

Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Corn

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Summary

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated corn in western Kansas. In 2019, N applied alone increased yields by 71 bu/a, whereas P applied alone increased yields 10 bu/a. Nitrogen and P applied together increased yields up to 131 bu/a, which is 10 bu/a less than the 10-year average of 141 bu/a. Application of 120 lb N/a (with highest P rate) produced 97% of maximum yield in 2019, which is slightly greater than the 10-year average. Application of 80 instead of 40 lb P₂O₅/a increased average yields 4 bu/a. Average grain N content reached a maximum of 0.6 lb/bu while grain P content reached a maximum of 0.15 lb/bu (0.34 lb P₂O₅/bu). At the highest N and P rate, apparent fertilizer nitrogen recovery in the grain (AFNR_g) was 41% and apparent fertilizer phosphorus recovery in the grain (AFPR_g) was 60%.

Introduction

This study was initiated in 1961 to determine responses of continuous corn and grain sorghum grown under flood irrigation to N, P, and potassium (K) fertilization. The study is conducted on a Ulysses silt loam soil with an inherently high K content. No yield benefit to corn from K fertilization was observed in 30 years, and soil K levels remained high, so the K treatment was discontinued in 1992 and replaced with a higher P rate.

Procedures

This field study is conducted at the Tribune Unit of the Kansas State University Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a without P and K; with 40 lb/a P₂O₅ and zero K; and with 40 lb/a P₂O₅ and 40 lb/a K₂O. The treatments were changed in 1992; the K variable was replaced by a higher rate of P (80 lb/a P₂O₅). All fertilizers were broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. The corn hybrids [Pioneer 1173H (2010), Pioneer 1151XR (2011), Pioneer 0832 (2012–2013), Pioneer 1186AM (2014), Pioneer 35F48 AM1 (2015), Pioneer 1197 (2016), Pioneer 0801 (2017–2018), and Pioneer 0339 (2019)] were planted at about 32,000 seeds/a in late April or early May. Hail damaged the 2010, 2015, 2017, and 2019 crops. The corn is irrigated to minimize water stress. Sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 15.5% moisture. Grain samples were collected at harvest, dried, ground, and analyzed for N and P concentrations. Grain N and P con-

tent (lb/bu) and removal (lb/a) were calculated. Apparent fertilizer N recovery in the grain (AFNR_g) was calculated as N uptake in treatments receiving N fertilizer minus N uptake in the unfertilized control divided by N rate. The same approach was used to calculate apparent fertilizer P recovery in the grain (AFPR_g). Grasshoppers were treated by aerial application of insecticide.

Results

Corn yields in 2019 were only 2% higher than the 10-year average (Table 1). Nitrogen alone increased yields 71 bu/a, whereas P alone increased yields 7–10 bu/a. However, N and P applied together increased corn yields up to 131 bu/a. Maximum yield was obtained with 200 lb/a N with 80 lb/a P₂O₅. Corn yields in 2019 (averaged across all N rates) were 4 bu/a greater with 80 than with 40 lb/a P₂O₅ applied.

The 10-year average grain N concentration (%) increased with N rates but tended to decrease when P was also applied, presumably because of higher grain yields diluting N content (Table 2). Grain N content reached a maximum of 0.6 lb/bu. Nitrogen removal (lb/a) was greater at the higher yield levels. Maximum N removal (116 lb/a) was attained with 200 lb N and 80 lb P₂O₅/a. At the highest N and P rate, AFNR_g was 41% and AFPR_g was 60%. Similar to N, average P concentration increased with increased P rates but decreased with higher N rates. Grain P content (lb/bu) of about 0.15 lb P/bu (0.34 lb P₂O₅/bu) was greater at the highest P rate with low N rates. Grain P removal averaged 29 lb P/a at the highest yields.

Acknowledgment

The International Plant Nutrition Institute partially supported this research project.

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Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2010–2019

Fertilizer		Yield										
N	P ₂ O ₅	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
----- lb/a -----		----- bu/a -----										
0	0	20	92	86	70	86	92	74	44	82	76	72
0	40	21	111	85	80	95	103	78	47	93	86	80
0	80	28	105	94	91	98	104	86	52	99	83	84
40	0	23	114	109	97	106	113	105	60	110	93	93
40	40	67	195	138	125	153	164	145	92	160	156	139
40	80	61	194	135	126	149	162	135	90	159	154	137
80	0	34	136	128	112	117	131	118	70	117	117	108
80	40	85	212	197	170	187	195	196	132	212	183	177
80	80	90	220	194	149	179	193	193	129	207	189	174
120	0	28	119	134	114	115	124	109	62	102	95	100
120	40	90	222	213	204	213	212	212	142	218	193	192
120	80	105	225	211	194	216	216	223	162	243	201	200
160	0	49	157	158	122	128	144	142	84	139	133	125
160	40	95	229	227	199	211	215	226	154	230	196	198
160	80	95	226	239	217	233	216	238	165	251	191	207
200	0	65	179	170	139	144	162	159	114	158	147	144
200	40	97	218	225	198	204	214	216	148	231	186	194
200	80	104	231	260	220	238	221	235	174	243	207	213

continued

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Fertilizer		Yield										
N	P ₂ O ₅	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
----- lb/a -----		----- bu/a -----										
ANOVA (P>F)												
Nitrogen		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
N × P		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
MEANS												
Nitrogen, lb/a												
0		23 e	103 d	88 f	80 e	93 e	100 e	79 e	48 e	91 d	82 d	79 e
40		50 d	167 c	127 e	116 d	136 d	146 d	129 d	81 d	143 c	135 c	123 d
80		70 c	189 b	173 d	143 c	161 c	173 c	169 c	110 c	179 b	163 b	153 c
120		74 bc	189 b	186 c	171 b	181 b	184 b	182 b	122 b	188 b	163 b	164 b
160		80 ab	204 a	208 b	179 ab	190 ab	192 ab	202 a	134 a	207 a	173 ab	177 a
200		89 a	209 a	218 a	186 a	196 a	199 a	203 a	145 a	211 a	180 a	184 a
LSD _(0.05)		9	13	10	10	10	9	10	11	13	13	8
P ₂ O ₅ , lb/a												
0		36 b	133 b	131 c	109 b	116 c	128 b	118 b	72 c	118 c	110 b	107 b
40		76 a	198 a	181 b	163 a	177 b	184 a	179 a	119 b	191 b	167 a	163 a
80		81 a	200 a	189 a	166 a	186 a	185 a	185 a	129 a	200 a	171 a	169 a
LSD _(0.05)		7	9	7	7	7	6	7	8	9	9	6

*Note: Hail events on 7/23/2010, 5/28/2015, 8/18/2017, and 9/20/2019.

LSD = least significant difference. ANOVA = analysis of variance.

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2010–2019

Fertilizer		Grain				Grain removal			
N	P ₂ O ₅	N	P	N	P	N	P	*AFNR _g	*AFPR _g
----- lb/a -----		----- % -----		----- lb/bu -----		----- lb/a -----		----- % -----	
0	0	0.99	0.228	0.47	0.108	33	8	---	---
0	40	0.94	0.306	0.45	0.145	35	12	---	22
0	80	0.94	0.318	0.45	0.151	36	13	---	14
40	0	1.17	0.183	0.55	0.087	51	8	44	---
40	40	0.96	0.297	0.46	0.141	62	20	74	67
40	80	0.97	0.317	0.46	0.150	61	21	72	36
80	0	1.26	0.178	0.60	0.084	63	9	38	---
80	40	1.04	0.249	0.49	0.118	86	21	66	72
80	80	1.01	0.305	0.48	0.145	82	25	62	49
120	0	1.28	0.172	0.60	0.081	60	8	23	---
120	40	1.12	0.226	0.53	0.107	101	20	57	71
120	80	1.08	0.293	0.51	0.139	101	28	57	56
160	0	1.26	0.176	0.59	0.083	74	10	26	---
160	40	1.16	0.241	0.55	0.114	108	22	47	83
160	80	1.14	0.275	0.54	0.130	111	27	49	53
200	0	1.22	0.189	0.58	0.090	82	13	25	---
200	40	1.17	0.234	0.55	0.111	106	21	37	77
200	80	1.15	0.288	0.55	0.136	116	29	41	60

continued

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Fertilizer		Grain				Grain removal			
N	P ₂ O ₅	N	P	N	P	N	P	*AFNR _g	*AFPR _g
----- lb/a -----		----- % -----		----- lb/bu -----		----- lb/a -----		----- % -----	
ANOVA (P>F)									
Nitrogen		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	---	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	---	0.001
Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	---
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	---
N × P		0.001	0.001	0.001	0.001	0.001	0.001	0.022	0.090
MEANS									
Nitrogen, lb/a									
0		0.96 e	0.284 a	0.45 e	0.134 a	35 e	11 e	---	18 c
40		1.03 d	0.266 b	0.49 d	0.126 b	58 d	16 d	64 a	52 b
80		1.10 c	0.244 c	0.52 c	0.116 c	77 c	18 c	55 b	61 a
120		1.16 b	0.230 d	0.55 b	0.109 d	87 b	19 bc	45 c	63 a
160		1.19 a	0.231 d	0.56 a	0.109 d	98 a	20 ab	41 d	68 a
200		1.18 ab	0.237 cd	0.56 ab	0.112cd	101 a	21 a	34 e	68 a
LSD _(0.05)		0.02	0.011	0.01	0.005	4	1	5	9
P ₂ O ₅ , lb/a									
0		1.19 a	0.188 c	0.57 a	0.089 c	60 b	9 c	31 b	---
40		1.07 b	0.259 b	0.50 b	0.122 b	83 a	19 b	56 a	65 a
80		1.05 b	0.299 a	0.50 b	0.142 a	85 a	24 a	56 a	45 b
LSD _(0.05)		0.02	0.008	0.01	0.004	3	1	4	5

*AFNR_g = Apparent fertilizer N recovery (grain). AFPR_g = Apparent fertilizer P recovery (grain). LSD = least significant difference. ANOVA = analysis of variance.