EFFECT OF TIME AND RATE OF N APPLICATION ON N USE EFFICIENCY AND SURFACE WATER CONTAMINATION WITH NITRATES[1]

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Abstract

Nitrate levels in excess of the public health standard of 10 mg N/l in public water supplies along with concern about hypoxia in the Gulf of Mexico have drawn renewed interest to improving fertilizer N use efficiency. Prior research has indicated that some farmers may be unknowingly contributing to these problems. The objectives of this research were to: determine the effect of rate and time of N application on nitrate-N concentrations in water from tile lines and to evaluate the effect of previous N rate on current N needs and on recovery of fertilizer N by plants. Tile line monitoring systems that record water flow rates and collect water samples on a predetermined schedule have been installed at 11 experimental sites. At each site N rate studies were conducted when the field was planted to corn. There appeared to be no relationship between previous N rate and current response to applied N. However, the relative yield response was higher for spring and sidedress treatments than for fall applied. Efficiency of fertilizer use was greater for spring-applied N than for fall-applied or sidedress N. Nitrate loss in tile line effluent was generally highest from those fields growing corn in that year and from those fields that had a previous history of excess rates of N application.

Introduction

Some Midwestern producers may be unknowingly contributing nitrates to water supplies. On-farm research identified 13 of 77 fields in which corn was non-responsive to fertilizer N. There was evidence to indicate that these fields had a previous history of high levels of fertilization and/or manure application (Brown et al., 1993). Based on these results, along with work by Torbert et al. (1992) showing that excess fertilizer N is assimilated into organic N compounds, and recent work by Stevens et al. (1997) demonstrating that these compounds mineralize more easily than native organic matter, we have theorized that these non-responding sites likely had adequate N release from the soil to meet the needs of the crop. Continued application of optimum or above-optimum N rates on these fields will enhance the potential for nitrate movement through tile line drainage. Buzicky et al. (1983) demonstrated that above-optimum application rates increased the loss of fertilizer-supplied N in tile drainage water and that the problem was even greater when the fertilizer was fall-applied.

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A survey of Champaign County producers indicated that nearly 70% were applying 40 lb N/acre or more above the recommended level for corn. The reasons for such overapplication are numerous, but one frequently mentioned reason is risk aversion.

The objectives of the project reported in this paper are to:

1. Ascertain the effect of rate and time of N application on nitrate-N concentrations in water from tile lines.
2. Evaluate the effect of previous N rate on current N needs.
3. Evaluate the effect of previous N rate on recovery of fertilizer N by plants.

Materials and Methods

Ten experimental sites having clearly defined tile systems that drain only that field or a known portion thereof were identified in 1997. Tile line monitoring systems that record water flow rates and collect water samples on a predetermined schedule based on flow rate were installed at each location. At four of the locations, air and soil temperatures are collected on 5-minute intervals, and precipitation is collected on 30 minute intervals at all locations. Past cropping records including yield, time and rate of N application, and crop rotation were recorded for each site (Table 1). Other than in the small plot area of the field, the farmers have been encouraged to continue to apply the same rate of N and to continue to manage the field in the same manner as in the past.

Small plot nitrogen rate studies were established at 7 of the sites in 1997 and at 4 sites in 1998, using ammonium sulfate in 40 lb N/acre increments. The total N fertilizer application ranged from 0 to 240 lb N/acre at 7 locations, from 36 to 276 lb N/acre at 2 locations, and from 45 to 285 lb N/acre at 2 locations. The differential in N rates was due to the application of DAP by the farmer. The ammonium sulfate was applied at each location near the time that the farmer made his application. At five locations, ^{15}N-labeled ammonium sulfate was applied to microplots within each N rate plot at the same rate of N. Corn was planted in mid to late-April and thinned to 29,000 plants per acre at the V-4 growth stage. At maturity, grain was hand-harvested for yield determination.

At physiological maturity, whole plant samples were collected from the microplot areas that had received the ^{15}N-labeled fertilizer and from the 0, 80, 160, and 240 lb N/acre rate plots that had received unlabeled ammonium sulfate. Following harvest, soil samples were collected to a 4-foot depth from all plots and analyzed for both inorganic and organic N and ^{15}N. The water samples collected by the automatic samplers were analyzed for nitrate and ammonium N.

Table 1. Characteristics of the experimental sites.

		Crop			Over-application[1]
Location No.	Soil type	1997	1998	Time N appl.	lb N/acre
1705	Drummer	Corn	Soybean	Fall	32
1833	Drummer	Soybean	Corn	Fall	52
2704	Drummer	Corn	Soybean	Spring	38
2720	Drummer	Corn	Soybean	Spring	87
2722	Drummer	Corn	Soybean	Spring	28
2806	Drummer	Soybean	Corn	Spring	
2822	Drummer	Soybean	Corn	Spring	28
3715	Drummer	Corn	Soybean	Sidedress	82
3717	Elliot-Ashkum	Corn	Soybean	Sidedress	55
3827	Drummer	Soybean	Corn	Sidedress	16

[1] Prior N rate applied minus recommended rate.

Results and Discussion

The weather differed considerably between the two cropping seasons (Figure 1). Temperatures were cooler than normal throughout the spring and early summer of 1997. In contrast, the winter and spring of 1998 were much warmer than normal, and soils never froze during the entire winter. Precipitation was near normal for the 1997 growing season, but above normal for the 1998 season. Even though the seasons were quite different, N availability was lower than normal in both seasons. The cool temperatures in 1997 likely resulted in lower mineralization rates. The warm winter and early spring of 1998 probably resulted in much higher nitrification rates than normal, and when that was followed by the abnormally high precipitation throughout the early summer, it likely resulted in increased leaching and denitrification rates.

The amount of fertilizer N needed to optimize grain yield was above normal at all locations in both years (Figure 2). This was likely due to the climatic conditions mentioned above and to the high yields obtained. There appeared to be no relationship between previous N rate and optimum N per unit of land area or per unit of production: or optimum yield; or relative yield increase (Table 2). When averaged across locations and years, the percent yield increase of the optimum N rate over the control was higher for spring and sidedress treatments than for fall applied N. Similarly, the amount of N required per bushel of yield obtained at the optimum N rate was higher for fall applied than spring or sidedressed treatments.

Table 2. Influence of prior N and time of N application on optimum N, yield at optimum N, and relative yield response.

Location No.	Prior N[1] Excess	Time of Appl.	Optimum N rate	Optimum N rate	Yield at Opt. N	Relative[2] Yield Incr.
	lb N/acre		lb N/acre	lb N/bu	bu/acre	%
1705	44	Fall	196	1.1	185	65
1833	29	Fall	240	1.6	148	108
2704	34	Spring	206	1.1	185	87
2720	74	Spring	198	1.0	193	107
2722	45	Spring	189	1.1	180	137
2725	43	Spring	139	0.7	189	32
2806	3	Spring	240	1.2	194	100
2822	12	Spring	240	1.6	155	308
3715	15	Sidedress	200	1.2	165	56
3717	14	Sidedress	186	1.1	171	190
3827	15	Sidedress	227	1.1	203	84

[1] Average N use above recommended rate.
[2] Yield at optimum N minus control yield divided by control yield.

Fertilizer N recovery at the optimum N rate was calculated by dividing the difference between the total N uptake on the 0 lb N/acre treatment and the total N uptake at the optimum N rate by the optimum N rate (Table 3). The recovery of fertilizer N measured in this way appeared to be higher for spring-applied than for fall-applied or sidedressed N. The lower recovery from the fall application may have been associated with the wet soils that resulted in denitrification loss. Even though that may have occurred, the yield obtained with the fall application was as high as from the spring applications. The lower recovery associated with the sidedress treatments was most likely the result of the lower yields obtained at those locations.

Table 3. Influence of prior N and time of N application on fertilizer N uptake and residual soil N.

Location No.	Prior N over-application[1]	Time of Application	Fert. N uptake at Opt. N	Residual Soil NO_3 -N at O N
	lb N/acre		%	lb N/acre
1705	44	Fall	36	45
1833	29	Fall		
2704	34	Spring	60	55
2720	74	Spring	52	5
2722	45	Spring	49	47
2725	43	Spring	55	31
2806	3	Spring		
2822	12	Spring		
3715	15	Sidedress	29	69
3717	14	Sidedress	47	52
3827	15	Sidedress		

1/ Average N use above recommended rate.

Residual soil nitrate-N levels ranged from 5 to 69 lb/acre in the top 4 ft. of soil in the untreated plot. This wide range was not related to prior N rate, nor to time of N application. The relatively low fertilizer N uptake observed at site 3715 may have been due to the high residual soil nitrate level at that location. Increased N application rate resulted in an increase in residual N levels at all locations.

In 1997, flow-weighted nitrate-N concentrations from tile lines tended to be highest on those fields planted to corn, and they tended to be greatest on those fields that had a history of higher N rates in the past (Figure 3). Notable exceptions to this statement included site 2704 that had a low concentration of nitrate-N in the tile line even though it was planted to corn and had a relatively high historical N application, and site 3827 for which a high nitrate-N concentration occurred despite being planted to soybeans and having a previous history of near optimum applications. Since site 3827 receives N as a sidedressing, it is possible that there may have been more carryover N available for leaching during the winter and early spring following the corn crop. Total N loss per acre in tile line flow followed a pattern associated with previous N history (Figure 4). The only exception was site 2704 that had a low N loss with a previous high rate of application.

The relationship between flow-weighted nitrate-N concentration and previous N history or time of N application was not evident in 1998 (Figure 5). There appeared to be a relationship between current crop and nitrate-N concentration with corn generally having the highest levels. Total N loss per unit of land area tended to be associated with previous N rate when soybeans were grown in 1998 (Figure 6). As in 1997, the greatest loss per unit of land area occurred when corn was grown, except for sites 1705 and 2720 which had high N loss values even though soybean was being grown. The results from site 2720 are rather confusing. The high flow-weighted nitrate concentrations and high loss per unit of land area could be attributed to the fact that this site had the highest excess application rate of all sites. However, this site had the lowest residual soil nitrate-N concentration in the soil profile of all sites, which would imply that the excess N had been immobilized and was rapidly mineralized during the soybean year.

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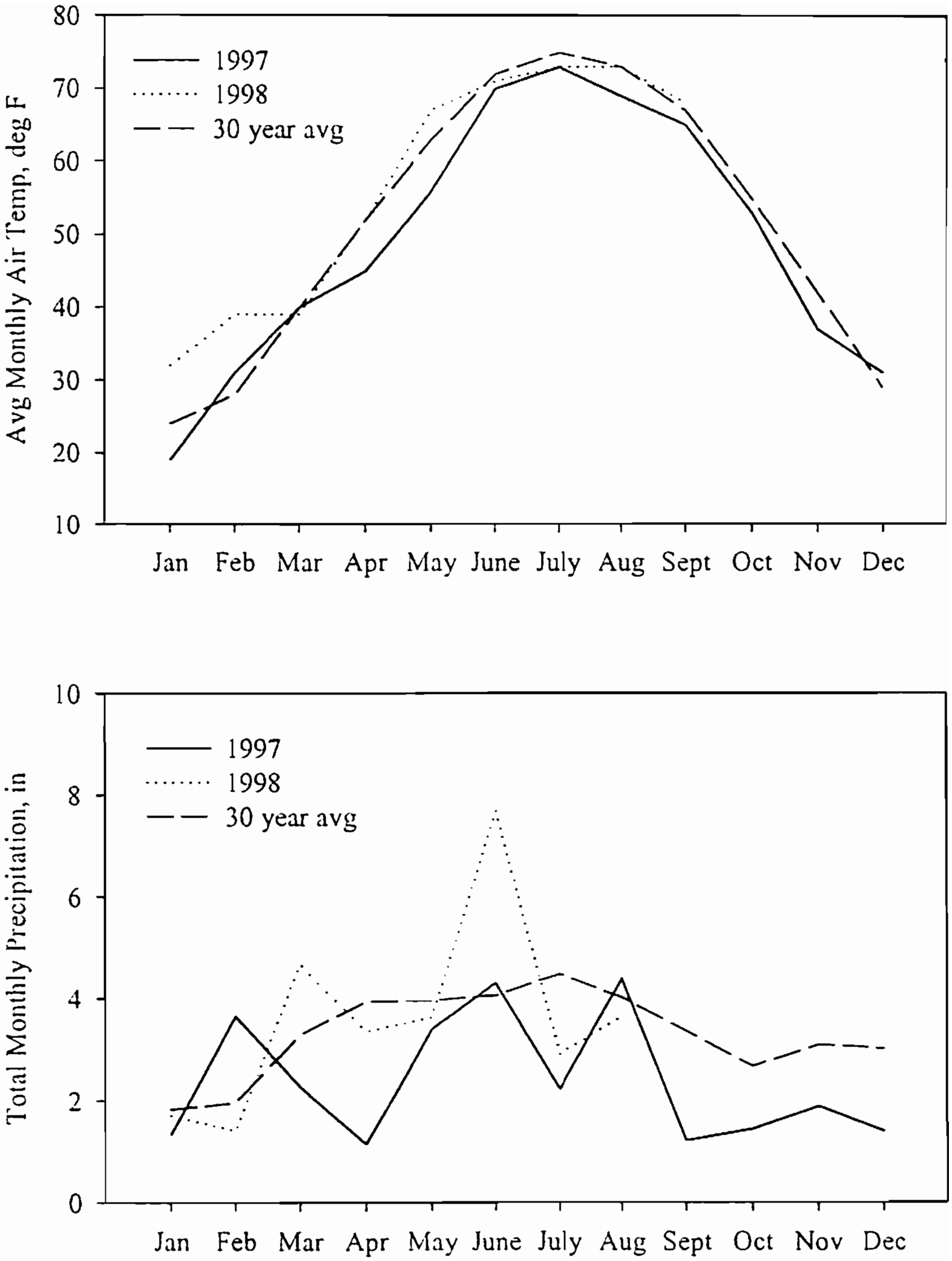


Fig. 1. Climate Data for Champaign, IL.

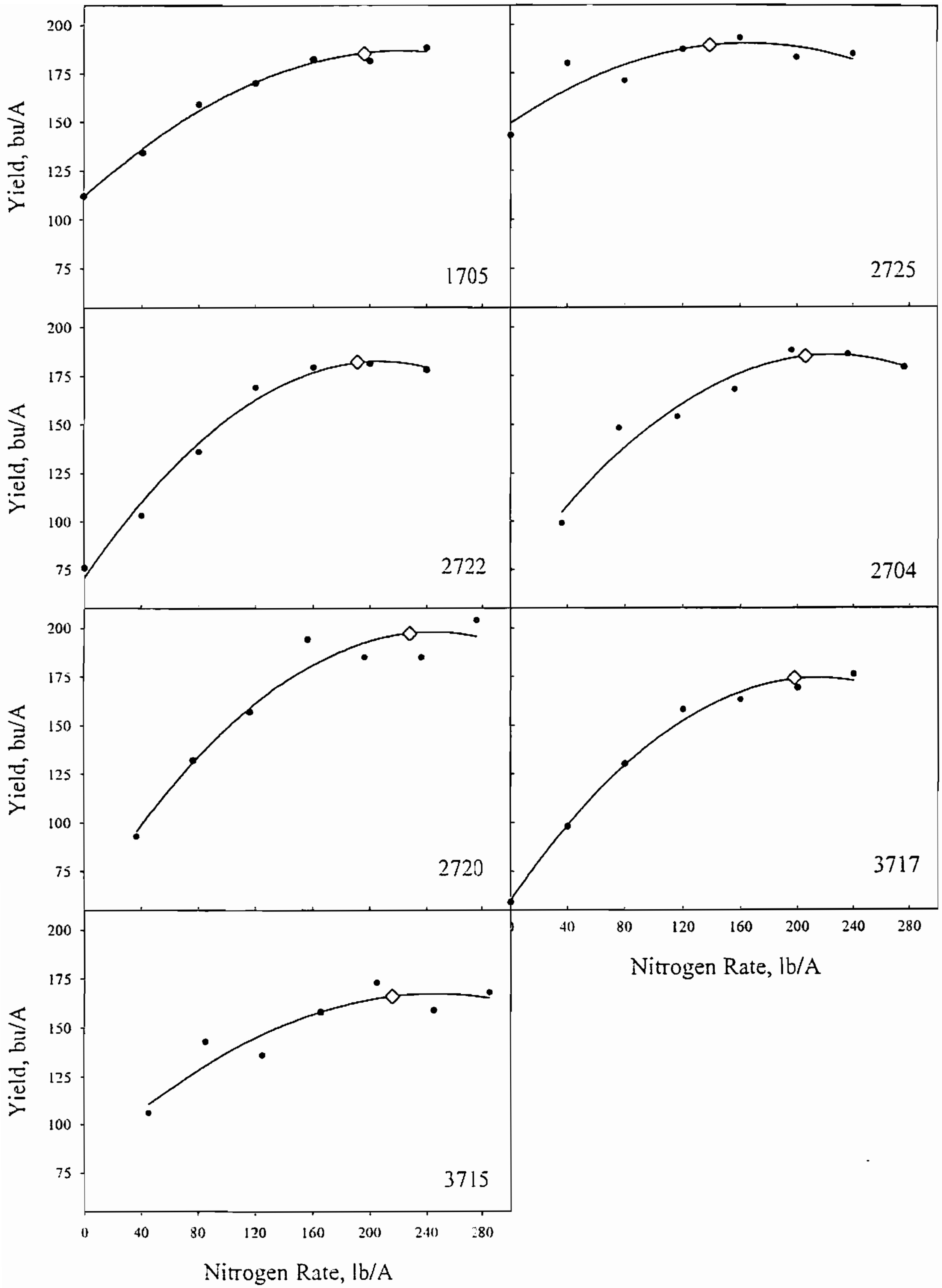
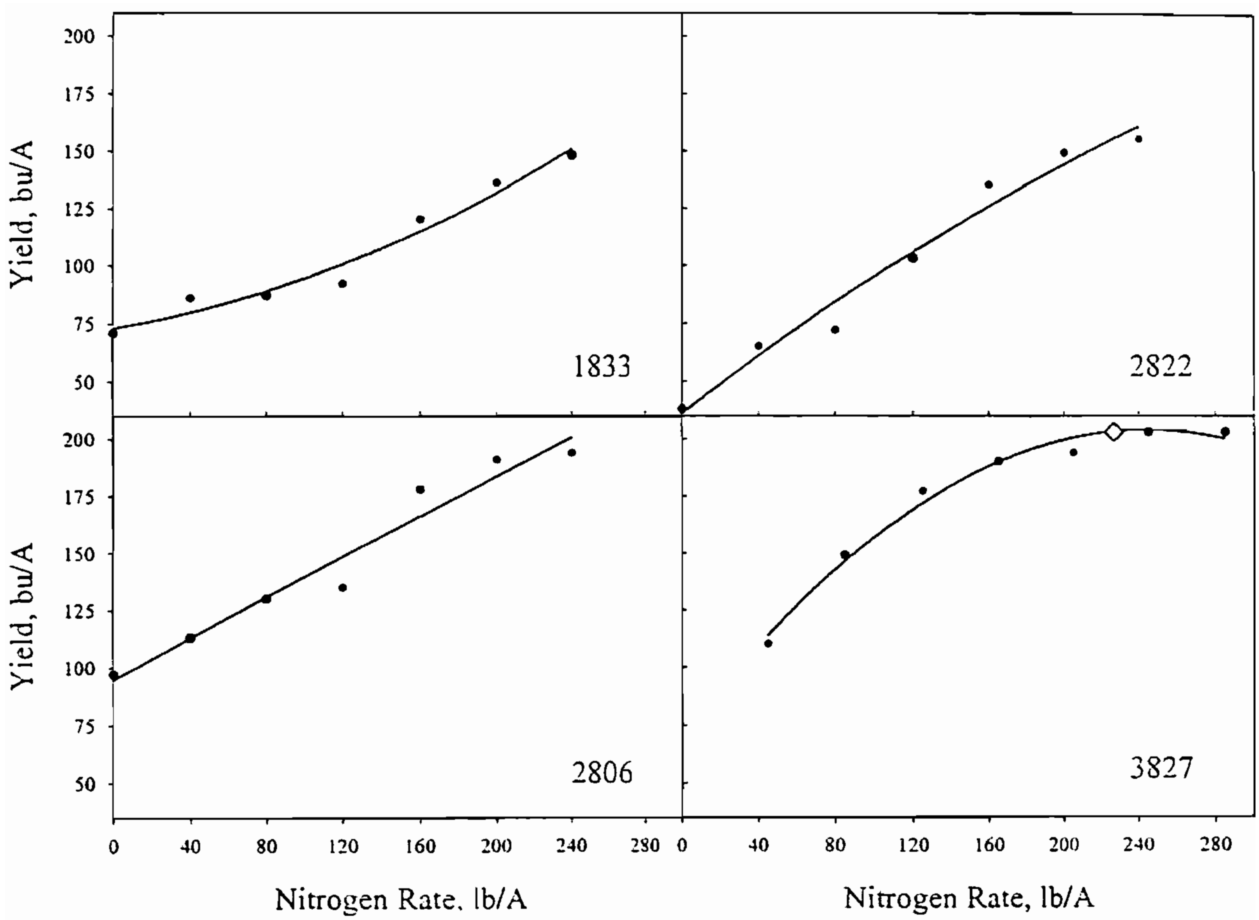


Fig. 2. Effect of nitrogen rate on corn yield.



Yield, bu/A
200
175
150
125
100
75
50
1833
2822
2806
3827
0
40
80
120
160
200
240
280
Nitrogen Rate, lb/A
Nitrogen Rate, lb/A

Fig. 2. (cont.)

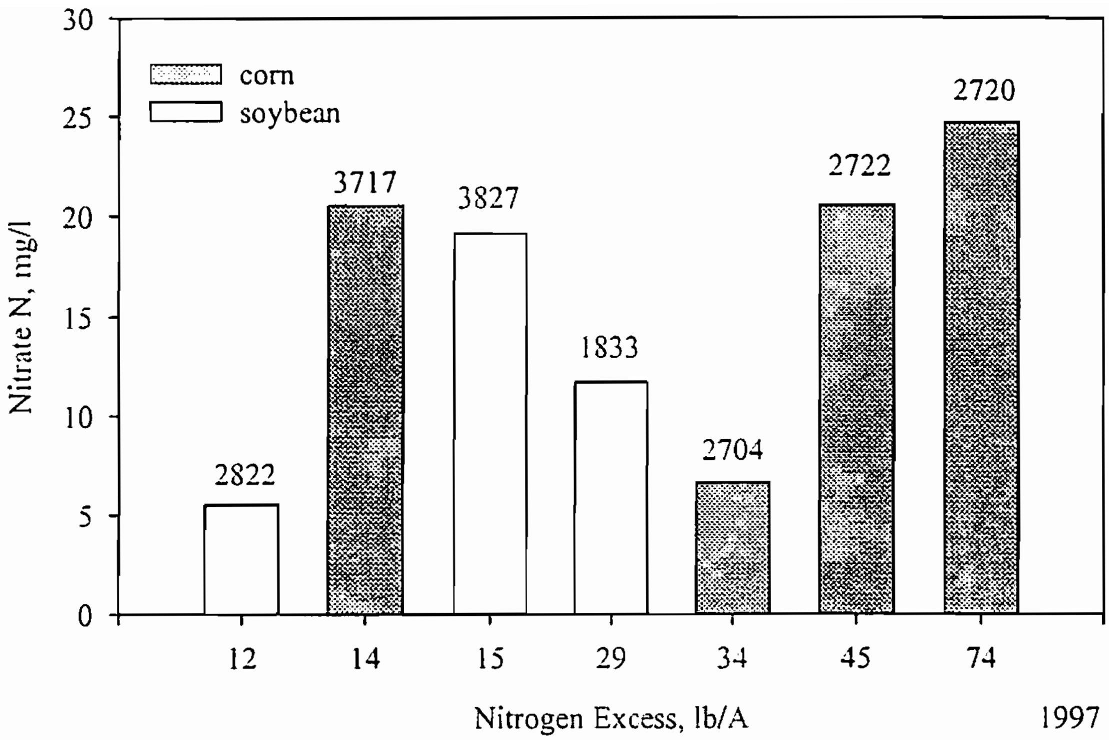


Fig. 3. Relationship between previous N rate, current crop, and flow weighted NO_3-N concentration in tile water - 1997.

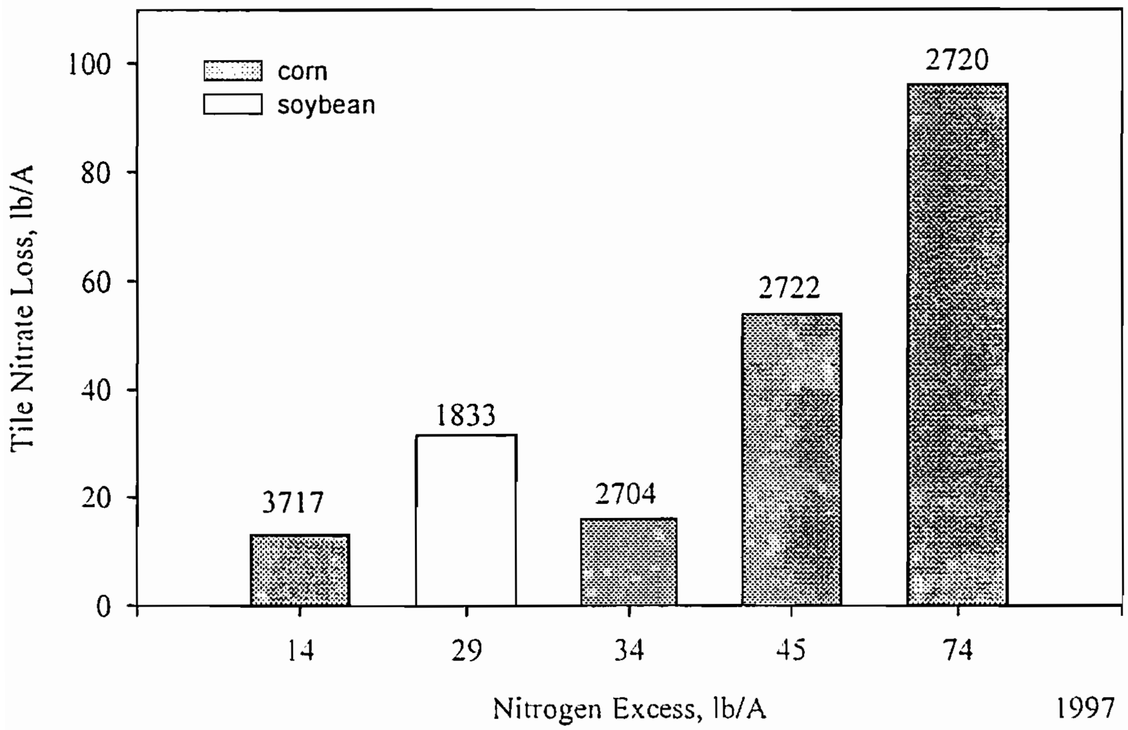


Fig. 4. Relationship between previous N rate, current crop, and total N lost per acre in tile line water - 1997.

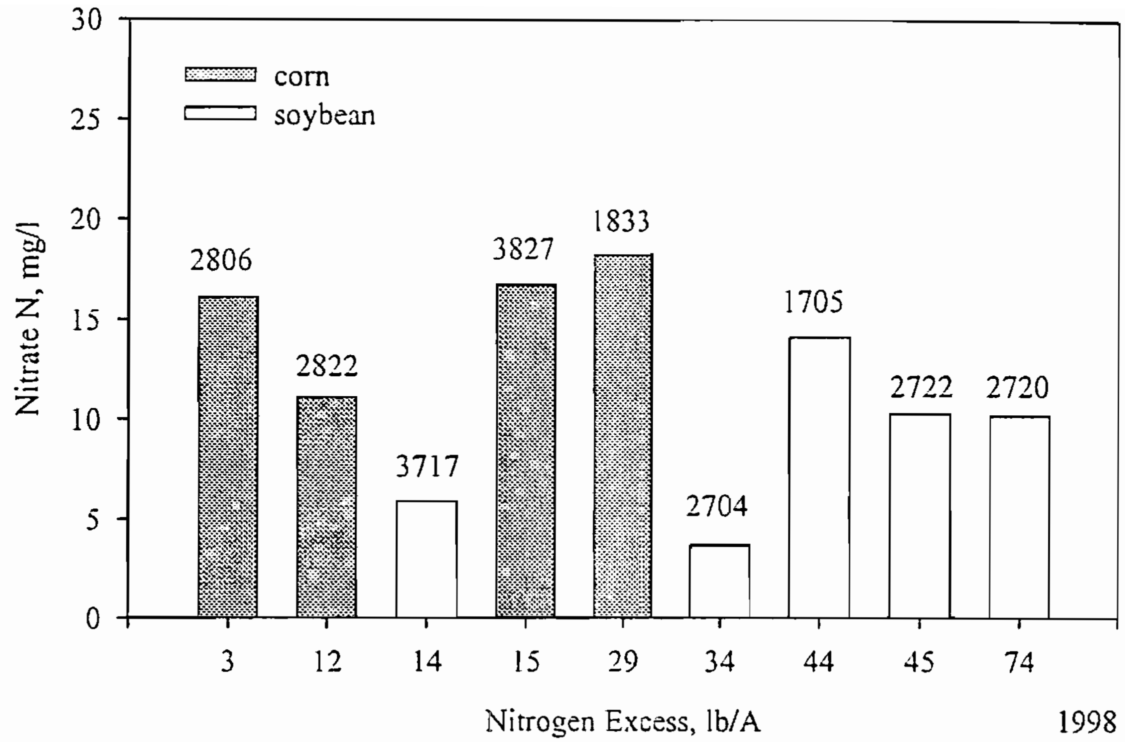


Fig. 5. Relationship between previous N rate, current crop, and flow weighted NO_3-N concentration in tile water - 1998.

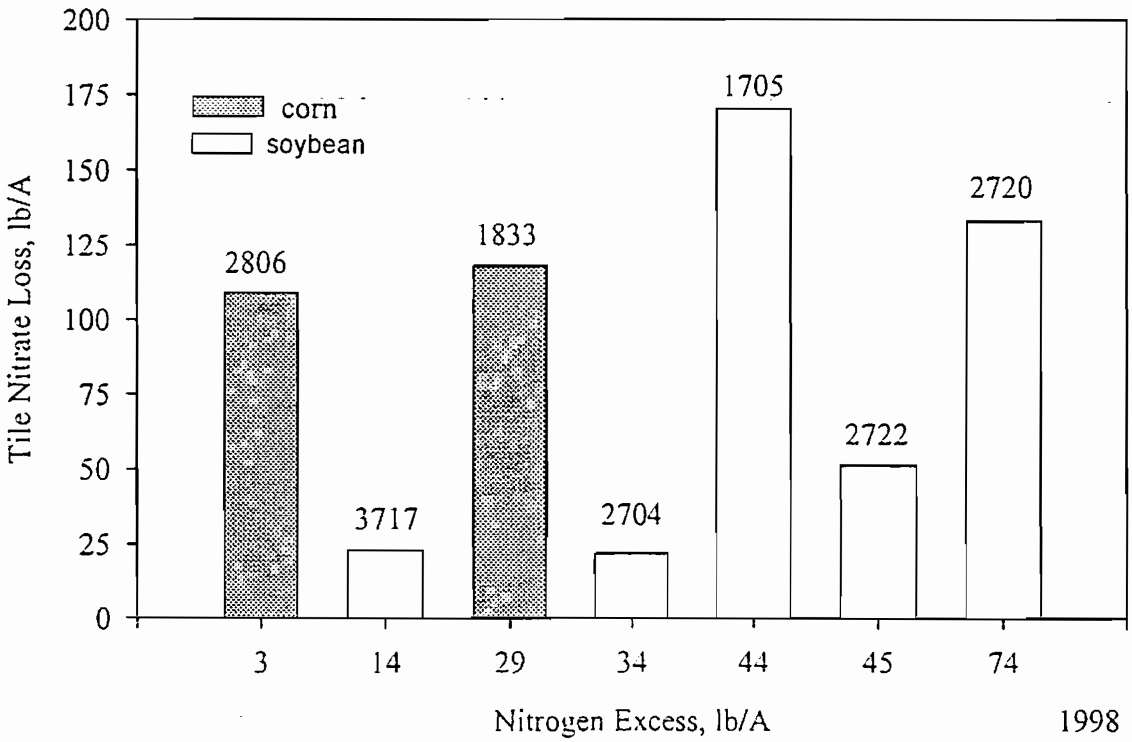


Fig. 6. Relationship between previous N rate, current crop, and total N lost per acre in tile line water - 1998.

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