N LOSS UNDER EXCESSIVE WATER CONDITIONS

R.G. Hoeft and W. Bart Stevens[1]

The impact of excessive soil moisture on N availability was reasonably well understood at the end of the 19th century when Wiley (1896) commented " Even in the case of rainfall. which may carry the soluble plant food below the arable soil, there may not be any notable loss. especially if such a downpour be followed by dry weather. But in case of heavy rains, producing a thorough saturation and leaching of the soil. the losses in a field lying fallow during the summer will be very great and it is not well at any time to take the risk". After ninety years of additional research, more is known about the details of N loss under excessive moisture conditions, but confidence in predicting the amount of that loss is still at a relatively low level.

When one looks at the number of N transformations and the number of factors, many of which are not manageable. affecting each transformation. it is easy to understand why the confidence level in predicting N loss is not high. In order to assess the impact of excess water on N availability for that crop year, one must be able to predict a) what potential exists for the soil to release N to compensate in part or total for that lost (mineralization), b) the amount of applied N that was present in the NO_3 form at the time of saturation (nitrification), c) what portion of the NO_3 was lost during the period of saturation (denitrification or leaching), and d) what crop demands will be following the excess water. In other words, one needs to be able to accurately predict the magnitude of many of the reactions in the N cycle (Fig. 1).

Mineralization

Wiley (1896) alluded to the fact that in some years of excessive rainfall, N loss may not be of significant consequence. While there is little research data to support or refute that comment. many of us have observed years in which even though soils were saturated early in the season, crop yields were very good. Those years are usually characterized by a warm, but not excessively hot summer with adequate moisture to maintain good microbial activity in the surface soil. Based on those observations, one could conclude that mineralization rates were adequate to overcome N loss that had occurred. However. in years when soils were saturated for longer time periods and/or when conditions conducive to mineralization were less favorable. yields have been adversely affected by excess soil moisture. These contrasting situations point out the difficulty in projecting the rate of mineralization in advance because one cannot predict the two most important factors affecting it. namely temperature and moisture.

There is little if any information in the literature on the impact of flooding on mineralization in a subsequent year. During the flooding period. mineralization of organic N has been shown to be increased as compared to non-flooded soils (Waring and Bremner 1964, Ono 1988). Patrick and Wyatt (1964) have attributed this increase in mineralization to an

[1] Professor of Soil Fertility Extension and Jonathan Baldwin Turner Fellow, Department of Agronomy, University of Illinois, Urbana, IL 61801. Presented at the North Central Extension-Industry Soil Fertility Workshop, Oct. 27, 1994.

increase in soil pH under flooding conditions. Others have felt that the difference was due to a change in microbial population (Furasaka et al 1969).

A 1994 Illinois experiment showed no significant increase in small plant growth due to the inclusion of N in starter fertilizer at two locations which had been flooded for several weeks in 1993 (Table 1). Since the primary N source for these fields was late spring or sidedress anhydrous ammonia, this data would indicate that mineralization was adequate to sustain early season growth following the flood.

Nitrification

Most of the N used for corn production is applied as ammonium or a form which quickly converts to ammonium. This would include anhydrous ammonia, urea, and UAN solutions. The first 2 materials convert to all ammonium shortly after application. Solution nitrogen contains 75 percent of its N as ammonium plus urea, with the other 25% present as nitrate.

In the ammonium form, N will not be lost even under excessive moisture conditions. However, even though most fertilizers supply N as ammonium, microorganisms rapidly convert it to nitrate, the form susceptible to loss under excessive moisture conditions. The rate of this conversion is dependent on several factors, primary of which are temperature and soil type.

Several experiments have been conducted in Illinois that have measured the conversion rate of anhydrous ammonia to nitrate under field conditions. Results of those studies show that both time of application and inclusion of nitrapyrin (N-Serve) are strongly correlated with rate of nitrification (retention of ammonium). Nearly all of the ammonia that was applied in mid-October was converted to nitrate by late April (Table 2). By delaying application until spring substantially more N was present as ammonium in mid-May. Inclusion of a nitrification inhibitor with the applied ammonia extended the time period for nitrification by 30 to 45 days for the spring applied N and for several weeks for fall applied N.

Grain yield results obtained over the last four years at Minnesota show the importance of being able to predict nitrification rates (Table 3) (Randall, 1994). In 1991, the wettest year on record, addition of nitrapyrin to fall applied ammonia increased yields by 21 bushel. Delaying application until spring or splitting the application between spring and sidedress increased yield another 8 to 10 bushel. In 1993, the second wettest year on record, use of treatments that would delay nitrification increased yield by 9 to 13 bushel.

Nitrogen movement from tile lines on these Minnesota plots showed a similar pattern to the yield results (Table 4). Among the N treatments, fall applied N resulted in the greatest loss, with spring and split applied N having the least. Interestingly, losses from the treatment which had received no fertilizer N and was kept fallow were 90 lb N/acre greater than the highest losses from any of the other treatments. Obviously, substantial amounts of N are mineralized from these high organic matter soils each year.

Based on the results of the Illinois studies, equations have been developed relating soil temperature to the rate of nitrification. A concept similar to growing degree days, referred to as nitrification degree days, has been used to relate soil temperature to nitrification rate (Table 5). Nitrification degree days are calculated by summing the average daily soil temperature from date of application until date in question. If soil temperature reaches 0 C, then no degree days are credited. While these equations may be used as a guide to predict nitrification rate, further work needs to be done with the data to fine tune the equations to account for differences in nitrification rate from fall versus spring applied N. A computer program has recently been developed at Iowa State University by Dr.s' Killorn and Taylor that will provide an estimate of the rate of nitrification by soil type based on long term climatic conditions. Further refinement of the Illinois and Iowa data bases will provide a reasonable estimate for persons wishing to determine the amount of N present as nitrate at the time soils become excessively wet in the spring.

Denitrification or Leaching Losses

Denitrification is the primary N loss mechanism for much of the humid region of the cornbelt. In Illinois, it is estimated that denitrification accounts for 2/3 of the N that is lost. In an attempt to quantify denitrification losses, experiments were carried out at four locations in Illinois during the mid 1980's. The objective of those experiments was to use relative grain yield obtained across a range of N rates applied in factorial combination with 3 moisture regimes ranging from inherent (no saturation during growing season) to soils being saturated for several days. The moisture regimes were imposed in late May to early June, the time period when denitrification usually occurs. Since denitrification is temperature and moisture dependent, it usually is not a problem during the winter or early spring. Late May to early June is frequently the time period when intensive rain storms occur. Combining that with soil temperatures that are ideal for denitrification and the relatively small plants that have low rates of evaporation creates a condition conducive to saturated soils and consequently denitrification.

Leaching is the primary N loss mechanism on sandy soils. It occurs whenever N is present as nitrate and the rate of water infiltration exceeds the rate of evaporation plus transpiration. In sandy soils, one inch of rainfall moves nitrates down about one foot. If the total rainfall at one time is more than 6 inches, little nitrate will be left within the rooting depth on sands. In silt loam and clay loams, one inch of rainfall moves down about 5 to 6 inches, though some of the water moves farther in large pores through the profile and carries nitrates with it. Corn roots penetrate up to 6 feet in Illinois soils. Thus, nitrates that leach only to 3 to 4 feet are well within normal rooting depth unless they reach tile lines and are drained from the field.

The experiments for this study were conducted at Brownstown on a Cisne silt loam, at DeKalb and Urbana on a Drummer silty clay loam, and at Havana on a Plainfield sand. At each location, N was applied when corn was in the V-3 to V-6 stage of growth as KNO_3 at rates of 0, 100, 150, and 200 lb N/acre in factorial combination with moisture levels of ambient; ambient plus 4-inches of water evenly distributed over a 3-day period; and ambient plus 6-inches of water evenly distributed over an 8 day period. While these moisture levels were rather minimal compared to what many areas received in 1993, they do simulate conditions typical of many years in the region. Following application of N, sufficient water was applied to the entire plot area to bring soil moisture to field capacity (0.33 bar) at a depth of 6 inches. Once that moisture level had been attained, the excess moisture treatments were applied. Tensiometers were installed to monitor soil moisture conditions at the DeKalb and Brownstown locations. After water treatments were imposed and soil moisture content was no longer at saturation, supplemental N was applied to one-half of each plot at a rate of 50 lb N/acre. ^{15}N labeled fertilizer was used for the 150 lb N/acre rate to facilitate monitoring of the fate of the applied N. At maturity, grain yield and whole plant samples were collected. The whole plant samples were used to determine total N uptake.

These experiments were conducted from 1983 through 1988, a period characterized by rather wide swings in climatic conditions, including two major drought periods. Since we did not have adequate irrigation facilities to overcome periods of moisture deficiency, significant differences in the impact of treatments across locations and years were observed. For purposes of this paper, I have selected those years and locations where the effect of excess soil water on yield was not confounded by other climatic conditions (Table 6). In those years when moisture for the growing season was limiting, excess water treatments on occasion increased yields even though they had caused some N loss.

Addition of 4 inches of excess water would result in saturated soils for about 3 to 4 days on the Cisne silt loam. Under those conditions, little if any yield reduction resulted. However, when 6 inches of water was added, causing saturation for 5-6 days, significant yield reductions were observed. In contrast, on the Drummer silty clay loam, the majority of the yield loss was associated with the 4 inch water application. Increasing the number of days of saturation resulted in small additional decreases in yield. The Cisne contains approximately 2 percent organic matter compared to about 4 percent for the Drummer. Other research has shown less microbial activity in the Cisne than the Drummer. Based on those facts, it is theorized that the initial rate of denitrification is slower on the Cisne, but that over a period of several days, it would approach the rate observed with the Drummer. When we related relative yield to the number of days the soils were saturated, we observed a relatively stable rate of decline in yield on the Drummer soil, whereas with the Cisne the rate of decline was slow for the first 3-4 days and then proceeded at a much faster rate (Fig. 2).

On the medium to heavy textured soils, the number of days at which soils were saturated provided a good estimate of the amount of yield and N loss. On the Drummer soil, yields were decreased about 1 percent for each day the soils were saturated. This 1 percent decrease in yield per day the soils were saturated was associated with a 4 percent decrease in recovery of applied N per day of saturation. On the Cisne soil, 5 days of saturated soils would have resulted in a nitrogen loss of about 2 percent per day of saturation.

Recovery of applied N was markedly reduced with the addition of excess water on both the Cisne and Drummer soils. In contrast to the yield data, the greatest reduction occurred with the first increment of water addition on the Cisne and with the second increment on the Drummer (Table 7).

On the Plainfield sand, yield losses were observed with both water treatments, but the greatest loss occurred with the highest rate of water application as would be expected when leaching is the primary loss mechanism. On the sandy soil, the total amount of precipitation plus irrigation provided the best estimate of N loss. Yield loss as high as 20 percent was recorded when 8 inches of precipitation plus irrigation was received in May and June.

The amount of N lost under the different moisture regimes was estimated using ^{15}N techniques, yield difference, and at the Urbana location only, we also used direct measurement of N evolution (Table 8). At Urbana, ^{15}N balance and yield difference indicated a loss of about 65 to 70 lbs N/acre with 4 inches of excess water. This was in close agreement with the values found at DeKalb on the same soil type. The fact that the values found at DeKalb were slightly higher than at Urbana would be expected as the DeKalb location is more poorly drained. On the Cisne soil, losses were slightly less than observed on the Drummer. The Plainfield sand had losses of over 125 lb N/acre with 6 inches of excess water.

On the Cisne and Drummer soils, there was little movement of fertilizer N below the first 12 inches of soil, indicating that the primary loss mechanism was denitrification (Table 9). This was true even with the highest rate of water application. On the Plainfield sand, the loss mechanism was leaching as considerable amounts of fertilizer N were found at depths of 3 to 4 feet as early as silking. By harvest time, there was essentially no fertilizer N left in the profile (Table 10). On all soil types, a significant portion of the fertilizer N that remained in the upper portion of the profile had been incorporated into organic forms by harvest.

Yield Response to Late Application of N

Once an estimate of the amount of N loss has been made, the question becomes one of whether or not the application of supplemental N will be profitable. Along with the few studies that have been conducted with that specific objective, there are several date of application studies that can be used to provide some indication of likely results.

In the work discussed above, application of 50 lb N/acre following the application of excess water resulted in yields equivalent to those obtained from the ambient water treatment on the Drummer silty clay loam (Fig 3). However, on the Plainfield sand, 50 lb N/acre as supplemental treatment was not adequate to bring yields back to the level attained with ambient moisture (Fig. 4). These data are in agreement with the N loss measurements made using ^{15}N.

Dr. Ed Varsa of Southern Illinois University evaluated the impact of supplemental N on fields which had received preplant N followed by excessive rains in May and early June. In mid-June, he applied N at rates of 0, 60, and 120 lbs/acre at 2 locations. At both sites, he selected areas in the field where the corn showed severe chlorotic symptoms characteristic of N deficiency (Table 11). At the Williams location, the field had received 160 lb N/acre preplant and at the Anderson farm it had received 60 lb N/acre preplant. Following application of his treatments, the Williams location received an additional aerial application of 50 lb N/acre. Application of the supplemental 60 lb N/acre treatment in mid-June resulted in yield increases of 20 bushel per acre at both locations. At the Anderson farm, increasing the rate to 120 lb N/acre provided an additional 20 bushel of corn. Increasing the N rate beyond 60 lb/acre did not increase yield at the Williams farm. This was not surprising considering the amount of N that the farmer had applied.

Both Illinois and Iowa have evaluated the impact of late N application on fields which had no preplant N (Table 12). Assuming that one can accurately predict N loss during the season, these data also provide an indication of the relative response that one might expect under severe loss situations. Application of N as late as tasseling resulted in yields within 6-8 percent of those obtained when the N was sidedressed. Delaying application until 10 days after tasseling, resulted in slightly lower yield than from N applied at silking. The results from experiments in Southern Illinois were comparable to the Iowa work. At all three locations, 60 lb N/acre optimized yield when N application was delayed until silking.

Data from the experiments discussed above clearly show that response to supplemental N late in the season is possible when excess moisture has resulted in significant N loss. However, before applying supplemental N be sure to accurately assess the stand remaining to determine if the initial N rate is still required (Table 13). Keep in mind re-planted or late planted corn will have a reduced yield potential (Table 14). Even then, response to supplemental N will require that you receive adequate moisture to move N into the active rooting zone.

In most years, by the time soils dry enough following an N loss event to allow for ground equipment to travel over the field, the corn is too tall for conventional application equipment. In that case, farmers are faced with a decision of using high clearance equipment or aerial application. If high clearance equipment is used, drop nozzles should be employed to keep the N solution off of the foliage. If aerial application is used, be sure to use a dry form of N. When urea was aerially applied in late June at rates up to 600 lb N/acre, there was no significant decrease in total dry matter yield of plants harvested one month after the urea was applied (Table 15). In the first experiment, 0.13 inches of rain was received within a few hours after treatment. In the second experiment, there was no precipitation for 5 days after treatment. There was some tissue damage observed at the point of prolonged contact of the urea with the leaf. The damage was contact rather than systemic. However, when UAN solutions were applied in late June, significant foliar damage and substantial reductions in dry matter yield were observed one month after the UAN was applied (Table 16).

Summary

Prediction of N loss has become more scientific in recent years, but it still remains an art, requiring the judgement of an experienced crop producer to know whether it will pay to apply additional N in fields that have been excessively wet. Those people faced with making a decision on applying additional N to fields that have already been adequately fertilized should follow the steps outlined above. First of all determine what portion of the N was present in the nitrate form at the time soils became excessively wet. Secondly determine the amount of nitrate N that would be lost based on the number of days the soil is saturated. Research has shown N losses of 4-5 percent per day the soils are saturated. And finally evaluate the yield potential for the field to determine whether the initial rate is still required. If the calculated amount lost is from 40 to 80 lbs/acre, apply an additional 60 lb N/acre. If the calculated loss is from 80 to 120 lb N/acre, apply an additional 100 lb N/acre.

Dr. Mike Schmitt of the University of Minnesota has proposed a scorecard to use in deciding whether supplemental N applications are needed following excess water. The factors and their corresponding scores are given below:

Factor 1. When was the fertilizer applied:?

Fall	Early Spring	Late Spring
4	3	2

Factor 2: What has been the predominant soil moisture status?

Saturated	Wet	Normal
4	3	1

Factor 3: What is the crop's current condition?

Chlorotic >16" tall	Chlorotic <16" tall	Green <16" tall	Green >16" tall
5	3	2	1

Sum the scores for each of the factors and use the following guidelines:

Less than 7	-No supplemental N is recommended
8-9	-Re-evaluate in one week
10 or more	-Add an additional 40-70 lb N/acre

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Table 1. Effect of starter fertilizer on early season plant weight.

Starter N lb N/acre	Location Hull	Ursa
0	11.3	0.66
25	11.5	0.70
lsd	0.97	0.07

Table 2. Effect of time and rate of application and nitrification inhibitor on the recovery of ammonium-N in soils over time.

	Date of N application						
	10/15				4/05		
N	Sample date				Sample date		
lb/acre	12/12	4/27	5/18	6/10	4/27	5/18	6/10
	Ammonium N, ppm						
60	12	7	9	5	121	74	18
120	35	11	10	6	229	141	43
240	145	18	9	9	383	328	119
60 +N-Serve	128	156	73	42	214	228	172

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Table 3. Corn grain yield as influenced by N treatment at Waseca, MN. 1990-1993.

	Year				
N Treatment	1990	1991	1992	1993	avg.
	yield (bu/acre)				
Fall	146	122	142	104	128
Fall + Nitrapyrn	146	143	144	114	137
Spring	142	151	142	113	137
Split	151	153	157	117	144

Table 4. Flow-weighted NO_3-N concentration, total NO_3-N lost in the drainage water over the 4-year period (1990-1993), and percent NO_3-N lost during the 7 year period as an equivalent of the amount of N applied.

Treatment	Flow-weighted NO_3-N concentration	Total NO_3-N lost in tile water	Percent of applied N
	mg/L	lb/acre	%
Fall	19.8	236	25
Fall + Nitrapyrin	17.2	186	20
Spring	15.8	158	17
Split	15.8	170	18
Fallow	35.8	326	--

Table 5. Relationship between soil temperature and percent recovery of applied ammonium in soils.

Spring applied ammonia-no inhibitor
% applied ammonium
remaining = $-21.84 - 0.031\ NDD + 0.00001\ (NDD)^2$

Spring applied ammonia-with an inhibitor
% applied ammonium
remaining = $-11.76 - 0.034\ NDD + 0.00001\ (NDD)^2$

Fall applied ammonia-no inhibitor
% applied ammonium
remaining = $-9.95 - 0.051\ NDD + 0.00002\ (NDD)^2$

Fall applied ammonia-with an inhibitor
% applied ammonium
remaining = $-5.24 - 0.042\ NDD + 0.00001\ (NDD)^2$

where NDD is calculated by summing the average soil temperature in C for each day from application until the date in question. If the minimum temperature is 0 or less, no degree days are accumulated for that day.

Table 6. Effect of soil moisture regime on relative yield of corn at 4 locations in Illinois.

N lb/acre	Soil Moisture Regime: Ambient	Ambient[1] + 4 in.	Ambient + 6 in.
	--------------------Relative Yield (%)--------------------		
	--Cisne sil--(Brownstown)		
0	32	32	32
100	93	92	81
150	99	99	93
200	100	107	95
	--Drummer sicl--(DeKalb)		
0	51	55	47
100	91	82	83
150	91	78	83
200	100	87	91
	--Drummer sicl--(Urbana)		
0	47	48	45
100	88	80	76
150	95	84	80
200	100	95	92
	--Plainfield s--(Havana)		
0	10	9	12
100	77	67	36
150	98	93	62
200	100	90	70

1. Soil moisture content was brought to field capacity prior to addition of supplemental water. Relative yield was assumed to be 100% at the 200 lb N/acre rate with ambient moisture.

Table 7. Effect of soil moisture regime on recovery of applied N.

N lb/acre	Soil Moisture Regime: Ambient	Ambient + 4 in.	Ambient + 6 in.
	% N Recovered[1]		
	--Cisne sil--(Brownstown)		
100	100	51	48
150	90	31	37
200	72	38	42
Based on ^{15}N	65	49	49
	--Drummer sicl--(DeKalb)		
100	74	51	20
150	67	51	23
200	62	40	22
Based on ^{15}N	40	36	34

1. N recovered calculated by

$$\frac{\text{N uptake (N treated plot)- N uptake(0 N treated plot)}}{\text{N rate of treatment}} \times 100$$

Table 8. Estimates of N loss by N balance (^{15}N), yield difference, and ^{15}N evolution.

Water Regime	Measurement Technique: Yield Difference	^{15}N Balance	^{15}N Evolution
	-------------N Loss (lb/acre)-------------		
		--Cisne sil--(Brownstown)	
Ambient	--	7	--
Ambient + 4in.	65	42	--
		--Drummer sicl--(DeKalb)	
Ambient	--	29	--
Ambient + 4in.	75	77	--
		--Drummer sicl--(Urbana)	
Ambient	--	27	24
Ambient + 4 in.	69	64	44

Table 9. Effect of excess moisture on fertilizer N (lb/acre) remaining in a Cisne sil and Drummer sicl, at the end of the growing season, calculated from ^{15}N data.

	Moisture Regime		
Depth (in.)	Ambient	Ambient + 4in.	Ambient + 6in.
	----------------Fertilizer N (lb/acre)----------------------		
		--Cisne sil---Brownstown	
0 - 12	29.5(22.5)[1]	25.2(17.8)	20.0(18.8)
12 - 24	13.5	8.3	5.6
24 - 36	1.2	+	+
36 - 48	+	0	0
		--Drummer sicl--DeKalb	
0 - 12	59.1(21.8)	27.4(26.3)	23.1(19.3)
12 - 24	8.5	5.8	2.7
24 - 36	2.9	2.7	1.9
36 - 48	1.1	+	+

1. ( ) Designates fertilizer N in the organic form, calculated as total N- inorganic N.

Table 10. Effect of excess moisture on fertilizer N (lb/acre) remaining in a Plainfield s, calculated from ^{15}N data.

Depth (in.)	Moisture Regime		
	Ambient	Ambient + 4in.	Ambient + 6in.
	----------------Fertilizer N (lb/acre)------------------------		
		--Silking--- Havana	
0 - 12	16.2	2.1	0.9
12 - 24	8.2	+	0
24 - 36	31.8	8.7	4.9
36 - 48	29.1	16.6	5.0
		--Harvest---Havana	
0 - 12	5.8(5.3)[1]	2.3(2.2)	+
12 - 24	1.3	0	0
24 - 36	1.7	+	0
36 - 48	+	0	3.1

1. ( ) Designates fertilizer N in the organic form, calculated as total N ÷ inorganic N.

Table 11. The effect of supplemental N fertilizers on corn grain yield.

N lb/acre	Location	
	Williams Farm	Anderson Farm
	Yield bu/acre	
0[1]	46	99
60	67	121
120	66	141

Data supplied by Dr. E.C. Varsa, SIU. 1981.

1. At the Williams farm, 50 lb N/acre was applied over all plots 2 days following experimental treatment application. Nitrogen was applied (preplant) at the rate of 160 and 60 lb N/acre respectively at the Williams and Anderson farms.

Table 12. Effect of time and rate of N application on yield of corn at three locations.

N lb/acre	Time of application[1] SD	S-10	S	S+10
			Yield bu/acre Kanawa, IA-1977	
0	120		120	120
60	146		143	139
120	153		146	138
180	156		144	141
			Brownstown, IL-1978	
0	85	85	85	85
60	96	93	97	100
120	100	97	97	92
180	107	108	103	97
			Toledo, IL-1978	
0	85	85		85
60	123	128		109
120	135	133		105
180	138	133		104

1. SD= sidedress, S-10 = 10 days prior to silking, S = silking, S+10 = 10 days after silking.

Table 13. Effect of N and plant population on corn yields, DeKalb, IL.

N. lb/acre	Plants per acre 16,000	22,000	28,000
		Yield, bu/acre	
0	77	67	58
80	119	120	116
160	128	135	135
240	132	140	139

Table 14. Effect of date of planting on corn yield potential.

Planting Date	N, lb/acre			
	0	80	160	240
Early May	125	146	161	166
Mid-May	124	147	163	162
Late May	125	145	153	156
Early June	99	120	121	122

Table 15. Dry matter yield as affected by aerial urea application.

Experiment I		Experiment II	
N,lb/acre	Yield, t/acre	N, lb/acre	Yield, t/acre
0	2.91	0	3.55
75	2.96	75	3.27
150	2.91	150	3.57
300	2.82	300	3.33
600	3.02	600	3.45

Dibb, D.W. and L.F. Welch. 1974. IFCA Proceedings

Table 16. Dry matter yield as affected by aerial application of UAN solution.

N, lb/acre	Yield, t/acre
0	3.56
75	2.71
150	2.46
225	2.36
300	2.05
450	1.82
600	1.71

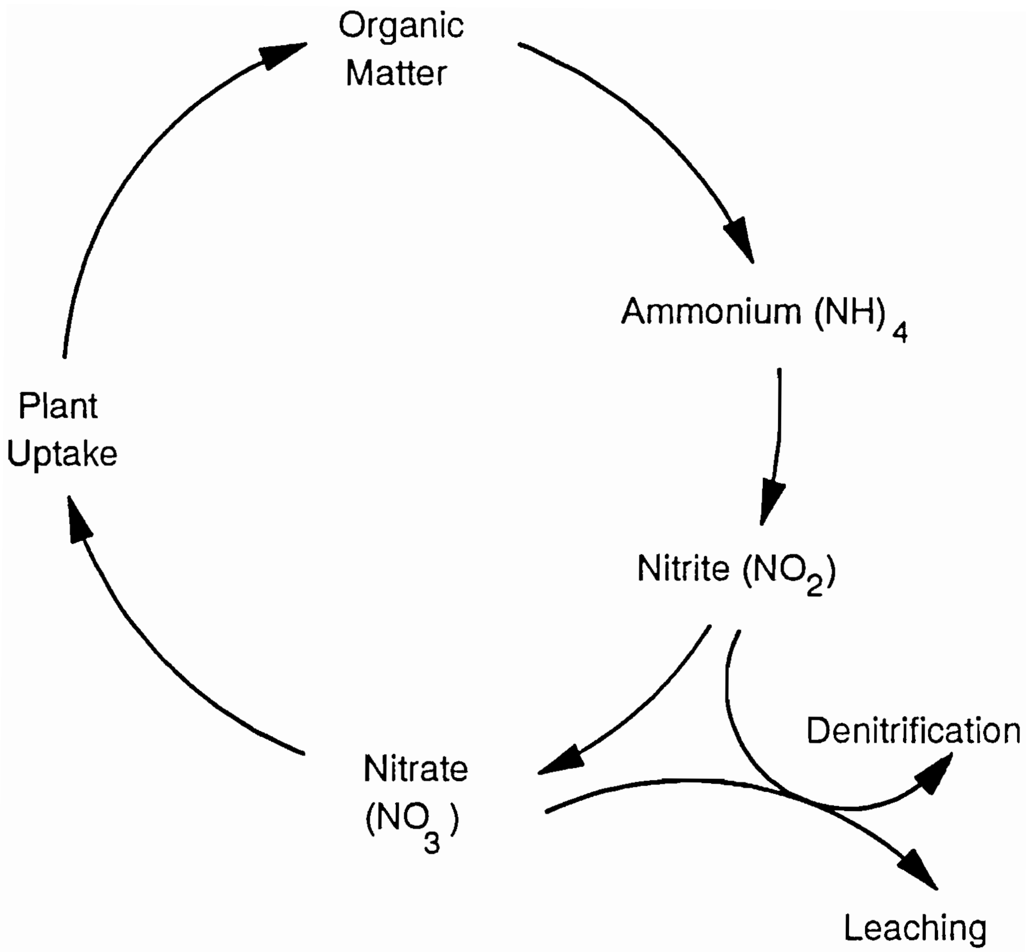

Figure 1. Soil nitrogen reactions

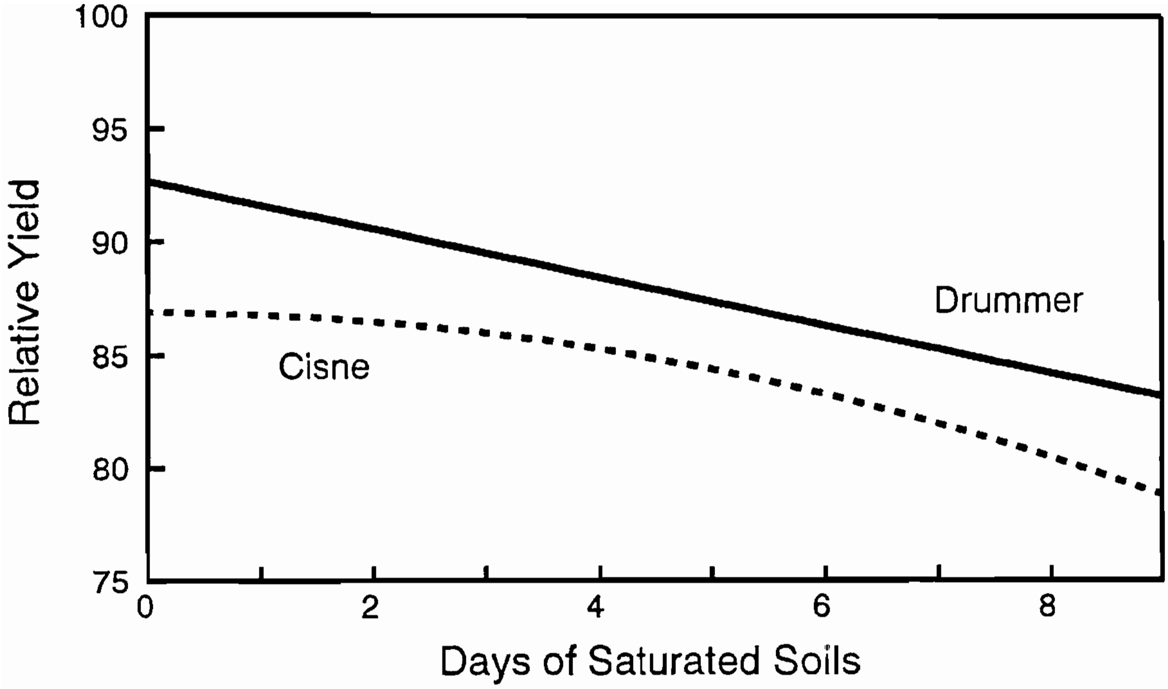

Figure 2. The effect of number of days that soils were saturated on the relative yield of corn grown on Cisne sil and Drummer sicl soils.

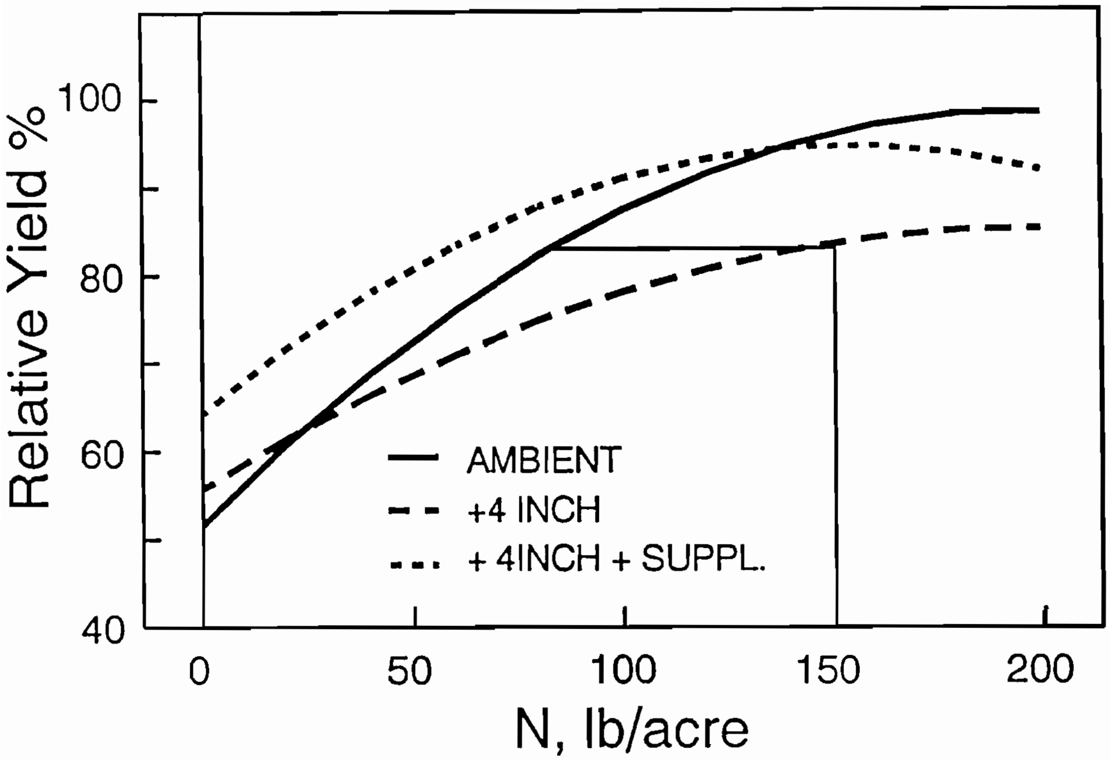

Fig 3. Effect of moisture regime, N rate, and supplemental N on corn grain yield on a Drummer sicl.

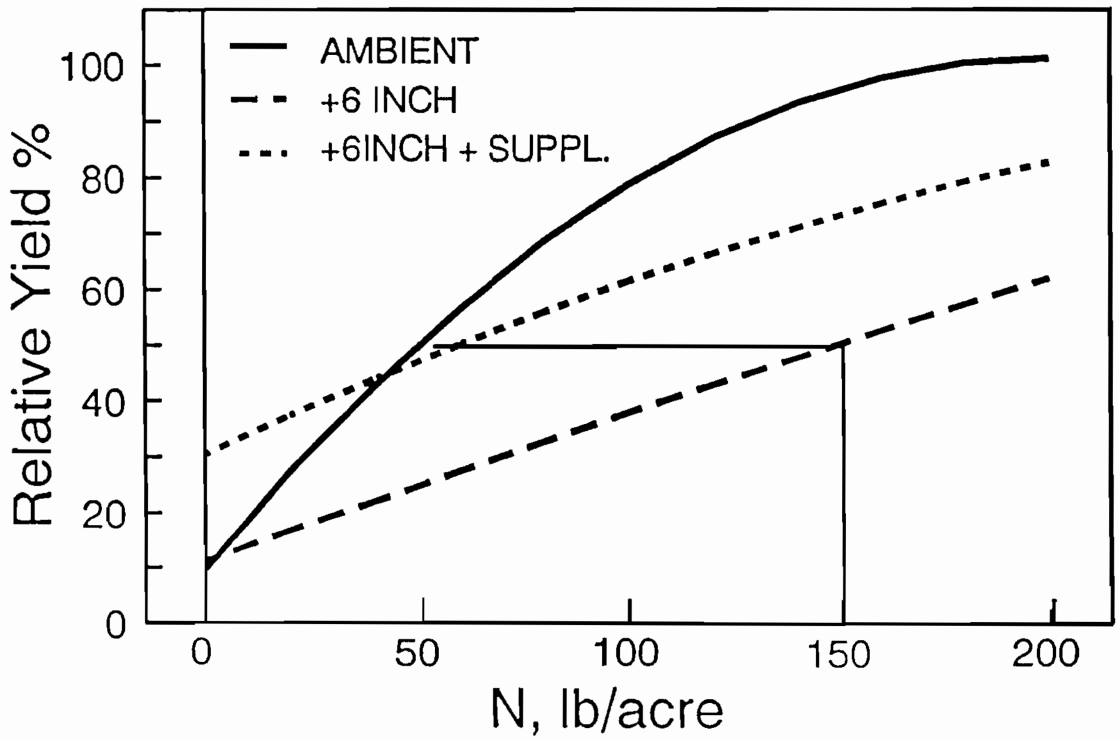

Fig 4. Effect of moisture regime, N rate, and supplemental N on corn grain yield on a Plainfield s.

PROCEEDINGS OF THE TWENTY-FOURTH

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Program Chairman and Editor:

Dr. Maurice Vitosh
Michigan State University
Dept. of Crop and Soil Sciences
Plant and Soil Sciences Building
East Lansing, MI 48824-1325