IMPACT OF EXCESS WATER ON N LOSS

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ABSTRACT

The impact of excess soil water on N use efficiency by corn was evaluated over several years at four locations in Illinois. At each location, 0, 4, or 6 inches of water was applied in late May to soils that were at field capacity. Prior to the addition of the excess water, potassium nitrate was applied at rates ranging from 0 to 200 lb N/acre. On medium to heavy textured soils, the number of days when soil moisture was at saturation provided a good estimate of the magnitude of N loss. Yields were decreased approximately 1 percent for each day that soils were wetter than field capacity on a Drummer sicl. On a Cisne sil, three days of excess water decreased yield by 1 percent, but 7 days of excess moisture decreased yields by 5 percent. On a sandy soil, the amount of precipitation plus irrigation in May and June provided the best estimate of N loss. A 20 percent yield reduction was observed when precipitation plus irrigation in May and June exceeded 8 inches.

INTRODUCTION

Experience has clearly shown that unpredictable, but frequently occurring heavy rains will result in significant N loss through denitrification or leaching. Unfortunately, little work has been done to develop a practical technique that could be used by farmers and their advisers to predict the magnitude of N loss under those conditions. The objectives of this study were to (i) determine the effect of soil moisture regimes on corn yield and N use efficiency and (ii) determine the effect of supplemental N after periods of excessive soil moisture on yield and N uptake.

METHODS

Experiments were conducted at Brownstown, DeKalb, Havana, and Urbana IL on a Cisne sil, Drummer sicl, Plainfield s, and Drummer sicl respectively. 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.

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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.

RESULTS AND DISCUSSION

These experiments were conducted over the time period 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 these 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 1). 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 Cisne sil. 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 sicl, 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 loss. The Cisne sil contains approximately 2 percent organic matter compared to about 4 percent for the Drummer sicl. 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 time 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. 1). On the Plainfield s, 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.

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 2).

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 3). The three systems were close in prediction at most locations. At Urbana, the ^{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 sil, losses were slightly less than observed on the Drummer sicl. The Plainfield s had losses of over 125 lb N/acre with 4 inches of excess water.

Application of 50 lb N/acre following the application of excess water resulted in yields equivalent to those obtained from the ambient water treatment (Fig 2). However, on the Plainfield s, 50 lb N/acre as supplemental treatment was not adequate to bring yields back to the level attained with ambient moisture (Fig. 3). These data further support the N loss measurements discussed above.

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 4). 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 5). 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.

Table 1. 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.

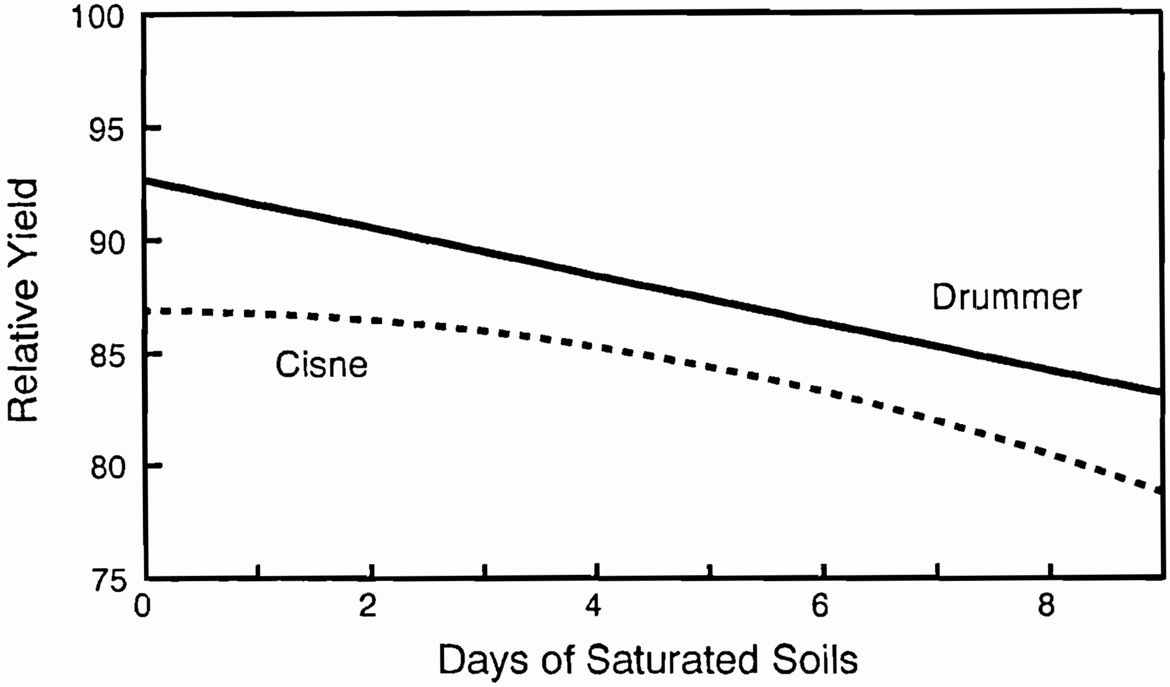

Figure 1. The effect of number of days that soils were saturated on the relative yield of corn grown on Cisne sil and Drummer sicl soils.

Table 2. 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

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

Table 3. 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

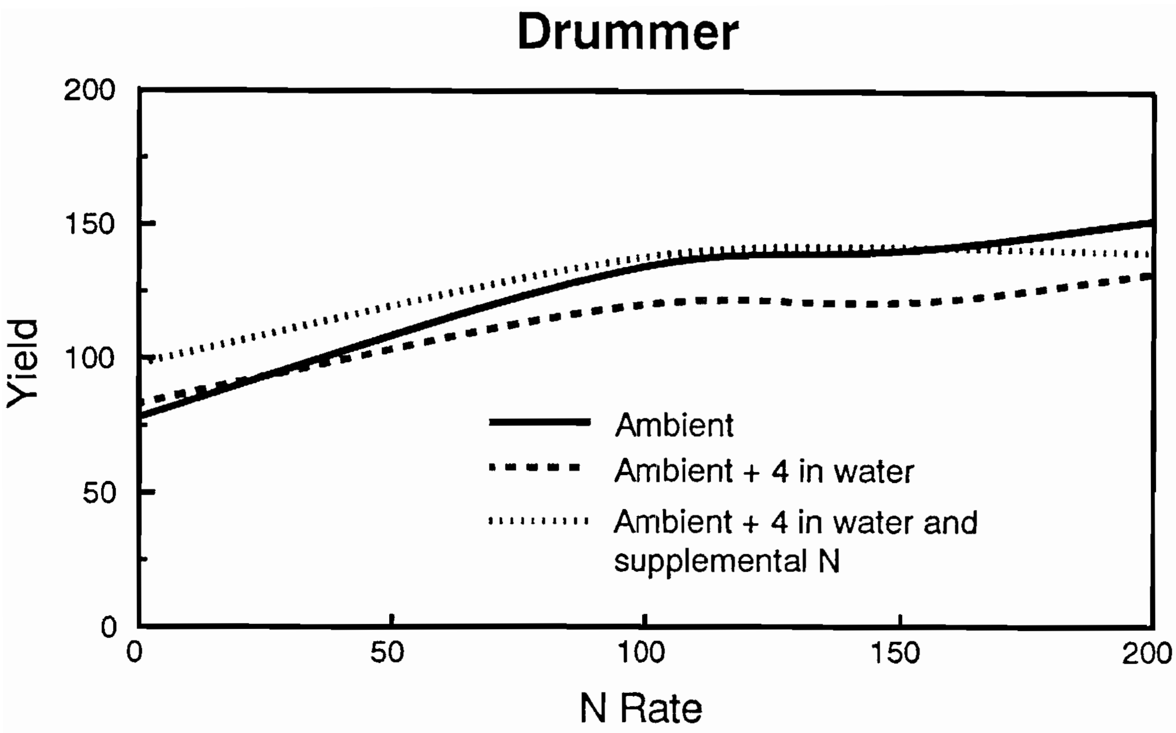

Figure 2. The effect of moisture regime, N ratio, and late season N application on corn yield, on a Drummer sicl.

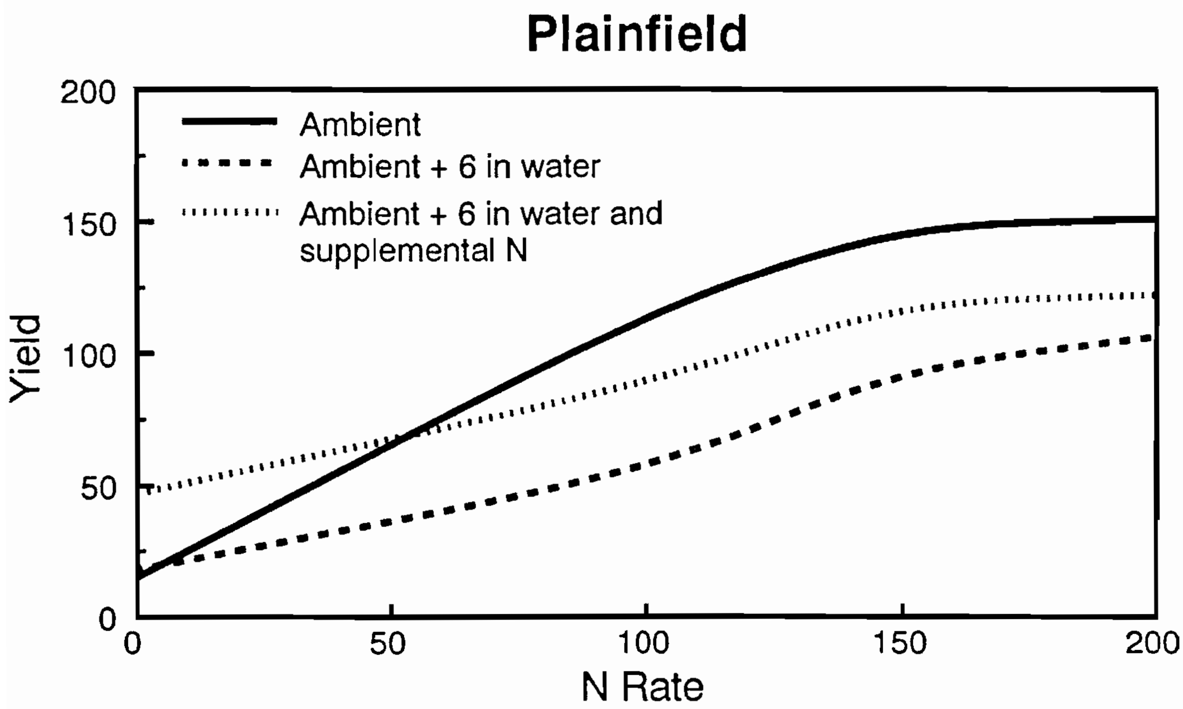

Figure 3. The effect of moisture regime, N ratio, and late season N application on corn yield, on a Plainfield s.

Table 4. 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.

Depth (in.)	Moisture Regime: 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 5. 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.

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