

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 the production of irrigated corn in western Kansas. In 2016, N applied alone increased yields by 85 bu/a, whereas P applied alone increased yields by only 12 bu/a. Nitrogen and P applied together increased yields up to 164 bu/a. This is 20 bu/a greater than the 10-year average, where N and P fertilization increased corn yields up to 144 bu/a. Application of 120 lb/a N (with the highest P rate) produced about 94% of maximum yield in 2016, which is similar to the 10-year average. Application of 80 instead of 40 lb P₂O₅/a increased average yields 6 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 (grain) (AFNR_g) was 44% and apparent fertilizer phosphorus recovery (grain) (AFPR_g) was 62%.

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.

Experimental 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 33B54 (2007), Pioneer 34B99 (2008), DeKalb 61-69 (2009), Pioneer 1173H (2010), Pioneer 1151XR (2011), Pioneer 0832 (2012-2013), Pioneer 1186AM (2014), Pioneer 35F48 AM1 (2015), and Pioneer 1197 (2016)] were planted at about 32,000 seeds/a in late April or early May. Hail damaged the 2008 and 2010 crops. The corn was 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 ($AFPR_g$).

Results and Discussion

Corn yields in 2016 were 10% greater than the 10-year average (Table 1). Nitrogen alone increased yields 85 bu/a, whereas P alone increased yields only 12 bu/a. However, N and P applied together increased corn yields up to 164 bu/a. Maximum yield was obtained with 160 lb/a N with 80 lb/a P_2O_5 . Corn yields in 2016 (averaged across all N rates) were 6 bu/a greater with 80 than with 40 lb/a P_2O_5 .

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. Maximum N removal (lb/a) was greatest at the highest yield levels, which were attained with 200 lb N and 80 lb P_2O_5 /a. At the highest N and P rate, $AFNR_g$ was 44% and $AFPR_g$ was 62%. 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 P_2O_5 /bu) was greater at the highest P rate with low N rates. Grain P removal averaged 30 lb P/a at the highest yields.

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2007-2016

Fertilizer		Yield										
Nitrogen	P ₂ O ₅	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
----- lb/a -----		----- bu/a -----										
0	0	49	36	85	20	92	86	70	86	92	74	69
0	40	50	57	110	21	111	85	80	95	103	78	79
0	80	51	52	106	28	105	94	91	98	104	86	81
40	0	77	62	108	23	114	109	97	106	113	105	91
40	40	112	105	148	67	195	138	125	153	164	145	135
40	80	116	104	159	61	194	135	126	149	162	135	134
80	0	107	78	123	34	136	128	112	117	131	118	108
80	40	163	129	179	85	212	197	170	187	195	196	171
80	80	167	139	181	90	220	194	149	179	193	193	171
120	0	106	65	117	28	119	134	114	115	124	109	103
120	40	194	136	202	90	222	213	204	213	212	212	190
120	80	213	151	215	105	225	211	194	216	216	223	197
160	0	132	84	139	49	157	158	122	128	144	142	125
160	40	220	150	210	95	229	227	199	211	215	226	198
160	80	227	146	223	95	226	239	217	233	216	238	206
200	0	159	99	155	65	179	170	139	144	162	159	143
200	40	224	152	207	97	218	225	198	204	214	216	196
200	80	232	157	236	104	231	260	220	238	221	235	213

continued

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2007-2016

Fertilizer		Yield										Mean
Nitrogen	P ₂ O ₅	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
----- lb/a -----		----- bu/a -----										
Analysis of variance (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
Nitrogen × Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Means ¹												
Nitrogen, lb/a												
0		50f	48e	100e	23e	103d	88f	80e	93e	100e	79e	76e
40		102e	91d	138d	50d	167c	127e	116d	136d	146d	129d	120d
80		146d	115c	161c	70c	189b	173d	143c	161c	173c	169c	150c
120		171c	118c	178b	74bc	189b	186c	171b	181b	184b	182b	163b
160		193b	127b	191a	80ab	204a	208b	179ab	190ab	192ab	202a	177a
200		205a	136a	199a	89a	209a	218a	186a	196a	199a	203a	184a
Least significant difference _(0.05)		11	9	12	9	13	10	10	10	9	10	8
P ₂ O ₅ , lb/a												
0		105b	71b	121c	36b	133b	131c	109b	116c	128b	118b	107c
40		160a	122a	176b	76a	198a	181b	163a	177b	184a	179a	162b
80		168a	125a	187a	81a	200a	189a	166a	186a	185a	185a	167a
Least significant difference _(0.05)		8	6	9	7	9	7	7	7	6	7	5

*Note: Hail events on 7/23/10 and 5/28/15

¹ Means within a column with the same letter are not statistically different at $P = 0.05$.

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2007-2016

Fertilizer		Grain				Grain removal		*AFNR _g	*AFPR _g
Nitrogen	P ₂ O ₅	N	P	N	P	N	P		
lb/a		%		lb/bu		lb/a		%	
0	0	0.99	0.230	0.47	0.109	31	7	---	---
0	40	0.95	0.312	0.45	0.147	35	12	---	24
0	80	0.96	0.321	0.45	0.152	36	12	---	14
40	0	1.15	0.182	0.55	0.086	49	8	45	---
40	40	0.97	0.301	0.46	0.143	61	19	75	67
40	80	0.98	0.323	0.46	0.153	61	21	75	37
80	0	1.26	0.177	0.60	0.084	64	9	40	---
80	40	1.05	0.257	0.50	0.122	84	21	66	74
80	80	1.03	0.310	0.49	0.147	82	25	63	49
120	0	1.25	0.170	0.59	0.081	61	8	24	---
120	40	1.14	0.226	0.54	0.107	102	20	58	71
120	80	1.10	0.297	0.52	0.140	102	28	59	57
160	0	1.25	0.176	0.59	0.083	73	10	26	---
160	40	1.18	0.242	0.56	0.114	110	22	49	84
160	80	1.17	0.281	0.56	0.133	114	27	51	55
200	0	1.24	0.186	0.59	0.088	83	12	26	---
200	40	1.20	0.239	0.57	0.113	110	22	39	82
200	80	1.19	0.295	0.56	0.140	119	30	44	62

continued

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2007-2016

Fertilizer		Grain				Grain removal		*AFNR _g	*AFPR _g
Nitrogen	P ₂ O ₅	N	P	N	P	N	P	%	%
lb/a		%		lb/bu		lb/a		%	
<u>Analysis of variance (ANOVA) (P > F)</u>									
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	---
Nitrogen × phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.036	0.126
Means ¹									
Nitrogen, lb/a									
0		0.97e	0.288a	0.46e	0.136a	34f	10e	---	19d
40		1.04d	0.269b	0.49d	0.127b	57e	16d	65a	52c
80		1.11c	0.248c	0.53c	0.117c	77d	18c	56b	62b
120		1.16b	0.231d	0.55b	0.109d	88c	19c	47c	64ab
160		1.20a	0.233d	0.57a	0.110d	99b	20b	42d	70ab
200		1.21a	0.240cd	0.57a	0.114cd	104a	21a	36e	72a
Least significant difference _(0.05)		0.02	0.011	0.01	0.005	4	1	5	8
P ₂ O ₅ , lb/a									
0		1.19a	0.187c	0.56a	0.088c	60b	9c	32b	---
40		1.08b	0.263b	0.51b	0.124b	84a	19b	57a	67a
80		1.07b	0.304a	0.51b	0.144a	86a	24a	58a	46b
Least significant difference _(0.05)		0.01	0.008	0.01	0.004	3	1	4	5

*AFNR_g and AFPR_g = Apparent Fertilizer N Recovery (grain) and Apparent Fertilizer P Recovery (grain).

¹ Means within a column with the same letter are not statistically different at P = 0.05.