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NITROGEN FERTILIZER MANAGEMENT TO REDUCE WATER POLLUTION POTENTIAL

by

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ABSTRACT

Both environmental and economic concerns have resulted in renewed interest in the potential for nitrogen loss under various climatic conditions. Experiments were conducted at three locations in Illinois to evaluate the effect of soil type, nitrogen rate, and excessive soil moisture levels on the potential for nitrogen loss. Addition of 10 cm of excessive water during the early part of the growing season resulted in N loss estimates of about 20 kg/ha on a silty clay loam at DeKalb and a sand at Havana. Increasing the excess water levels to 15 cm increased the N loss to 50 to 70 kg/ha at the same two locations, respectively. Since excessive rains in the fall prevented the collection of soil samples to use in monitoring nitrogen movement, conclusive results are not available to indicate the relative magnitude of loss from leaching and denitrification at these two locations. However, it is likely that a majority of the loss at the Havana site would have been through leaching, whereas at the DeKalb site most of the loss was probably due to denitrification.

INTRODUCTION

During the 1960's, considerable amounts of research were conducted to evaluate the effect of nitrogen fertilization practices on water quality (Welch, 1979). The consensus of opinion based on that work was that practices in use at that time would not adversely affect water quality. Since that time, nitrogen fertilizer rates have increased over 32% in Illinois and nitrate levels in selected water supplies have exceeded the accepted standard of 10 ppm NO_3-N with increasing frequency. In addition, preliminary results from surrounding states indicate that the potential for nitrate leaching into water supplies is greater than had been previously thought.

The objectives of the project were: (1) to elucidate the fate of soil applied fertilizer nitrogen under Illinois soil and climatic conditions and (2) to utilize the data collected to develop a computer based expert system on nitrogen fertilizer management strategies. These objectives are attainable now, but were not in the past due to new developments in research and computer modeling techniques.

Since this was the initial year of the project, the data base collected was not adequate to develop a final computer model. Additionally, owing to the lateness with which the project was "approved relative to the growing season, delays in equipment purchases resulted in some operations not being done in as timely a fashion as desired and thus the full magnitude of some of the treatment effects were not expressed in the data.

MATERIALS AND METHODS

Field experiments were established at three locations in Illinois. Each location represented a distinct major soil region for which nitrogen loss problems have been identified. The soils selected for the study were a Cisne silt loam at Brownstown, a Drummer silty clay loam at DeKalb, and a Plainfield sand at Havana.

At each location, a factorial arrangement of four nitrogen rates and three soil moisture levels was established. The nitrogen rates used were 0, 112, 168, and 224 kg N/ha and the moisture levels were ambient rainfall, ambient plus 10 cm of supplemental water over a 3 day period, and ambient plus 15 cm of supplemental water over an 8 day period. Prior to establishment of the water regimes, the soil moisture level on all plots was brought to field capacity. After the moisture treatments were imposed and the soil moisture levels were no longer at saturation, the plots were subdivided with one half of the plots receiving no supplemental nitrogen and the other half receiving an additional 56 kg N/ha.

Corn was grown at all locations. Ear leaf samples were collected at silking and analyzed for nitrogen concentration. Data for both grain yield and total nitrogen uptake in the above ground portion of the plant were collected at maturity as a measure of the influence of treatment on nitrogen loss. Grain yield was collected from a 3 x 15 m area in the center of the plots at DeKalb and Brownstown, and from a 1.5 x 4.6 m area at Havana. Samples of the above ground portion of the plant were collected from a 1.5 x 1.5 m area at all locations at plant maturity. Date of nitrogen and water applications, planting, plant sampling, and harvesting are shown in Table 1.

Table 1. Cultural practices, sampling and application dates for the three study sites. 1985.

	Brownstown	DeKalb	Sand Farm
Planting Date	May 21	May 10	May 17
Variety	P. 3297	P. hybrid brand 3540	P. 3377
Population	26100	28000	26000
Nitrogen Application:			
Initial	June 10	June 30	June 5
Supplemental	July 9	July 25	July 5
Water Application	June 25	July 2	June 16
Plant Samples:			
Ear leaf	July 24	July 25	July 26
Yield	October 3	November 11	September 19
Preplant Pesticide	Atrazine Lasso Lorsban	AAtrex 90 Lasso	Atrazine Sutan+ Lorsban

RESULTS AND DISCUSSION

Brownstown: When averaged across moisture levels, both N concentration and total N uptake were increased with increasing N rates (Tables 2 and 3). Addition of supplemental N after the water treatments had been applied increased N concentration, N uptake, and yield. Grain yield was increased with increasing N rates up to 168 kg/ha (Table 4). The addition of excessive amounts of water did not have an adverse effect on crop growth and development.

Table 2. Effect of rate of N application and soil moisture level on total N uptake (kg/ha). Brownstown, 1985.

N (kg/ha)	Soil Moisture Level: Ambient	Ambient + 10 cm	Ambient + 15 cm	Mean	Suppl. N Mean
	N Uptake (kg/ha)				
0	109.3	139.0	114.6	121.0 a	
112	175.8	183.6	190.7	183.4 a	
168	195.1	226.0	218.7	213.3 b	188.6 a
224	233.8	250.3	226.4	236.8 c	
0	188.6	144.6	150.8	161.3 a	
112 + 56 suppl.	229.1	199.0	226.3	218.1 a	
168 + 56 suppl.	230.0	254.5	226.9	237.1 b	213.2 b
224 + 56 suppl.	249.0	246.1	213.2	236.1 c	
Mean	205.4 a	205.4 a	196.0 a		

Table 3. Effect of rate of N application and soil moisture level on N concentration in ear leaf samples. Brownstown, 1985.

N (kg/ha)	Soil Moisture Level: Ambient	Ambient + 10 cm	Amibent + 15 cm	Mean	Suppl. N Mean
	% N				
0	1.54	1.78	1.89	1.74 a	
112	2.72	2.60	2.59	2.64 b	
168	2.82	2.81	2.38	2.67 b	2.50 a
224	3.03	2.98	2.90	2.97 c	
0 + 56 suppl.	2.63	2.59	2.56	2.59 a	
112 + 56 suppl.	2.98	2.81	2.96	2.92 b	
168 + 56 suppl.	3.01	2.92	2.86	2.93 b	2.87 b
224 + 56 suppl.	3.08	3.08	2.92	3.03 c	
Mean	2.73 a	2.70 a	2.63 a		

Table 4. Effect of rate of N application and soiL moisture level on corn yield. Brownstown, 1985.

N (kg/ha)	Soil Moisture Level: Ambient	Ambient + 10 cm	Amibent + 15 cm	Mean	Suppl. N Mean
	Yield (kg/ha)				
0	4856	6669	5617	5714 a	
112	7950	7705	7821	7825 b	
168	9058	9114	9399	9190 c	8116 a
224	9792	9914	9498	9792 c	
0 + 56 suppl.	8826	. 8234	7314	8125 a	
112 + 56 suppl.	9339	8279	9487	9035 b	
168 + 56 suppl.	9639	9748	8534	9307 c	9698 b
224 + 56 suppl.	9584	9958	9678	9740 c	
Mean	8630 a	8703 a	8418 a		

DeKalb: Nitrogen concentration in the ear leaf samples was increased with increasing N rates up to 168 kg N/ha, but neither supplemental N nor soil moisture level had an influence on N concentration in the leaves (Table 5). Rate of N application, supplemental N additions, and soil moisture levels all had a significant influence on both grain yield and total N uptake (Tables 6 and 7). When averaged over, soil moisture levels, both yield and total N uptake were increased with increasing N rates up to 168 kg/ha. At the ambient moisture level, addition of supplemental N had little if any influence on yield or total N uptake. However, at the two higher moisture levels, supplemental N applied after flooding resulted in a significant increase in both yield and total N uptake. Using yield as an estimate of the amount of N lost would indicate a loss of approximately 20 and 50 kg N/ha for the 10 and 15 cm excess water treatments (Figure 1). The method used to estimate N loss using yields is illustrated by the dotted line. For the 10 cm water application, yields were reduced to an equivalent of about 148 kg of N for the ambient treatment, or a 20 kg loss. The same approach was used for the 15 cm treatment and for the other locations. The losses observed for both water treatments were higher than would have been expected due to the lateness in the season at which the water treatments were applied.

Table 5. Effect of rate of N application and soil moisture level on N concentration in ear leaf samples. DeKalb, 1985.

N (kg/ha)	Soil Moisture Level Ambient	 Ambient + 10 cm	 Amibent + 15 cm	Mean	Suppl. N Mean
		% N			
0	1.78	2.05	2.34	2.06 a	
112	2.93	2.94	3.05	2.97 b	
168	3.06	3.04	2.99	3.03 c	2.79 a
224	3.13	3.14	3.00	3.09 c	
0 + 56 suppl.	1.85	2.12	2.04	2.00 a	
112 + 56 suppl.	2.78	2.91	2.59	2.76 b	
168 + 56 suppl.	3.07	3.05	3.12	3.08 c	2.75 a
224 + 56 suppl.	3.18	3.08	3.17	3.14 c	
Mean	2.72 a	2.79 a	2.79 a		

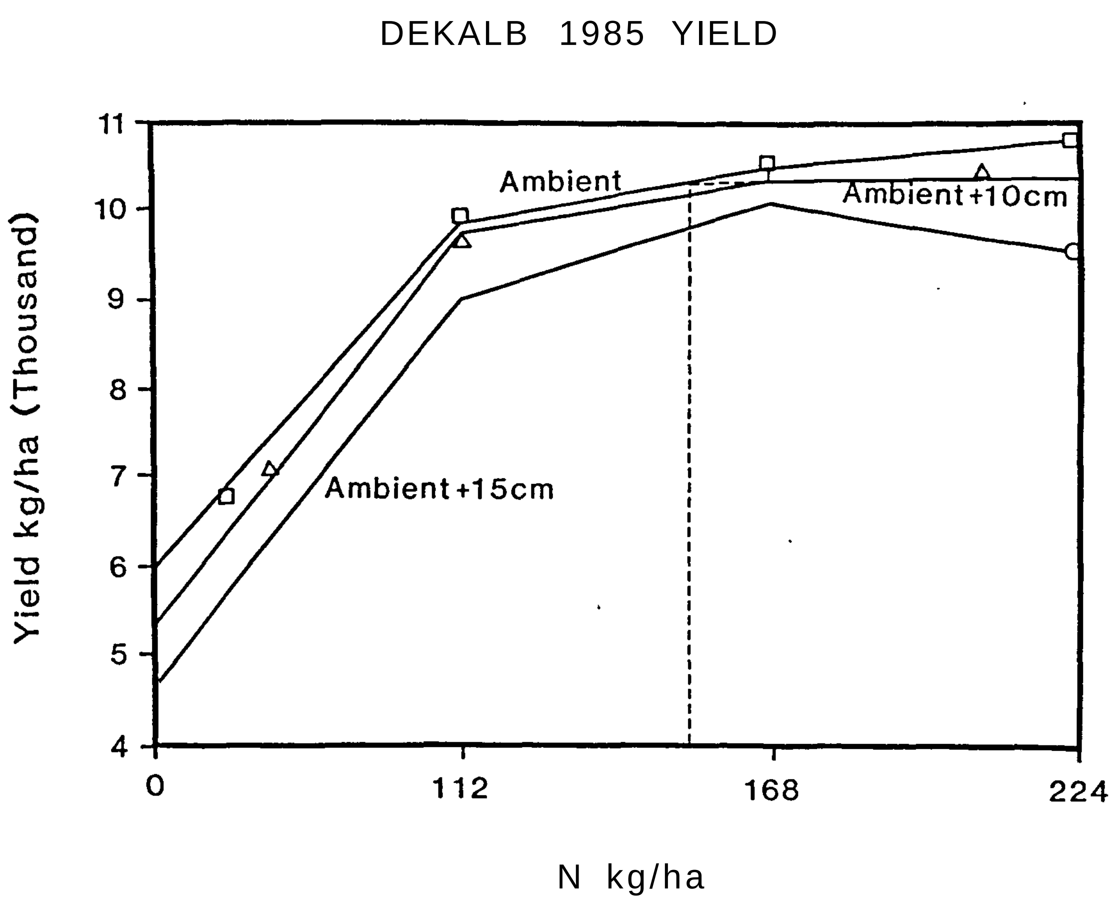
Table 6. Effect of rate of N application and soil moisture level on total N uptake (kg/ha). DeKalb, 1985.

N (kg/ha)	Soil Moisture Level Ambient	 Ambient + 10 cm	 Amibent + 15 cm	Mean	Suppl. N Mean
		N Uptake (kg/ha)			
0	96.2	76.0	62.5	78.2 a	
112	148.3	148.8	133.2	143.4 b	
168	179.1	179.1	171.5	176.6 c	145.28 a
224	193.5	179.3	176.8	183.2 c	
0 + 56 suppl.	105.1	107.6	100.0	104.2 a	
112 + 56 suppl.	157.7	173.0	168.7	166.5 b	
168 + 56 suppl.	198.2	182.8	172.1	184.4 c	162.78 b
224 + 56 suppl.	200.7	198.2	189.5	196.1 c	
Mean	159.9 a	155.6 ab	146.8 b		

Table 7. Effect of rate of N application and soil moisture level on corn yield (kg/ha). DeKalb, 1985.

N (kg/ha)	Soil Moisture Le el Ambient	 Ambient + 10 cm	 Amibent + 15 cm	Mean	Suppl. N Mean
	Yield (kg/ha)				
0	5917	5337	4677	53310 a	
112	9857	9778	9002	9546 b	
168	10492	10312	10052	10285 c	8846 a
224	10791	10403	9534	10243 c	
0 + 56 suppl.	6927	7552	7029	7170 a	
112 + 56 suppl.	9624	10501	9448	9858 b	
168 + 56 suppl.	9747	9752	10507	9960 c	9305 b
224 + 56 suppl.	10551	10611	9542	10234 c	
Mean	9238 a	9281 a	8708 b		

Figure 1. Corn yield response to rate of N application and soil moisture level. DeKalb, 1985.



Havana: When averaged across all soil moisture levels, increasing N levels resulted in an increase in N concentration in the ear leaf samples. Similarly, the addition of supplemental N after flooding resulted in a significant increase in N concentration (Table 8). In contrast to the DeKalb data, the presence of excessive water resulted in a decrease in N concentration. This difference between locations was likely due to the fact that the excess water levels were applied earlier in the growing season at Havana than at DeKalb. At DeKalb, the water treatments were not applied until shortly before the plant samples were collected, whereas at Havana the water had been applied 5 weeks before the plant samples were collected.

Both total N uptake and yield were increased with increasing N rates and supplemental N and decreased with increasing levels of excessive moisture (Table 9 and 10). Using yield as a measure of the magnitude of N loss at Havana indicated a loss of' 20 and 70 kg N/ha for the 10 and 15 cm levels of excessive moisture, respectively (Figure 2). On the sandy soil at this location, the majority of the loss would have been due to leaching. Therefore, the potential for ground water contamination would have been significant.

Table 8. Effect of rate of N application and soil moisture level on N concentration in ear leaf samples. Havana, 1985.

	Soi1 Moisture Level				
N (kg/ha)	Ambient	Ambient + 10 cm	Amibent + 15 cm	Mean	Suppl. N Mean
		% N			
0	1.07	0.96	1.11	1.05 a	
112	2.50	1.68	1.38	1.85 b	
168	2.78	2.24	1.81	2.78 c	1.95 a
224	3.19	2.66	1.98	2.61 d	
0 + 56 suppl.	2.51	2.44	2.37	2.44 a	
112 + 56 suppl.	2.96	2.42	2.30	2.56 b	
168 + 56 suppl.	3.23	3.09	2.73	3.02 c	2.78 b
224 + 56 suppl.	3.30	3.16	2.88	3.11 d	
Mean	2.69 a	2.33 b	2.07 c		

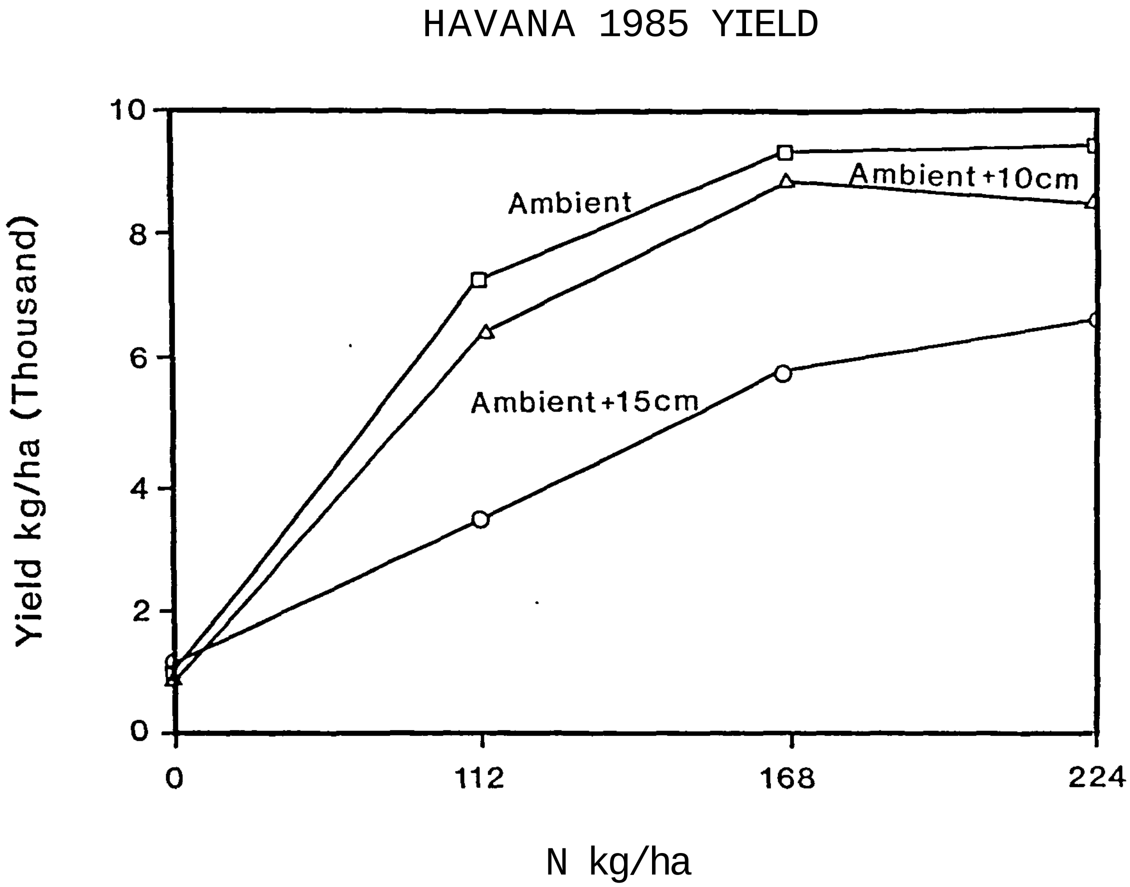
Table 9. Effect of rate of N application and soil moisture level on total N uptake. Havana, 1985.

N (kg/ha)	Soill Moisture Level Ambient	 Ambient + 10 cm	 Amibent + 15 cm	Mean	Suppl. N Mean
		N Uptake (kg/ha)			
0	18.5	12.6	17.0	16.0 a	
112	81.8	68.6	39.8	63.4 a	
168	114.2	97.6	56.4	89.4 b	68.06 a
224	142.2	101.8	66.2	103.4 c	
0 + 56 suppl.	67.7	51.5	43.5	54.2 a	
112 + 56 suppl.	108.5	81.4	74.7	88.2 a	
168 + 56 suppl.	141.6	120.7	86.0	116.1 b	95.40 b
224 + 56 suppl.	158.2	110.3	100.6	123.0 c	
Mean	65.5 a	53.4 b	36.3 c		

Table 10. Effect of rate of N application and soil moisture Level on corn yield (kg/ha). Havana, 1985.

N (kg/ha)	Soil Moisture Level Ambient	 Ambient + 10 cm	 Amibent + 15 cm	Mean	Suppl. N Mean
		Yield (kg/ha)			
0	974	793	1131	966 a	
112	7294	6367	3446	5703 b	
168	9312	8863	5895	8023 c	5729 a
224	9485	8516	6668	8223 c	
0 + 56 suppl.	6020	4937	2924	4627 a	
112 + 56 suppl.	8556	7278	5499	7111 b	
168 + 56 suppl.	8675	9287	7467	8457 c	7236 b
224 + 56 suppl.	10214	8394	7641	8750 c	
Mean	7584 a	6797 b	5084 b		

Figure 2. Corn yield response to rate of N application and soil moisture level. Havana, 1985.



CONCLUSIONS

Results collected at the DeKalb and Havana locations clearly show that significant nitrogen loss occurred under conditions of excessive soil moisture levels. The soil moisture levels used in the study are typical of those which occur during the growing season at these locations. These results imply that there is a potential for water contamination from fertilizer under some situations. Since excessive rains in the fall prevented the collection of soil samples to use in monitoring nitrogen movement, conclusive results are not available to indicate the relative magnitude of loss from denitrification and leaching under the different experimental conditions.

The differential response to water treatments at the Brownstown location may have been due to the lateness with which the water applications were made and/or to the extremely dry July which limited yield potential (Table 11). The excess water applied in June may have been more beneficial under the dry July conditions for the development of the plants than was the nitrogen which may have been lost during the water treatment period.

Table 11. Monthly total rainfall at three study sites during growing season. 1985.

	Location		
	Brownstown	Havana	DeKalb
April			1.05
May	3.61	1.85	2.77
June	6.17	2.40	5.92
July	2.05	5.21	4.29
August	5.26	3.49	2.86
September	0.03	2.11	1.36
October	0.21		5.23
November			5.87

These results, when combined with those to be obtained in future years, will result in the development of a predictive model which farmers and their advisers can utilize to predict the magnitude of loss which has occurred under various climatic conditions. Consequently, farmers will not need to apply excessive amounts of nitrogen in the early part of the growing season to offset the potential loss which may occur.

REFERENCES

Welch, L. F. 1979. Nitrogen use and behavior in crop production. Illinois Agric. Exp. Stn. Bull. 761.