

Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Corn

A. Schlegel and H.D. Bond

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 2016, N applied alone increased yields 85 bu/a, whereas P applied alone increased yields 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 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, AFNR_g was 44% and 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.

Procedures

This field study is conducted at the Tribune Unit of the 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 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 less 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

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 P₂O₅. Corn yields in 2016 (averaged across all N rates) were 6 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. Maximum N removal (lb/a) was greatest at the highest yield levels, which were attained with 200 lb N and 80 lb P₂O₅/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 P₂O₅/bu) was greater at the highest P rate with low N rates. Grain P removal averaged 30 lb P/a at the highest yields.

Key words. Nitrogen fertilization, phosphorus fertilization, irrigated corn, long-term fertility, nutrient removal

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

Fertilizer		Yield										Mean
N	P ₂ O ₅	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
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
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		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
LSD _(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
LSD _(0.05)		8	6	9	7	9	7	7	7	6	7	5

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

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

Fertilizer		Grain				Grain removal			
N	P ₂ O ₅	N	P	N	P	N	P	*AFNR _g	*AFPR _g
lb/a		-%		lb/bu		lb/acre		-%	
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
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	0.036	0.126
MEANS									
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
LSD _(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
LSD _(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).

Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Grain Sorghum

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Summary

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated grain sorghum in western Kansas. In 2016, N applied alone increased yields 71 bu/a, whereas N and P applied together increased yields up to 93 bu/a. Averaged across the past 10 years, N and P fertilization increased sorghum yields up to 77 bu/a. Application of 80 lb/a N (with P) was sufficient to produce 89% of maximum yield in 2016 which is slightly less than the 10-yr average. Application of potassium (K) has had no effect on sorghum yield throughout the study period. Average grain N content reached a maximum of ~0.7 lb/bu while grain P content reached a maximum of 0.15 lb/bu (0.34 lb P₂O₅/bu) and grain K content reached a maximum of 0.19 lb/bu (0.23 lb K₂O/bu). At the highest N, P, and K rate, apparent fertilizer recovery in the grain was 33% for N, 69% for P, and 40% for K.

Introduction

This study was initiated in 1961 to determine responses of continuous grain sorghum grown under flood irrigation to N, P, and K fertilization. The study is conducted on a Ulysses silt loam soil with an inherently high K content. The irrigation system was changed from flood to sprinkler in 2001.

Procedures

This field study is conducted at the Tribune Unit of the Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a N without P and K; with 40 lb/a P₂O₅ and zero K; and with 40 lb/a P₂O₅ and 40 lb/a K₂O. All fertilizers are broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. Sorghum (Pioneer 8505 in 2007, Pioneer 85G46 in 2008–2011, Pioneer 84G62 in 2012–2014, Pioneer 86G32 in 2015, and Pioneer 84G62 in 2016) was planted in late May or early June. Irrigation is used 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 12.5% moisture. Grain samples were collected at harvest, dried, ground and analyzed for N, P, and K concentrations. Grain N, P, and K 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 less 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) and apparent fertilizer K recovery (AFKR_g).

Results

Grain sorghum yields in 2016 were 10% greater than the 10-year average (Table 1). Nitrogen alone increased yields 71 bu/a while P alone increased yields 11 bu/a. However, N and P applied together increased yields up to 93 bu/a. Averaged across the past 10 years, N and P applied together increased yields up to 77 bu/a. In 2016, 40 lb/a N (with P) produced about 82% of maximum yield, which is slightly less than the 10-year average of 84%. The 10-year average for 80 lb/a N (with P) and 120 lb/a N (with P) was 93% and 96% of maximum yield, respectively.

Sorghum yields were not affected by K fertilization, which has been the case throughout the study period.

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 ~0.7 lb/bu. Maximum N removal (lb/a) was obtained with 160 lb N/a or greater with P. Similar to N, average P concentration increased with P application but decreased with higher N rates. Grain P content (lb/bu) of ~0.15 lb P/bu (0.34 lb P₂O₅/bu) was similar for all N rates when P was applied. Grain P removal was similar for all N rates of 40 lb/a or greater with P removal ranging from 19 to 23 lb/a. Average K concentration (%) and content (lb/bu) tended to decrease with increased N rates. Similar to P, K removal was similar for all N rates of 40 lb/a or greater plus K ranging from 23 to 27 lb/a. At the highest N, P, and K rate, apparent fertilizer recovery in the grain was 33% for N, 69% for P, and 40% for K.

Key words. Nitrogen fertilization, phosphorus fertilization, irrigated grain sorghum, long-term fertility, nutrient removal

Table 1. Nitrogen, phosphorus, and potassium fertilizers on irrigated grain sorghum yields, Tribune, KS, 2007-2016.

Fertilizer			Grain sorghum yield										
N	P ₂ O ₅	K ₂ O	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
lb/a			bu/a										
0	0	0	80	66	64	51	75	78	62	90	89	80	74
0	40	0	97	60	70	51	83	90	77	94	102	91	82
0	40	40	94	65	76	55	88	93	72	96	97	91	83
40	0	0	123	92	84	66	106	115	94	115	122	106	102
40	40	0	146	111	118	77	121	140	114	144	160	142	127
40	40	40	145	105	109	73	125	132	110	142	155	137	123
80	0	0	138	114	115	73	117	132	102	120	133	120	116
80	40	0	159	128	136	86	140	163	136	151	173	154	143
80	40	40	166	126	108	84	138	161	133	164	178	160	142
120	0	0	138	106	113	70	116	130	100	116	127	108	112
120	40	0	164	131	130	88	145	172	137	162	177	164	147
120	40	40	165	136	136	90	147	175	142	170	178	170	151
160	0	0	146	105	108	74	124	149	117	139	150	135	125
160	40	0	170	138	128	92	152	178	146	171	181	173	153
160	40	40	167	133	140	88	151	174	143	176	179	161	151
200	0	0	154	120	110	78	128	147	119	139	155	151	130
200	40	0	168	137	139	84	141	171	136	165	177	167	149
200	40	40	170	135	129	87	152	175	138	170	179	170	151
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
P-K			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zero P vs. P			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P vs. P-K			0.992	0.745	0.324	0.892	0.278	0.826	0.644	0.117	0.806	0.943	0.974
N × P-K			0.965	0.005	0.053	0.229	0.542	0.186	0.079	0.012	0.002	0.001	0.012
MEANS													
Nitrogen, lb/a													
0			91d	64d	70c	52c	82d	87d	70d	94e	96d	87d	79d
40			138c	103c	104b	72b	117c	129c	106c	134d	146c	129c	118c
80			155b	123b	120a	81a	132b	152b	124b	145c	161b	145b	134b
120			156ab	124ab	126a	82a	136ab	159ab	126b	149bc	161b	147b	137b
160			161ab	125ab	125a	84a	142a	167a	135a	162a	170a	156a	143a
200			164a	131a	126a	83a	141a	165a	131ab	158ab	170a	163a	143a
LSD _(0.05)			9	7	11	5	8	9	8	9	8	8	6
P ₂ O ₅ -K ₂ O, lb/a													
0 - 0			130b	101b	99b	68b	111b	125b	99b	120b	129b	117b	110b
40 - 0			151a	117a	120a	80a	130a	152a	124a	148a	162a	149a	133a
40 - 40			151a	117a	116a	79a	133a	152a	123a	153a	161a	148a	133a
LSD _(0.05)			6	5	7	4	6	6	5	6	5	6	4

Table 2. Nitrogen, phosphorus, and potassium fertilizers on grain N, P, and K content of irrigated grain sorghum, Tribune, KS, 2007-2016.

Fertilizer			Grain						Grain removal					
N	P ₂ O ₅	K ₂ O	N	P	K	N	P	K	N	P	K	*AFNR _g	*AFPR _g	*AFKR _g
----- lb/a -----			----- % -----			----- lb/bu -----			----- lb/acre -----			----- % -----		
0	0	0	1.04	0.267	0.370	0.51	0.131	0.181	37	9	13	---	---	---
0	40	0	1.02	0.314	0.389	0.50	0.154	0.191	41	13	16	---	18	---
0	40	40	1.02	0.312	0.386	0.50	0.153	0.189	41	13	16	---	18	7
40	0	0	1.14	0.239	0.344	0.56	0.117	0.169	57	12	17	49	---	---
40	40	0	1.11	0.318	0.377	0.54	0.156	0.185	69	20	24	79	59	---
40	40	40	1.11	0.311	0.373	0.54	0.152	0.183	67	19	23	73	53	28
80	0	0	1.35	0.226	0.339	0.66	0.111	0.166	76	13	19	49	---	---
80	40	0	1.23	0.299	0.360	0.60	0.146	0.176	85	21	25	60	65	---
80	40	40	1.20	0.311	0.367	0.59	0.153	0.180	83	22	25	57	69	37
120	0	0	1.40	0.213	0.335	0.69	0.104	0.164	77	12	18	33	---	---
120	40	0	1.33	0.287	0.354	0.65	0.141	0.174	95	21	26	48	63	---
120	40	40	1.33	0.309	0.360	0.65	0.151	0.176	98	23	27	50	76	40
160	0	0	1.43	0.233	0.345	0.70	0.114	0.169	87	14	21	31	---	---
160	40	0	1.39	0.309	0.362	0.68	0.151	0.177	104	23	27	42	78	---
160	40	40	1.36	0.288	0.355	0.66	0.141	0.174	100	21	26	39	67	39
200	0	0	1.43	0.239	0.348	0.70	0.117	0.171	91	15	22	27	---	---
200	40	0	1.39	0.288	0.361	0.68	0.141	0.177	101	21	26	32	66	---
200	40	40	1.40	0.294	0.361	0.69	0.144	0.177	103	22	27	33	69	40
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	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	0.001
Quadratic			0.001	0.014	0.001	0.001	0.014	0.001	0.001	0.001	0.001	0.054	0.001	0.001
P-K			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.790	---
Zero P vs. P			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	---	---	---
P vs. P-K			0.435	0.707	0.963	0.435	0.707	0.963	0.672	0.822	0.991	---	---	---
N × P-K			0.407	0.014	0.083	0.407	0.014	0.083	0.101	0.001	0.007	0.001	---	---
MEANS														
Nitrogen, lb/a														
0			1.03e	0.298a	0.382a	0.50e	0.146a	0.187a	40e	12c	15d	---	18c	7c
40			1.12d	0.289ab	0.365b	0.55d	0.142ab	0.179b	64d	17b	21c	67a	56b	28b
80			1.26c	0.279bc	0.355cd	0.62c	0.137bc	0.174cd	82c	18a	23b	55b	67a	37a
120			1.35b	0.269c	0.350d	0.66b	0.132c	0.171d	90b	18a	24b	44c	69a	40a
160			1.39ab	0.277bc	0.354cd	0.68ab	0.136bc	0.174cd	97a	19a	25a	37d	72a	39a
200			1.41a	0.274c	0.357c	0.69a	0.134c	0.175c	98a	19a	25a	30e	67a	40a
LSD _(0.05)			0.04	0.012	0.006	0.02	0.006	0.003	4	1	1	6	8	4
P ₂ O ₅ -K ₂ O, lb/a														
0 - 0			1.30a	0.236b	0.347b	0.64a	0.116b	0.170b	71b	13b	19b	38b	---	---
40 - 0			1.25b	0.303a	0.367a	0.61b	0.148a	0.180a	82a	20a	24a	52a	58	---
40 - 40			1.24b	0.304a	0.367a	0.61b	0.149a	0.180a	82a	20a	24a	51a	59	---
LSD _(0.05)			0.03	0.009	0.004	0.01	0.004	0.002	3	1	1	4	5	---

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