ECONOMIC OPTIMUM RATES OF N FOR CORN PRODUCTION IN IOWA[1]

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Abstract

Proper nitrogen (N) fertilizer is essential if crop producers are to maximize profits and minimize environmental contamination. A study to determine economic optimum N fertilizer rates was conducted in Iowa from 1987 to 1991. The results show that Iowa crop producers over-applied N during those years primarily due to not considering residual N in the soil. This was especially true following the drought year of 1988.

Introduction

Iowa crop producers purchase and apply 7.6% of all the nitrogen (N) fertilizer used in the United States to support production of corn, small grains, and pasture on nearly twenty million acres annually (Hargett and Berry, 1990). The annual cost of the nitrogen fertilizer (1.5 million tons in 1990) exceeds $300 million.

Our ability to manage nitrogen for crop production in Iowa depends to a large extent on local weather conditions that may be entering a period of extreme fluctuations (Carlson, 1990) making it difficult to estimate accurately the amount of soil N that will be available for crop production in any field and year. Available nitrogen concentration in soils is very dynamic due to the rate at which cycling occurs during warm, moist, aerated conditions. Because nitrate (NO_3^-) is not attracted to negatively charged soil and organic matter particles it is free to move in soil by both diffusion and mass flow. Large quantities of NO_3-N can leach below the root zone rapidly in response to rainfall. Thus, the amount of crop available N in soil depends on the rate of cycling, the amount of N fertilizer applied, and rainfall after fertilizer application.

The amount of N fertilizer applied on a per acre basis for corn production is important from both an economic and environmental standpoint. The goal of producers is to apply the amount of N that will maximize the profit for an individual field. If the producer doesn't apply enough N yield and profit are reduced. If more than enough N is applied, profits are reduced and the potential for environmental contamination increases. The problem agriculture faces is predicting the most profitable amount of N fertilizer to apply without knowing what the weather conditions will be. Because fertilizer recommendations are based on "normal" weather, there will be times when yields are reduced by inclement conditions and more N is applied than will be used by the crop.

The objective of the project reported here was to determine optimum N

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fertilizer rates for corn production in Iowa.

Materials and Methods

Sixty-five experiments were conducted between 1987 and 1991. General site information is listed in Table 1. The studies were conducted on farmers' fields and at Iowa State University Outlying Research Farms. At 48 of the sites the previous crop was soybeans. The previous crop at the other seventeen sites was corn. The sites were located statewide to include all major soil series. Other than the N fertilizer, the management at sites was that of the cooperator.

The experiments consisted of a factorial combination of rates of N fertilizer ranging from 0 to 180 lb N/a, and two times of application, preplant and sidedressed. The exact rates used are listed in Table 2 because they were not the same in all years. One treatment at each site was a simulation of the cooperator's N rate. The treatments were arranged in a randomized, complete-block design with four replications at all sites. The size of individual plots varied depending on the distance between corn rows at each site. All plots were 40 ft. long and contained six rows of corn.

Preplant N fertilizer was applied between mid-April and mid-May in all years. Sidedressed N fertilizer was applied when most of the plants at the site had reached the V6 growth stage (six leaf collars visible on the stalk). This usually occurred in early June. The fertilizer material used was liquid urea-ammonium nitrate (28% N) if the application could be incorporated. If incorporation was not possible, dry ammonium nitrate (34-0-0) was hand applied to the plots because it is not a volatile source of N.

Yields were determined by hand-harvesting ears from twenty feet of the center two rows of each plot. Grain was shelled from the ears at the site and the total weight of the harvested material was recorded. All yields are reported at 15.5% moisture content.

The data from each site were analyzed using routines of the Statistical Analysis System (SAS) (SAS Institute, 1985). If the analysis of variance (ANOVA) showed there was a significant response to N fertilizer, two regression models were used to define the relationship between yield and N fertilizer, a linear response plus plateau (LRP) and a quadratic (second order polynomial). The optimum N rate based on the LRP is the N rate required to reach the plateau yield if the slope of the linear portion of the model exceeds the price ratio of N fertilizer cost/corn cost. The optimum N rate for the quadratic model is calculated by setting the first derivative of the model equal to the ratio of the cost of N and the cost of corn (N cost/corn cost) and solving for X. If the ANOVA showed that a significant response did not occur, the optimum N rate was assumed to be 0.

Results

Table 3 shows the optimum N rate calculated from the harvest data and estimated using two different models, the N rate used by the cooperator, and the difference between the two. The data in Table 3 are from demonstrations in cooperators' fields. Data from ISU Outlying Research Farms aren't included.

The data in Table 3 show that in the dry years of 1987 and especially 1988 the cooperators applied more than the optimum rate of N. The amount of the over-application depends on which model is used to estimate the optimum rate. Current N fertilizer recommendations are based on the Quadratic Model that results in the lowest average estimate of over-application, 90 lb N/a in 1987 and 126 lb N/a in 1988. It is commonly accepted that the Quadratic

Model overestimates optimum so there is interest in using the LRP Model. Over-applications using the LRP Model were 104 lb N/a in 1987 and 128 lb N/a in 1988.

The greatest source of error was in applying N to fields that did not respond to additions of N fertilizer although yields were high (Table 4)- so the optimum N rate was 0. This was especially true in 1988 when yields were limited by a severe drought. Average over-applications at responsive sites were 50 lb N/a for the LRP Model and 20 lb N/a for the Quadratic Model in 1987 and 30 lb N/a for the LRP Model and 16 lb N/a for the Quadratic Model in 1988.

There was a response to N at only one site in 1989. Optimum N rate at this site was similar for both Models, 116 lb N/a for the LRP and 102 lb N/a for the Quadratic. The cooperator's rate was 110 lb N/a. The rest of the 1989 sites did not respond to additions of N fertilizer because there were large amounts of residual N in the soil. The drought in 1988 dramatically reduced yields so much of the N fertilizer applied was not used. There was not enough rainfall to cause losses of N from the soil so many fields did not require N fertilizer to attain maximum yield in 1989.

1990 was a wet year and yields were normal. The optimum N rate averaged over sites was 98 lb N/a using the LRP model and 100 lb N/a using the Quadratic model. The average cooperator's rate was 145 lb N/a. There were two sites that did not respond to N. Four sites responded to N in 1991, and five sites did not. Rainfall was above normal in April and May and below normal from June through September. The lack of a response to N at Adair, Keokuk, Muscatine, and Lee Counties was due to local dry conditions.

These data suggest that the most important aspect of N fertilizer management is applying the correct rate. In drought years like 1988 average application rates will exceed the optimum because weather will limit production. However, even in years when rainfall is above normal there will be fields that need little or no N fertilizer. These data underscore the importance of developing a soil test that can be used to differentiate between fields that will and those that will not respond to additions of N fertilizer.

References

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Table 1. General description of nitrogen management demonstration sites, 1987-1991.

Site	County	Previous Crop	Soil Series	Hybrid
		1987		
1	Lyon	Corn	Moody	P3732
2	Winnebago	Soybean	Webster	GH2343
3	Howard	Soybean	Protivin/Lourdes	P3737
4	O'Brien	Corn	Primghar	P3277
8	Clayton	Corn	Tama	P3475
9	Woodbury	Soybean	Galva	L4355
10	Hamilton	Soybean	Nicollet/Webster	LOL845
11	Hardin	Soybean	Nicollet	GR8171
12	Black Hawk	Corn	Donnan	P3475
17	Linn	Soybean	Tama	W48
18	Audubon	Corn	Marshall	P3475
19	Jasper	Corn	Tama	D636
20	Lucas	Corn	Hadina	P3377
		1988		
22	Lyon	Corn	Moody	P3732
23	Mitchell	Soybean	Dinsdale	P3737
24	Howard	Soybean	Protivin/Lourdes	P3737
25	O'Brien	Corn	Primghar	P3732
27	Clay	Soybean	Marcus	F-G4309
28	Kossuth	Soybean	Nicollet	A-Rx626
30	Plymouth	Soybean	Galva	P3475
31	Franklin	Soybean	Harps	P3475
32	Bremer	Soybean	Readlyn	P3475
33	Clayton	Corn	Tama	P3475
35	Hamilton	Soybean	Nicollet	LOL845
36	Greene	Soybean	Clarion/Nicollet	T-114
38	Jones	Soybean	Dinsdale	P3475
39	Audubon	Corn	Marshall	P3475
42	Clinton	Soybean	Tama	P3295
43	Warren	Soybean	Sharpsburg	A-788
44	Mahaska	Soybean	Otley	P3475
47	Lucas	Soybean	Hadina	P3377
48	Henry	Soybean	Otley	M8611
49	Page	Soybean	Macksburg/Judson	NC+
		1989		
50	Lyon	Corn	Moody	P3615
52	Palo Alto	Soybean	Clarion	P3475
57	Clayton	Corn	Tama	P3475
59	Grundy	Soybean	Muscatine	P3379
60	Delaware	Soybean	Clyde/Floyd	A-Rx626
64	Benton	Soybean	Mahaska	OG6882
65	Audubon	Soybean	Marshall	G8519
66	Guthrie	Soybean	Clarion/Nicollet	P3379
67	W. Pottawattamie	Soybean	Nodaway	NK9540
69	Montgomery	Soybean	Marshall	McCurdy

Table 1. General description of nitrogen management demonstration sites, 1987-1991.

Site	County	Previous Crop	Soil Series	Hybrid
71	Monroe	Soybean	Grundy	G85XX
		1990		
76	Dickinson	Soybean	Nicollet	P3475
80	Buena Vista	Soybean	Nicollet	D535
81	Humboldt	Soybean	Nicollet	J5700
82	Clayton	Corn	Tama	P3475
84	Jackson	Corn	Dinsdale	NK-X628
85	Dallas	Soybean	Clarion	P3379
86	Scott	Soybean	Muscatine	GH2540
87	Marion	Soybean	Haig	LOL648
89	Mills	Soybean	Zook	NK-G560
90	Clarke	Soybean	Haig	D612
91	Fremont	Soybean	Kennebec	P3189
		1991		
96	Chickasaw	Soybean	Readlyn	P3615
97	Clayton	Corn	Tama	P3475
98	Sac	Soybean	Galva	G8532
99	Calhoun	Soybean	Nicollet/Webster	CG4385
103	Marshall	Corn	Downs	P3379
104	Harrison	Soybean	McPaul	P3417
105	Adair	Soybean	Sharpsburg	P3362
106	Keokuk	Soybean	Taintor	P3357
108	Muscatine	Soybean	Tama	L432
110	Lee	Soybean	Haig	A-Rx899

P=Pioneer; GH=Golden Harvest; A=Asgrow; CG=Ciba Geigy; AP=Agri-Pro; LOL=Land O'Lakes; T=Trivalley; D=Dekalb; W=Wyffles; SC=Super Crost; M=McAllister; L=Lynx; OG= Old's Gold; NK=Northrup King; G=Garst; J=Jacques; Pf=Pfister; F=Funks.

Table 2. Nitrogen fertilizer rates (lb/a) used in nitrogen management demonstrations from 1987 to 1991.

1987		1988		1989-1990		1991	
Preplant	Sidedressed	Preplant	Sidedressed	Preplant	Sidedressed	Preplant	Sidedressed
0		0		0		0	
60		40		40		30* (60)**	
80		80		80		60 (90)	
100		100		100		90 (120)	
120		120		120		120 (150)	
140		140		180		150 (180)	
180		180			0	0	0
	60		40		40	30 (60)	30
	80		80		80	30 (60)	60
	100		100		100	30 (60)	90
	120		120		120	30 (60)	120
	140		140		180		
	180		180				
	------------Cooperators' Rate------------						

Sidedressed N was applied when the plants were in the V4 to V6 growth stage - usually in early June.

*For corn following soybeans.
**For corn following corn.

Table 3. Optimum and cooperator's N fertilizer rates, 1987-1991.

Site	County	Optimum N Rate: LRP	Optimum N Rate: Quadratic*	Cooperator's N Rate	Diff. between Opt. and Coop. LRP	Diff. between Opt. and Coop. Quadratic*
		lb/a	lb/a	lb/a	lb/a	lb/a
			1987			
2	Winnebago	0	0	120	-120	-120
3	Howard	0	0	135	-135	-135
8	Clayton	0	0	180	-180	-180
9	Woodbury	0	0	100	-100	-100
11	Hardin	75	130	130	-55	0
12	Black Hawk	0	0	200	-200	-200
17	Linn	78	113	160	-82	-47
18	Audubon	119	130	160	-41	-30
19	Jasper	160	180	180	-20	0
1987 Ave.		48	61	152	-104	-90
			1988			
23	Mitchell	0	0	150	-150	-150
24	Howard	0	0	135	-135	-135
27	Clay	104	160	140	-36	20
28	Kossuth	0	0	150	-150	-150
30	Plymouth	107	78	130	-23	-52
31	Franklin	0	0	125	-125	-125
32	Bremer	0	0	160	-160	-160
33	Clayton	0	0	175	-175	-175
38	Jones	0	0	160	-160	-160
39	Audubon	0	0	140	-140	-140
42	Clinton	0	0	150	-150	-150
43	Warren	0	0	120	-120	-120
44	Mahaska	0	0	120	-120	-120
48	Henry	0	0	120	-120	-120
49	Page	0	0	150	-150	-150
1988 Ave.		14	16	142	-128	-126
			1989			
52	Palo Alto	0	0	150	-150	-150
57	Clayton	0	0	150	-150	-150
59	Grundy	0	0	140	-140	-140
60	Delaware	0	0	140	-140	-140
64	Benton	0	0	145	-145	-145
65	Audubon	116	102	110	6	-8
66	Guthrie	0	0	120	-120	-120
67	W. Pottawattamie	0	0	140	-140	-140
69	Montgomery	0	0	135	-135	-135
71	Monroe	0	0	125	-125	-125
1989 Ave.		12	10	136	-124	-125

Table 3. Optimum and cooperator's N fertilizer rates, 1987-1991.

Site	County	Optimum N Rate: LRP	Optimum N Rate: Quadratic*	Cooperator's N Rate	Diff. between Opt. and Coop. LRP	Diff. between Opt. and Coop. Quadratic*
		lb/a	lb/a	lb/a	lb/a	lb/a
			1990			
76	Dickinson	98 PP	101	160	#VALUE!	-59
		83 SD				
81	Humboldt	94 PP				
		94 SD	94	120	#VALUE!	-26
82	Clayton	106 PP	117	175	#VALUE!	-58
		126 SD				
84	Jackson	147 PP	124	180	#VALUE!	-56
		122 SD				
85	Dallas	125	134	160	-35	-26
86	Scott	0	0	100	-100	-100
87	Marion	137	152	165	-28	-13
89	Mills	128	128	140	-12	-12
90	Clarke	143	153	110	33	43
91	Fremont	0	0	140	-140	-140
1990 Ave.		89	100	145	#VALUE!	-45
			1991			
96	Chickasaw	89	116	135	-46	-19
97	Clayton	67	132	160	-93	-28
98	Sac	125	179	150	-25	29
99	Calhoun	60	91	130	-70	-39
104	Harrison	0	0	160	-160	-160
105	Adair	0	0	130	-130	-130
106	Keokuk	0	0	140	-140	-140
108	Muscatine	0	0	130	-130	-130
110	Lee	0	0	160	-160	-160
1991 Ave.		38	58	144	-106	-86
5 Yr. Ave.		40	49	144	-103	-94
Ave. excluding 1988		47	57	144	-97	-87

PP=Preplant; SD=Sidedress
LRP=Linear Response + Plateau Model
Quadratic=Quadratic Model
*Assumes N costs $.15/lb and corn costs $2.25/bu.

Table 4. Effect of N fertilizer rate and time of application on corn grain yields in Iowa from 1987 to 1991.

			Response to:	
Site	Preplant	Sidedress	Time	N Rate
	bu/a	bu/a		
		1987		
1	117	113	ns	***
2	184	186	ns	ns
3	182	178	ns	ns
4	113	110	ns	***
8	181	180	ns	ns
9	132	133	ns	ns
10	163	157	**	***
11	188	184	ns	*
12	175	171	ns	ns
17	204	199	*	*
18	166	161	**	*
19	174	155	***	**
20	93	126	***	***
1987 Ave.	159	158		
		1988		
22	43	37	ns	ns
23	97	100	ns	ns
24	85	85	ns	ns
25	83	75	*	***
27	163	164	ns	***
28	175	175	ns	ns
30	139	138	ns	***
31	117	112	ns	ns
32	106	98	ns	ns
33	61	56	ns	ns
35	110	121	ns	ns
36	120	119	ns	ns
38	104	99	ns	ns
39	103	100	ns	ns
42	83	84	ns	ns
43	137	138	ns	ns
44	42	39	ns	ns
47	73	62	ns	ns
48	92	91	ns	ns
49	88	84	ns	ns
1988 Ave	101	99		
		1989		
50	136	134	ns	***
52	99	102	ns	ns
57	188	190	ns	ns

Table 4. Effect of N fertilizer rate and time of application on corn grain yields in Iowa from 1987 to 1991.

Site	Preplant	Sidedress	Response to: Time	Response to: N Rate
	bu/a	bu/a		
59	153	156	ns	ns
60	132	130	ns	ns
64	158	156	ns	ns
65	132	135	ns	***
66	169	165	ns	ns
67	157	145	ns	ns
69	177	178	ns	ns
71	104	108	ns	ns
1989 Ave	146	145		
		1990		
76	139	135	*	***
80	131	126	ns	ns
81	151	157	**	**
82	164	157	*	***
84	192	182	**	***
85	118	119	ns	***
86	183	182	ns	ns
87	137	138	ns	***
89	180	180	ns	***
90	166	169	ns	**
91	162	163	ns	ns
1990 Ave	157	155		
		1991		
96	166	169	ns	***
97	166	163	ns	***
98	133	135	ns	***
99	127	121	ns	***
103	147	146	ns	ns
104	206	205	ns	ns
105	149	150	ns	ns
106	159	156	ns	ns
108	141	142	ns	ns
110	160	162	ns	ns
1991 Ave	155	155		
5 Yr Ave	138	137		

ns=not sig. at $P<0.10$; *=sig. at $P<0.10$; **=sig. at $P<0.05$; ***=sig. at $P<0.01$

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