

Irrigated Corn Response to Long-Term Nitrogen and Phosphorus Fertilization

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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 2020, N applied alone increased yields by 85 bu/a, whereas P applied alone increased yields 10 bu/a. Nitrogen and P applied together increased yields up to 136 bu/a which is 11 bu/a less than the 10-year average of 147 bu/a. The application of 120 lb N/a (with highest P rate) produced 98% of maximum yield in 2020, which is greater than the 10-year average (2011–2020). The application of 80 instead of 40 lb P_2O_5 /a increased average yields 1 bu/a. The 10-year 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 P_2O_5 /bu). At the highest N and P rate, apparent fertilizer nitrogen recovery in the grain (AFNR_g) was 43% and apparent fertilizer phosphorus recovery in the grain (AFPR_g) was 63%. Nitrogen fertilization increased soil organic matter and decreased soil pH. Phosphorus fertilization at 40 lb/a P_2O_5 was not sufficient to maintain soil test levels.

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 P_2O_5 and zero K; and with 40 lb/a P_2O_5 and 40 lb/a K_2O . The treatments were changed in 1992; the K variable was replaced by a higher rate of P (80 lb/a P_2O_5). All fertilizers were broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. The corn hybrids (Pioneer 1151XR, 2011; Pioneer 0832, 2012–2013; Pioneer 1186AM, 2014; Pioneer 35F48 AM1, 2015; Pioneer 1197, 2016; Pioneer 0801, 2017–2018; Pioneer 0339, 2019; and Mycogen 10Z29, 2020) were planted at about 32,000 seeds/a in late April or early May. Hail damaged the 2017, 2019, and 2020 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 content (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). After harvest in 2020, all plots were soil sampled (8 probes/plot) to a depth of 6 inches, dried, and ground. Servi-Tech Laboratories analyzed the samples for soil pH, organic matter (OM), P (Bray-1 and Mehlich-3), K, zinc (Zn), manganese (Mn), and iron (Fe).

Results

Corn yields in 2020 were only 1% higher than the 10-year average (Table 1). Nitrogen alone increased yields 85 bu/a, whereas P alone increased yields 10 bu/a. However, N and P applied together increased corn yields up to 136 bu/a. Maximum yield was obtained with 200 lb/a N with 80 lb/a P₂O₅. Corn yields in 2020 (averaged across all N rates) were 1 bu/a greater with 80 than with 40 lb/a P₂O₅.

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 (121 lb/a), was attained with 200 lb N and 80 lb P₂O₅/a. At the highest N and P rate, AFNR_g was 43% and AFPR_g was 63%. Similar to N, the 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 31 lb P/a at the highest yields.

After 60 years, pH of the surface soil was decreased up to 0.5 unit by N fertilization (Table 3). Nitrogen fertilization increased soil OM, Mn, and Fe concentrations while decreasing P and Zn concentrations. Phosphorus fertilization slightly increased OM and substantially increased P (both Bray-1 and Mehlich-3) and Zn concentrations with little effect on other soil properties. The original soil test P level (in 1961) was about 17 ppm (Bray-1), so annual applications of 40 lb/a P₂O₅ was not sufficient to maintain soil test P levels but 80 lb/a increased soil test P levels.

Acknowledgment

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Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2011–2020

Fertilizer		Yield										
N	P ₂ O ₅	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean
---- lb/a ----		----- bu/a -----										
0	0	92	86	70	86	92	74	44	82	76	79	78
0	40	111	85	80	95	103	78	47	93	86	88	87
0	80	105	94	91	98	104	86	52	99	83	89	90
40	0	114	109	97	106	113	105	60	110	93	98	100
40	40	195	138	125	153	164	145	92	160	156	168	150
40	80	194	135	126	149	162	135	90	159	154	153	146
80	0	136	128	112	117	131	118	70	117	117	121	117
80	40	212	197	170	187	195	196	132	212	183	191	187
80	80	220	194	149	179	193	193	129	207	189	191	184
120	0	119	134	114	115	124	109	62	102	95	100	107
120	40	222	213	204	213	212	212	142	218	193	205	204
120	80	225	211	194	216	216	223	162	243	201	210	210
160	0	157	158	122	128	144	142	84	139	133	129	133
160	40	229	227	199	211	215	226	154	230	196	206	209
160	80	226	239	217	233	216	238	165	251	191	208	218
200	0	179	170	139	144	162	159	114	158	147	164	154
200	40	218	225	198	204	214	216	148	231	186	205	205
200	80	231	260	220	238	221	235	174	243	207	215	225

continued

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2011–2020

Fertilizer		Yield										
N	P ₂ O ₅	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	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		103 d	88 f	80 e	93 e	100 e	79 e	48 e	91 d	82 d	85 e	85 e
40		167 c	127 e	116 d	136 d	146 d	129 d	81 d	143 c	135 c	140 d	132 d
80		189 b	173 d	143 c	161 c	173 c	169 c	110 c	179 b	163 b	168 c	163 c
120		189 b	186 c	171 b	181 b	184 b	182 b	122 b	188 b	163 b	172 bc	174 b
160		204 a	208 b	179 ab	190 ab	192 ab	202 a	134 a	207 a	173 ab	181 b	187 a
200		209 a	218 a	186 a	196 a	199 a	203 a	145 a	211 a	180 a	195 a	194 a
LSD _(0.05)		13	10	10	10	9	10	11	13	13	13	8
P ₂ O ₅ , lb/a												
0		133 b	131 c	109 b	116 c	128 b	118 b	72 c	118 c	110 b	115 b	115 b
40		198 a	181 b	163 a	177 b	184 a	179 a	119 b	191 b	167 a	177 a	173 a
80		200 a	189 a	166 a	186 a	185 a	185 a	129 a	200 a	171 a	178 a	179 a
LSD _(0.05)		9	7	7	7	6	7	8	9	9	9	6

Different letters in the same column indicate significant differences ($P < 0.05$).

Hail events occurred on 8/18/2017, 9/20/2019, and 8/10/2020.

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2011–2020

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	0.96	0.231	0.46	0.109	36	9	---	---
0	40	0.91	0.312	0.43	0.148	37	13	---	24
0	80	0.91	0.324	0.43	0.153	39	14	---	15
40	0	1.15	0.187	0.55	0.088	54	9	47	---
40	40	0.93	0.300	0.44	0.142	66	21	77	71
40	80	0.94	0.319	0.44	0.151	65	22	74	38
80	0	1.25	0.182	0.59	0.086	68	10	41	---
80	40	1.02	0.250	0.48	0.118	90	22	69	76
80	80	0.99	0.307	0.47	0.145	86	27	64	51
120	0	1.28	0.175	0.60	0.083	64	9	24	---
120	40	1.10	0.228	0.52	0.108	106	22	59	75
120	80	1.06	0.293	0.50	0.139	106	29	59	58
160	0	1.25	0.180	0.59	0.085	78	11	27	---
160	40	1.15	0.241	0.54	0.114	114	24	49	86
160	80	1.13	0.273	0.53	0.129	116	28	51	55
200	0	1.21	0.190	0.57	0.090	87	14	26	---
200	40	1.14	0.232	0.54	0.110	110	23	38	79
200	80	1.14	0.290	0.54	0.137	121	31	43	63

continued

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2011–2020

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	0.047	0.056
MEANS									
Nitrogen, lb/a									
0		0.93 d	0.289 a	0.44 d	0.137 a	37 e	12 e	---	20 c
40		1.01 c	0.269 b	0.48 c	0.127 b	62 d	17 d	66 a	55 b
80		1.09 b	0.246 c	0.51 b	0.117 c	82 c	20 c	58 b	64 a
120		1.15 a	0.232 d	0.54 a	0.110 d	92 b	20 bc	47 c	67 a
160		1.17 a	0.231 d	0.56 a	0.109 d	103 a	21 ab	42 c	71 a
200		1.16 a	0.237 cd	0.55 a	0.112 cd	106 a	22 a	35 d	71 a
LSD _(0.05)		0.03	0.011	0.01	0.005	4	1	5	9
P ₂ O ₅ , lb/a									
0		1.18 a	0.191 c	0.56 a	0.090 c	65 b	10 c	33 b	---
40		1.04 b	0.260 b	0.49 b	0.123 b	87 a	21 b	58 a	69 a
80		1.03 b	0.301 a	0.49 b	0.143 a	89 a	25 a	58 a	47 b
LSD _(0.05)		0.02	0.008	0.01	0.004	3	1	4	5

*AFNR_g, AFPR_g = Apparent Fertilizer N Recovery (grain), Apparent Fertilizer P Recovery (grain).
Different letters in the same column indicate significant differences ($P < 0.05$).

Table 3. Effect of 60 years of nitrogen (N) and phosphorus (P) fertilizers to irrigated corn on soil properties (0–6 inch), Tribune, KS, 2020

N	P ₂ O ₅	pH	OM	Mehlich		K	Zn	Mn	Fe
				Bray 1 P	3P				
----- lb/acre -----			%	----- ppm -----					
0	0	8.0	1.7	5	11	589	0.74	4.2	5.2
0	40	8.1	1.8	26	49	586	0.92	4.4	5.6
0	80	8.0	1.8	54	86	597	0.94	4.6	5.6
40	0	8.0	1.8	6	16	576	0.74	4.2	5.0
40	40	7.9	1.9	17	34	640	0.88	4.8	5.6
40	80	7.9	2.0	43	74	668	1.00	5.0	6.2
80	0	7.9	1.9	5	11	615	0.68	4.8	5.8
80	40	7.9	2.0	10	22	620	0.70	4.8	5.6
80	80	7.9	2.0	30	55	641	0.92	5.0	5.8
120	0	7.8	1.9	4	10	571	0.66	4.4	5.2
120	40	7.9	2.0	10	22	623	0.72	5.0	5.4
120	80	7.8	2.1	26	52	643	0.92	4.8	6.0
160	0	7.6	1.9	6	14	594	0.70	5.4	5.8
160	40	7.6	2.0	10	22	622	0.78	5.6	6.2
160	80	7.9	2.0	20	39	632	0.74	4.6	5.4
200	0	7.4	2.0	5	11	595	0.72	6.6	7.2
200	40	7.6	2.1	11	20	631	0.76	6.2	6.8
200	80	7.6	2.1	22	36	623	0.84	6.0	6.8

continued

Table 3. Effect of 60 years of nitrogen (N) and phosphorus (P) fertilizers to irrigated corn on soil properties (0–6 inch), Tribune, KS, 2020

N	P ₂ O ₅	pH	OM	Mehlich		K	Zn	Mn	Fe
				Bray 1 P	3P				
----- lb/acre -----			%	----- ppm -----					
ANOVA (P>F)									
Nitrogen		0.001	0.001	0.001	0.001	0.080	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.305	0.001	0.001	0.001
Quadratic		0.011	0.028	0.001	0.011	0.062	0.053	0.006	0.005
P ₂ O ₅		0.230	0.001	0.001	0.001	0.001	0.001	0.586	0.436
Linear		0.090	0.001	0.001	0.001	0.001	0.001	0.735	0.204
Quadratic		0.814	0.257	0.001	0.004	0.303	0.761	0.330	0.854
Zero P vs. P		0.175	0.001	0.001	0.001	0.001	0.001	0.435	0.233
40 P vs. 80 P		0.291	0.142	0.001	0.001	0.140	0.001	0.499	0.632
N × P		0.111	0.697	0.001	0.001	0.326	0.056	0.380	0.384
MEANS									
0		8.0 a	1.8 c	28 a	49 a	591	0.87 a	4.4 c	5.5 b
40		8.0 ab	1.9 b	22 b	41 b	628	0.87 a	4.7 bc	5.6 b
80		7.9 b	2.0 b	15 c	30 c	625	0.77 b	4.9 bc	5.7 b
120		7.9 b	2.0 ab	13 c	28 c	613	0.77 b	4.7 bc	5.5 b
160		7.7 c	2.0 ab	12 c	25 c	616	0.74 b	5.2 b	5.8 b
200		7.5 d	2.1 a	12 c	23 c	616	0.77 b	6.3 a	6.9 a
LSD _{0.05}		0.1	0.1	5	7	26	0.07	0.6	0.6
	0	7.8	1.9 b	5 c	12 c	590 b	0.71 c	4.9	5.7
	40	7.8	2.0 a	14 b	28 b	620 a	0.79 b	5.1	5.9
	80	7.9	2.0 a	32 a	57 a	634 a	0.89 a	5.0	6.0
	LSD _{0.05}	0.1	0.1	3	5	18	0.05	0.4	0.4

K = potassium. Zn = zinc. Mn = manganese. Fe = iron.

Different letters in the same column indicate significant differences ($P < 0.05$).