Southern Experiment Station. The nutrient content of manure used at all sites is reported in Table 1. After manure application, all plots were moldboard plowed at Rosemount and disked twice at Waseca, incorporating the manure within 60 min. Manure was applied April 23 at Rosemount and May 14 at Waseca.

At Waseca, Pioneer 3751 was planted on both sites on May 21 at 30,600 seed/A and the stand was thinned to 27,500 plants/A on June 12. To control rootworms, Force insecticide (8.7 lb/A) was applied over the row at planting. Weeds were controlled with a preemergence application of Lasso (3.5 lb/A) and Bladex (3 lb/A). At Rosemount, Pioneer 3751 was planted on both sites May 21 at 26,100 seeds/A. To control rootworms, Force insecticide (8.7 lb/A) was applied over the row at planting. Lasso and Bladex (2 lb/A each) were applied preemergence to control weeds.

Table 3. Effect of previous crop, dairy manure the second year after application, and urea on corn yield and N uptake at Waseca, MN, in 1991.

Cropping[1] sequence	N source	Rate		Grain Yield	Grain N uptake	Silage Yield	Silage N uptake
				bu/A	lb/A	T DM/A	lb/A
A-A-A-C-C		control		174	100	6.88	122
	Urea	60	lb/A	200	124	8.13	155
		100		203	132	8.23	166
		140		206	141	8.25	177
		180		206	138	8.53	180
			P>F	0.07	0.01	0.02	0.01
			MSD[2]	29	17	1.06	19
			CV (%)	8.0	8.1	7.6	7.5
	Manure[3]	3000	gal/A	187	108	7.50	132
		5000		186	111	7.45	135
		7000		192	113	7.83	142
			P>F	0.11	0.11	0.05	0.08
			MSD[2]	-	-	0.70	17
			CV (%)	5.0	6.2	5.3	6.9
A-C-C-C-C		control		145	78	6.14	102
	Urea	60	lb/A	161	96	6.75	117
		100		190	119	7.94	149
		140		202	128	8.19	162
		180		193	130	8.02	166
			P>F	0.01	0.01	0.01	0.01
			MSD[2]	15	12	0.57	13
			CV (%)	5.8	7.7	5.3	6.7
	Manure[3]	3000	gal/A	136	71	5.74	87
		7000		141	75	5.73	92
		11000		158	84	6.49	104
			P>F	0.20	0.25	0.33	0.21
			MSD[2]	-	-	-	-
			CV (%)	9.2	11.4	10.5	12.2

1 A = alfalfa, C = corn, and the 1991 crop is underlined
2 Minimum significant difference (0.10)
3 Manure applied spring 1990.

At Waseca, grain and stover were harvested on September 27 in the 1990 plots and on October 2 in the 1991 plots plots. At Rosemount, all grain was harvested on September 25 and 26, and all stover was sampled on October 2. Grain and stover DM samples were harvested from 40 and 20 ft. of row, respectively. Plant samples were dried at 60° C and ground in preparation for analysis. Total N was determined using the salicylic acid predigest modification to the Kjeldahl total N digest.

Results and Discussion

Second year corn grain and silage yields following alfalfa responded to urea N at Rosemount and Waseca (Tables 2 and 3). Optimum yields were obtained with applications of 100 lbs N/A or less. Residual effects of the 1990 manure application on grain yield were not significant at both locations for manure applied to corn or alfalfa (Tables 2 and 3). At Rosemount, residual manure N consistently increased N-uptake of grain and silage (Table 2). The increases were consistent with the low estimates of mineralized manure N available the second year after application (Table 4).

First year corn grain and silage yields following alfalfa did not respond to additions of fertilizer at Rosemount (Table 5). Applications of manure to first year corn following alfalfa at Rosemount were associated with a significant increase in grain and stover yields compared to the control. This effect was due primarily to reduced yield variability on manured plots. At Waseca, first year corn grain and stover yields following alfalfa responded to low rates of fertilizer N, but manured plots did not differ from the 0 N control (Table 6). In contrast to Rosemount, N-uptake of corn following alfalfa was not affected by manure applications at Waseca.

Table 4. Estimated N availability and determined N credits in 1991 for dairy manure applied to continuous corn and corn following alfalfa at Rosemount and Waseca, MN.

Year of manure application	Location	Cropping[1] sequence	Rate	Available N in 1991[2] Estimated	Determined
			gal/A	- - lb / acre	- -
1990	Rosemount	A-A-A-C-C	3000	15	NM[3]
			5000	25	
			7000	35	
		A-C-C-C-C	3000	15	NM
			7000	35	
			11000	60	
	Waseca	A-A-A-C-C	3000	10	NM
			5000	15	
			7000	20	
		A-C-C-C-C	3000	10	NM
			7000	20	
			11000	30	
1991	Rosemount	A-A-A-C	3330	85	NR[4]
			6660	170	
			9990	255	
		C-C-C-C	3330	85	95
			6660	170	150
			9990	255	150
	Waseca	A-A-A-C	3200	75	NM
			6400	150	
			10660	240	
		C-C-C-C	3200	75	10
			6400	150	60
			10660	240	60

1 A = alfalfa, C = corn, and the 1991 crop is underlined.
2 Estimated available N based on 25% of organic N available the year of application, 100% of NH_4^+-N available the year of application, and 15% of organic N available the year after application. Determined available N based on the fertilizer response of grain yield on nonmanured plots with the same cropping sequence.
3 NM = no significant grain yield response to manure.
4 NR = no significant grain yield response to fertilizer N.

Manure N was effectively substituted for urea on continuous corn at Rosemount in 1991. Application of 6660 gal/A provided ample N for maximum grain yields, in agreement with estimates based on the manure N content (Table 4). No additional yield benefit was gained from a higher application (Table 5). At Waseca, corn response to manure was much lower than anticipated. Nitrogen was not the limiting factor since the grain yield of the two highest manure rates did not differ. Negative effects of the manure were probably related to high precipitation and wet soil in spring 1991, compaction problems associated with incorporating the manure into a limited soil volume with the disk, and the high salt content of the Waseca manure source.

This study compared two methods for determining alfalfa N credits, the indirect method with the less common direct method. The indirect method of determining N credits is based on the fertilizer response of continuous corn. The N credit is the quantity of fertilizer N required for continuous corn grain yield to equal the grain yield of corn following alfalfa with no fertilizer N applied. Direct determination of the N credit based on the fertilizer response of corn following alfalfa. A maximum N credit must be assumed to convert the direct method fertilizer N recommendation to an alfalfa N credit. We used the University of Minnesota maximum N credit recommendation of 150 lb N/A. With this assumption a direct method fertilizer recommendation of 60 lb N/A is equivalent to an N credit of 90 lb N/A (150 lb N/A - 60 lb N/A = 90 lb N/A).

The indirect method estimated lower N credits in second year corn following alfalfa compared to the direct method (Table 7). Determining an estimate by the direct method was made difficult by the limited N response of corn yield following alfalfa. It is easier to model the highly responsive continuous corn plots facilitating estimates of the second year N credit by the indirect method.

In first year corn following alfalfa, the direct method of determining N credits is more likely to identify responsive sites compared to the indirect method. For example, the indirect method failed to determine the potential yield response to fertilizer N of first year corn following alfalfa at Waseca (Table 7). This was probably due to the indirect method's inability to fully account for rotation effects.

Table 5. Effect of previous crop, spring incorporated dairy manure, and urea on corn yield and N uptake at Rosemount, MN in 1991.

Cropping[1] sequence	N source	Rate		Grain Yield	Grain N uptake	Silage Yield	Silage N uptake
				bu/A	lb/A	T DM/A	lb/A
A-A-A-C		control		168	129	7.79	156
	Urea	30	lb/A	181	150	8.35	179
		60		177	148	8.02	177
		100		190	162	8.56	206
		140		172	145	7.91	186
			P>F	0.23	0.08	0.41	0.01
			MSD[2]	-	24	-	24
			CV (%)	6.2	7.8	6.4	6.9
	Manure[3]	3330	gal/A	188	154	8.53	190
		6660		179	156	8.49	207
		9990		189	166	8.77	216
			P>F	0.01	0.01	0.01	0.01
			MSD[2]	5	14	0.48	20
			CV (%)	1.3	4.7	2.8	5.2
C-C-C-C		control		114	81	5.30	98
	Urea	60	lb/A	136	101	6.31	120
		100		159	123	7.40	150
		140		166	142	7.91	179
		180		165	147	7.90	183
			P>F	0.01	0.01	0.01	0.01
			MSD[2]	18	27	0.75	32
			CV (%)	6.6	12.0	5.9	12.0
	Manure[3]	3330	gal/A	148	112	7.13	136
		6660		164	140	7.58	166
		9990		165	145	7.90	188
			P>F	0.04	0.03	0.05	0.02
			MSD[2]	37	43	1.91	52
			CV (%)	11.9	17.0	12.9	17.2

1 A = alfalfa, C = corn, and the 1991 crop is underlined
2 Minimum significant difference (0.10)
3 Manure applied spring 1991.

Future reports in this series will discuss the second year grain and silage results from the two sites initiated in 1991 and soil inorganic N data collected in the spring and fall of each growing season at all four sites.

Table 6. Effect of previous crop, spring incorporated dairy manure, and urea on corn yield and N uptake at Waseca, MN in 1991.

Cropping[1] sequence	N source	Rate		Grain Yield	Grain N uptake	Silage Yield	Silage N uptake
				bu/A	lb/A	T DM/A	lb/A
A-A-A-C		control		162	95	6.35	113
	Urea	30	lb/A	173	108	6.59	127
		60		180	116	6.93	137
		100		187	125	7.39	154
		140		189	130	7.01	154
			P>F	0.04	0.01	0.04	0.01
			MSD[2]	20	12	0.75	15
			CV (%)	6.7	7.2	6.2	7.3
	Manure[3]	3200	gal/A	160	96	6.21	113
		6400		157	96	6.06	113
		9600		161	100	6.24	119
			P>F	0.70	0.26	0.86	0.48
			MSD[2]	-	-	-	-
			CV (%)	4.1	4.0	4.7	5.5
C-C-C-C		control		95	49	3.92	59
	Urea	60	lb/A	130	70	5.07	84
		100		144	80	5.68	96
		140		158	101	6.18	120
		180		174	118	6.63	140
			P>F	0.01	0.01	0.01	0.01
			MSD[2]	15	13	0.53	14
			CV (%)	7.8	10.8	6.7	10.2
	Manure[3]	3200	gal/A	104	53	4.05	63
		6400		126	71	5.04	85
		9600		125	72	4.48	82
			P>F	0.05	0.01	0.04	0.01
			MSD[2]	28	14	0.87	13
			CV (%)	14.0	14.1	11.3	11.4

1 A = alfalfa, C = corn, and the 1991 crop is underlined
2 Minimum significant difference (0.10)
3 Manure applied spring 1991.

Table 7. Nitrogen credit for first and second year corn following alfalfa in 1991 determined at at Rosemount and Waseca, MN.

Year of alfalfa incorporation	Cropping[1] sequence	Location	Nitrogen Credit[2] Direct	Nitrogen Credit[2] Indirect
			- - lb / acre	- -
1990	A-A-A-C-C	Rosemount	90	45
		Waseca	90	85
1991	A-A-A-C	Rosemount	150	150
		Waseca[3]	90	150

1 A = alfalfa, C = corn, and the 1991 crop is underlined.
2 See text for discussion of direct and indirect N credits
3 Alfalfa was incorporated fall 1990.

WATER QUALITY RESEARCH WITH NITROGEN AT THE HERMAN ROSHOLT WATER QUALITY RESEARCH FARM, WESTPORT, MN 1991 [1]

Large and Small plot phases

G.L. Malzer, T.J. Graff[2]

Abstract: The objective of the **small plot** water quality research phase is to evaluate and quantify the impact of a variety of agricultural practices on crop nitrogen utilization efficiency and the potential impact on water quality. Currently agricultural practices such as crop rotation, tillage, and fertilizer N management including, rates, sources, time of application, methods of application and use of nitrification inhibitors are being evaluated. Corn grain and soybean yields were not influenced by tillage systems (chisel-plow vs. ridge-till systems). Nitrogen fertilizer significantly increased corn grain yield when 105 lbs N/A was applied with continuous corn. No yield increase was obtained with N rates over 105 lbs N/A under continuous corn. Late sidedressed N application with chisel plow tillage system produced higher grain yields than early N application. High amounts of precipitation during 1991 apparently leached some of the fertilizer N which had been applied early. Nitrification inhibitors increased grain yield when used at the lower rates of fertilizer N. Rates of fertilizer N in excess of plant need resulted in higher concentrations of nitrate-N in the percolate water.

The objective of the **large plot** groundwater phase is to monitor the movement of nitrate-N through the soil profile into the underlying aquifer and to quantify subsequent impact on groundwater quality. Experimentation utilizes several sampling devices, including suction lysimeters, glass blocks, sheet metal (pan) containers, wick samplers, and wells established at three different levels in the aquifer. Three treatments replicated twice were established in 1987. Each plot area is in excess of one acre and the treatments include continuous corn at a moderate (160 # N/A) and high (215 # N/A) rate of N, and a corn-soybean rotation at the moderate N rate. Corn grain yields were not increased by the high N rate in 1987,1988, 1989,1990 but were in 1991. Concentration of nitrate-N in the percolate water increased as the rate of fertilizer N increased. Method of water collection influenced the actual concentration measured.

In 1987 three phases of nitrogen (N) research were started at the Herman Rosholt Water Quality Research Farm at Westport, MN. The three phases of research included a lysimeter phase, a large plot groundwater phase and a small plot N management/crop production phase. The large and small plot phases are reported here, the lysimeter phase will be reported separately.

The soil at the Rosholt farm is an Estherville sandy loam with 15-30 inches of sandy loam soil overlying glacial outwash composed mainly of coarse sand and gravel. Because of the coarse nature of these soils and the low water holding capacity, they are frequently irrigated to attain high yields. The higher yield potential along with higher fertilizer inputs, low water holding capacity, and shallow underlying aquifer create conditions which could result in groundwater contamination with nitrate N. Improper fertilizer N management can result in reduced yields, reduced fertilizer use efficiency, decreased profits, and increased groundwater contamination. The purpose of these phases of research was to determine the impacts of different N and crop management practices on crop yield, N utilization and their resulting impacts on groundwater quality.

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2. Professor and Asst. Scientist respectively, Dept. of Soil Science. University of MN.

Experimental Procedures

Small Plot N Management/Crop Production Phase: consisted of 25 N treatments randomized within a split-split plot design with three replications. The main plot consisted of two cropping sequences (continuous corn and corn following soybeans) with the sub-plots being tillage (ridge till and chisel plow). Ridges were constructed in 1987. In 1990 the entire experiment was planted to corn and in 1991 soybeans were planted in the corn-soybean rotation. The 25 N treatments within each sub-plot consisted of a control (zero N) plus four N rates (60, 120, 180, and 240 kg N/ha -- these will be reported as 50, 105 160, and 215 # N/A), two nitrification inhibitors (none and N-Serve) and three times/methods of application (all N early-6 leaf growth stage, all N late-8 leaf growth stage, and split with 2/3 N early and 1/3 N late). All fertilizer N treatments were applied as anhydrous ammonia. Early application was applied on June 10th and late application was applied on June 19th. The nitrification inhibitor N-Serve was applied with an in-line injection pump which inserted the chemical in front of a bidirectional flow integrator and the manifold. N-Serve was applied at a rate of 0.5 #/A active ingredient.

Soil samples were taken from 0-1 and 1-2 ft depth from 13 of the 25 treatments on April 25th before planting and on September 19th before harvest. The soil samples were analyzed for ammonium and nitrate concentration and the data is reported in tables 2 and 3. Spring samples were taken on corn following corn and the corn following soybeans. Fall samples were taken from corn following corn and the soybean check plots.

Corn (Pioneer 3790 - 95 day R.M.) was planted on May 9th in 30 inch rows at a population of 29,900 seeds/A using a four-row Buffalo planter. Starter fertilizer was applied to the corn plots at the rate of 10 gal/A of 7-22-5 as a band below the seed and Counter was banded in the row at planting. Lasso (3 #/A) and AAtrex 90 DF (1 #/A) was applied on May 20th for weed control in the corn. For additional weed control the corn was cultivated twice. The first cultivation was on June 17th, and second on July 5th, ridges were also built on July 5th. Soybeans were planted on May 22nd at the rate of 63 #/A. A tank mix of Basagran (1 qt/A), Blazer (.5 pt/A), Poast (1.5 pt/A) and oil concentrate (1 qt) applied June 5th at the rate of 20 gal/A. For additional weed control the plots were cultivated twice. The irrigation program (traveling boom) was started on August 18th with 1 inch of water being applied through irrigation. An additional 21.89 inches of water was obtained during the growing season as rainfall.

Soybean yields were taken October 2nd with a plot combine harvesting two 50 ft rows. Corn grain yields were obtained on October 9th by hand harvesting 100 ft^2 of plot area. All corn grain yields were adjusted to 15.5% and soybeans to 13%. Grain yields and N concentration are reported in table 1.

Large Plot Groundwater Phase:

In 1987 six large plots (approximately one acre) were established at the Rosholt farm. The experiment area consisted of three treatments with two replications. Two treatments are continuous corn with N rates of 160 and 215 lbs N/A. The third treatment is in a corn following soybeans sequence with 160 lbs N/a applied during the corn year. In 1987 all treatments were planted to corn. In 1988 soybeans were planted into the corn-soybean rotation treatment. Soybean have been present in the rotation on even number years. Nitrogen was applied as anhydrous ammonia in split application of two-thirds of the N rate with a nitrification inhibitor (N-Serve) at an early growth stage 6-leaf (June 10), and one-third at the 8-leaf growth stage (June 19th). N-Serve was applied only at the 6-leaf stage utilizing an in-line injection pump which inserted the chemical in front of a bidirectional flow integrator and the manifold. N-Serve was applied at a rate of 0.5 #/A a.i.

Corn (Pioneer 3790 - 95 day R.M.) was planted on May 10 in 30 inch rows at a population of 29,900 seeds/A using a four-row Buffalo planter. Starter fertilizer was applied at the rate of 10 gal/A of 7-22-5 as a band below the seed. Counter was banded in the row at planting. Lasso (3.0 #/A) and AAtrex 90 DF (1#/A) were sprayed on May 14th for weed control. The irrigation program (traveling boom) consisted of 1.0 inch of water being applied through irrigation on August 18th and an additional 21.89 inches of water coming through rainfall during the growing season. Grain yields were obtained on October 9th by hand harvesting 800 ft^2 of plot area. Corn grain yields were adjusted to 15.5% moisture. Grain yields results are presented in table 5.

Chemical movement through soils to groundwater

The movement of nitrate-N through soils to the groundwater is being evaluated utilizing several types of soil water sampling devices. These include suction lysimeters, glass blocks, sheet metal pans, wick samplers, and wells. The wells were installed by the United States Geological Survey.

Data from the wells and suction lysimeters will not be presented at this time. The glass blocks did not collect enough water in 1991 to present the data in tabular form.

Glass block samplers are made from glass building blocks,(12" X 12"X 4" - L X W X D). Holes were drilled into the blocks to allow water to enter and permit access for removing the water collected. Three glass blocks were installed in plots at a soil depth of 18-24 inches (depth where soil becomes very coarse). Three blocks were installed side by side, one directly under a crop row and one on either side.

Suction lysimeters were installed at depths of 4 and 7 feet during 1987. The ceramic cup of the suction sampler was cast into a silica slurry which hardens in the soil to insure continuous contact between the soil and the ceramic cup. Outflow tubes were run to the soil surface for sampling. This type of sampler allows for the collection of soil water samples at the aforementioned depths.

Pan sheet metal samplers consist of 18-gauge sheet metal, cut, bent, and spot welded into a trough-like collection box. The samplers are 30" long 12" wide and 3" deep and made watertight by soldering along seams. Holes were drilled into the top of the sampler to allow entry of water. Access tubes were installed to the soil surface to facilitate extraction of the water collected.

Wick samplers are a one-half inch glass plate, 12 inches X 30 inches. A hole was drilled in the center of the glass plate and a 2 inch length of PVC pipe was attached to it. A braided glass rope was inserted through the PVC pipe and onto the glass plate. The strands of glass rope were unraveled over the surface of the glass plate and epoxied to the edges of the plate, forming a spider web-like pattern. The glass rope thus acted as a wicking device to draw water from the surface of the plate into a one gallon collection jar. These also have outflow tubes going to the surface. The pan sheet metal and wick samplers were installed at approximately the same depth as the glass blocks.

General Results

Small Plot N Management/Crop Production Phase:

When no fertilizer N was applied corn yields were about 65 bu/A and soybeans yields were about 35 bu/A. Tillage systems had relatively little influence on corn and soybean grain yields.

Yield increases were obtained with fertilizer N up to 105 #/A although 85% of the yield increase was obtained with the first 50 # N/A. The wet growing season created conditions for some very interesting responses to fertilizer management. Fertilizer use efficiency and grain yields increased when the time of fertilizer N application was delayed there by minimizing N loss. In the dryer years 1988 and 1989 highest yields were obtained when the fertilizer was applied early (4-leaf) rather than in split or 8-leaf applications. In 1991 the yields response associated with delaying time of fertilizer N would indicate that substantial N losses occurred during the early portion of the growing season. The chisel plow tillage system appeared to be more prone to N loss than did the ridge-till system. A significant yield increase (12 bu/A) was obtained with the use of N-Serve on corn. N-Serve is a chemical additive used with N fertilizer to minimize N loss from the soil. Although the overall yield increase due to N-Serve was not high, substantial yield increases (10-15 bu/A) were obtained at the lower rates of N in the chisel plow system. Previous N management practices had no influence on soybean yields.

The soil nitrate-N concentration in the spring, before planting, and in the fall, following harvest, were similar. Since the concentrations were relatively low at both samplings it would suggest that the NO_3-N not used by the plant was probably moved out of the root zone by the high rainfall in 1990 and 1991. The highest rate of fertilizer N tended to have higher concentrations of nitrate-N in the soil profile. The NO_3-N concentration of water collected in the pan lysimeters tended to be high in the corn following soybeans plots than in the continuous corn plots (table 4). Water samples collected by the wick lysimeters had higher NO_3-N concentrations than the water collected in the pan lysimeters.

Large Plot Groundwater Phase:

Results displayed in table 5 suggest that there was a yield advantage to the highest rate of fertilizer N in 1991. This is contrary to any results obtained in the preceding four years of research. Corn yields following soybeans were higher than yields following corn. Application of more fertilizer N in 1991 did not compensate for the rotation effect in 1991. Higher rates of fertilizer N resulted in higher concentration of NO_3-N in the water samples collected in the pan and wick samplers (table 6). Concentration of NO_3-N was higher under continuous corn than the corn-soybean sequence. The pan samplers provided lower estimates of the concentration of NO_3-N in the soil water than the wick samplers.

Table 1. Influence of N-rate, nitrification inhibitors, method of application and tillage on continuous corn grain yields, N-concentration, and N removal. Influence of treatments applied in 1990 on soybeans yields (soybeans following corn). Westport, MN. 1991

Total N-Rate	Early N	Inh.	Late N	Tillage	Corn Grain Yield	Corn Grain N-content	Corn Grain N-removal	Soybean Yield
#/A	#/A		#/A		Bu/A	%	#/A	Bu/A
Control	----	--	----	C	63.7	1.23	37.09	36.5
50	50	--	----	C	100.7	1.19	56.90	41.4
50	----	--	50	C	113.4	1.37	73.73	34.2
50	35	--	15	C	110.2	1.27	66.17	37.3
50	50	NS	----	C	116.3	1.37	75.33	34.5
50	----	NS	50	C	124.9	1.36	80.32	34.4
50	35	NS	15	C	118.8	1.41	79.45	36.8
105	105	--	----	C	107.8	1.40	71.39	32.1
105	----	--	105	C	128.8	1.36	82.57	32.9
105	70	--	35	C	120.6	1.37	78.14	37.2
105	105	NS	----	C	111.0	1.37	71.91	30.8
105	----	NS	105	C	117.7	1.34	74.58	36.3
105	70	NS	35	C	120.5	1.50	85.51	38.8
160	160	--	----	C	108.8	1.37	70.63	39.6
160	----	--	160	C	118.2	1.45	81.13	43.3
160	105	--	55	C	116.3	1.39	76.76	36.6
160	160	NS	----	C	120.5	1.42	81.19	33.6
160	----	NS	160	C	117.7	1.42	78.99	36.3
160	105	NS	55	C	125.0	1.49	87.76	42.3
215	215	--	----	C	105.3	1.54	76.80	33.8
215	----	--	215	C	109.9	1.44	74.68	35.9
215	145	--	70	C	115.5	1.45	79.13	38.5
215	215	NS	----	C	110.5	1.49	78.00	38.8
215	----	NS	215	C	115.9	1.43	78.61	35.8
215	145	NS	70	C	110.3	1.46	76.45	38.4
Control	----	--	----	R	68.4	1.18	38.20	34.8
50	50	--	----	R	116.3	1.24	68.39	32.9
50	----	--	50	R	113.1	1.37	73.43	31.9
50	35	--	15	R	107.1	1.41	71.28	34.8
50	50	NS	----	R	121.4	1.30	74.54	37.4
50	----	NS	50	R	118.7	1.33	74.92	33.5
50	35	NS	15	R	118.0	1.39	77.41	33.2
105	105	--	----	R	125.6	1.42	84.51	31.3
105	----	--	105	R	127.9	1.28	77.59	36.6
105	70	--	35	R	124.0	1.46	85.70	32.8
105	105	NS	----	R	125.1	1.42	84.02	36.5
105	----	NS	105	R	128.2	1.38	83.53	36.1
105	70	NS	35	R	122.6	1.32	76.10	33.9
160	160	--	----	R	124.6	1.41	83.43	37.8
160	----	--	160	R	125.8	1.50	89.29	26.0
160	105	--	55	R	119.4	1.45	82.16	41.4
160	106	NS	----	R	120.4	1.57	89.17	39.3
160	----	NS	160	R	119.9	1.41	79.60	36.2
160	105	NS	55	R	117.5	1.38	76.22	29.4
215	215	--	----	R	121.0	1.45	83.23	37.0
215	----	--	215	R	121.8	1.40	80.80	34.9
215	145	--	70	R	126.1	1.41	84.48	37.0
215	215	NS	----	R	117.3	1.48	81.98	38.7
215	----	NS	215	R	124.5	1.39	81.81	36.6
215	145	NS	70	R	120.5	1.49	84.87	33.3

Table 1. continued. Continuous Corn Split Plot Statistical Analysis
Corn Soybean Rotation Split Plot Statistical Analysis

	Corn Grain			Soybean
	Yield	N-Content	N-Removal	Yield
	Bu/A	%	#/A	Bu/A
Tillage				
Chisel	115.2	1.40	76.5	36.6
Ridge Till	121.1	1.40	80.3	34.8
P-Value	84	19	83	60
N-Rate X Method X Inhibitor				
N-Rate #/A				
50	114.9	1.33	72.6	35.0
105	121.6	1.38	79.6	34.6
160	119.4	1.43	81.3	36.8
215	116.5	1.45	80.0	36.5
P-Value	99	99	99	82
BLSD (.05)	2.5	0.02	2.2	
Method				
1. 4 leaf	115.7	1.40	79.6	36.0
2. 8 leaf	120.4	1.38	79.0	35.0
3. Split 2/3 1/3	118.2	1.41	79.2	36.2
P-Value	99	89	95	52
BLSD (.05)	2.3		2.2	
Inhibitor				
None	117.0	1.39	77.1	35.7
N-Serve	119.3	1.41	79.6	35.7
P-Value	98	94	98	4
N-Rate X Method	57	99	87	42
N-Rate X Inhibitor	99	61	99	36
Method X Inhibitor	55	94	96	57
N-Rate X Method X Inhibitor	71	97	89	8
N-Rate X Method X Inhibitor X Tillage				
N-Rate X Tillage	99	81	68	63
Method X Tillage	99	50	99	94
Inhibitor X Tillage	97	93	99	48
N-Rate X Method X Tillage	69	86	94	62
N-Rate X Inhibitor X Tillage	85	90	87	26
Method X Inhibitor X Tillage	85	99	91	99
N-Rate X Method X Inhibitor X Tillage	18	95	95	97

Table 2. Influence of N-rates, nitrification inhibitors, method of application and tillage in **continuous corn** on soil ammonium and soil nitrate from spring and fall soil samples depth 1 (0-1 ft) and depth 2 (1-2 ft) Westport, MN 1991.

Total N-Rate	Early N	Inh.	Late N	Tillage	Depth	Ammonium Spring	Ammonium Fall	Nitrate Spring	Nitrate Fall
#/A	#/A		#/A			------ppm-----		------ppm-------	
Control	---	---	---	C	1	4.5	1.7	1.7	3.2
					2	3.9	2.0	1.6	1.3
50	50	---	---	C	1	5.4	1.9	1.0	3.3
					2	4.1	2.0	1.5	1.3
50	---	---	50	C	1	4.7	2.0	2.0	3.7
					2	4.1	1.7	1.9	1.8
105	105	---	---	C	1	5.6	1.8	1.6	3.5
					2	4.1	1.6	1.8	2.3
105	---	---	105	C	1	4.6	1.8	2.5	3.7
					2	3.8	1.6	2.4	2.3
160	160	---	---	C	1	5.1	1.9	4.3	4.3
					2	4.1	1.7	4.2	3.4
160	---	---	160	C	1	5.0	2.4	2.2	4.3
					2	4.0	1.9	3.0	2.8
160	105	---	50	C	1	3.9	3.1	2.7	4.2
					2	3.5	2.0	2.9	3.6
160	160	NS	---	C	1	6.0	4.7	2.1	6.4
					2	4.4	3.1	3.6	6.9
160	---	NS	160	C	1	4.7	2.1	3.2	3.6
					2	6.5	1.9	3.9	3.9
160	105	NS	50	C	1	5.5	3.3	1.7	7.3
					2	4.1	2.1	2.1	3.0
215	215	---	---	C	1	7.4	9.0	3.1	10.2
					2	5.3	3.3	4.1	15.0
215	---	---	215	C	1	5.3	5.7	1.7	10.8
					2	6.0	1.9	2.4	10.3
Control	---	---	---	R	1	4.1	1.8	3.0	3.1
					2	3.8	1.6	2.4	1.3
50	50	---	---	R	1	4.8	2.0	4.0	2.9
					2	4.1	2.1	3.2	2.2
50	---	---	50	R	1	5.2	2.0	3.1	3.7
					2	4.3	2.0	2.9	2.0
105	105	---	---	R	1	5.2	1.9	4.6	3.9
					2	3.3	1.8	3.9	2.9
105	---	---	105	R	1	4.6	2.1	3.9	4.4
					2	3.7	1.8	4.1	3.4
160	160	---	---	R	1	5.1	2.6	2.8	4.6
					2	3.7	2.2	3.1	4.1
160	---	---	160	R	1	5.0	1.7	4.0	4.8
					2	3.8	1.6	4.5	2.5
160	105	---	50	R	1	4.6	2.2	4.0	4.2
					2	4.1	1.2	3.9	2.9
160	160	NS	---	R	1	4.8	2.6	5.6	4.7
					2	3.6	1.9	5.7	3.5
160	---	NS	160	R	1	5.7	2.5	3.7	4.9
					2	8.2	1.9	6.8	3.2
160	105	NS	50	R	1	4.9	2.3	3.3	3.2
					2	4.1	1.8	3.1	1.4
215	215	---	---	R	1	4.6	1.5	5.2	5.1
					2	3.8	1.7	3.9	3.4
215	---	---	215	R	1	7.5	2.5	6.7	5.2
					2	5.5	1.9	6.4	4.5

Table 3. Influence of N-rate, nitrification inhibitors, methods of application and tillage in **soybeans following corn** on soil ammonium and soil nitrate from spring and fall soil samples depth 1 (0-1 ft) and depth 2 (1-2 ft) Westport, MN 1991.

Total N-Rate	Early N	Inh.	Late N	Tillage	Depth	Ammonium Spring	Ammonium Fall	Nitrate Spring	Nitrate Fall
#/A	#/A		#/A			-----ppm-----		-----ppm------	
Control	---	---	---	C	1	4.1	1.9	2.1	2.5
					2	3.3	2.1	1.8	1.1
50	50	---	---	C	1	4.7		1.9	
					2	3.5		1.4	
50	---	---	50	C	1	3.7		1.0	
					2	3.4		0.8	
105	105	---	---	C	1	4.5		1.4	
					2	3.6		2.0	
105	---	---	105	C	1	3.9		2.1	
					2	3.3		2.1	
160	160	---	---	C	1	4.2		2.2	
					2	4.2		3.0	
160	---	---	160	C	1	5.1		3.0	
					2	3.9		3.1	
160	105	---	50	C	1	4.7		1.7	
					2	2.9		1.8	
160	160	NS	---	C	1	4.8		1.9	
					2	3.6		1.8	
160	---	NS	160	C	1	4.9		2.5	
					2	5.3		3.3	
160	105	NS	50	C	1	4.7		2.8	
					2	3.5		4.5	
215	215	---	---	C	1	4.9		3.0	
					2	3.2		3.0	
215	---	---	215	C	1	7.8		2.5	
					2	3.7		4.2	
Control	---	---	---	R	1	3.9	2.1	2.5	3.1
					2	3.4	1.8	2.4	1.3
50	50	---	---	R	1	4.3		2.5	
					2	3.7		2.5	
50	---	---	50	R	1	4.1		4.4	
					2	3.2		3.5	
105	105	---	---	R	1	4.3		2.9	
					2	3.1		2.8	
105	---	---	105	R	1	3.5		2.9	
					2	3.1		3.2	
160	160	---	---	R	1	4.6		4.9	
					2	3.7		4.3	
160	---	---	160	R	1	4.6		3.9	
					2	4.3		3.7	
160	105	---	50	R	1	4.5		3.8	
					2	3.4		4.6	
160	160	NS	---	R	1	6.4		4.9	
					2	4.6		5.3	
160	---	NS	160	R	1	4.5		2.9	
					2	3.8		4.3	
160	105	NS	50	R	1	4.4		3.0	
					2	3.9		3.3	
215	215	---	---	R	1	4.2		2.6	
					2	3.2		3.7	
215	---	---	215	R	1	4.6		3.5	
					2	4.5		3.4	