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 2015, N applied alone increased yields 70 bu/a, whereas P applied alone increased yields only 12 bu/a. Nitrogen and P applied together increased yields up to 129 bu/a. This is below the 10 year average, where N and P fertilization increased corn yields up to 144 bu/a. Application of 120 lb/a N (with P) produced about 98% of maximum yield in 2015, which is 5% more than the 10-year average. Application of 80 instead of 40 lb P_2O_5/a increased average yields only 1 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 P_2O_5/bu).

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 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 34N50 (2006), Pioneer 33B54 (2007), Pioneer 34B99 (2008), DeKalb 61-69 (2009), Pioneer 1173H (2010), Pioneer 1151XR (2011), Pioneer 0832 (2012-2013), Pioneer 1186AM (2014), and Pioneer 35F48 AM1 (2015)] were planted at about 32,000 seeds/a in late April or early May. Hail damaged the 2008 and 2010 crops (slight damage on 2015 crop). 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.

Results

Corn yields in 2015 were 17% greater than the 10-year average (Table 1). Nitrogen alone increased yields 70 bu/a, whereas P alone increased yields only 12 bu/a. However, N and P applied together increased corn yields up to 129 bu/a. While maximum yield was obtained with the highest N and P rate, 160 lb/a N with 80 lb/a P_2O_5 caused less than a 2% yield reduction. Corn yields in 2015 (averaged across all N rates) were only 1 bu/a greater with 80 than with 40 lb/a P_2O_5.

Ten-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_2O5/a. 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 less than 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, 2006-2015.

Fertilizer		Yield										Mean
N	P_2O_5	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
- - - - - - - - lb/a - - - - - - - -		- bu/a -										
0	0	42	49	36	85	20	92	86	70	86	92	**66**
0	40	68	50	57	110	21	111	85	80	95	103	**78**
0	80	72	51	52	106	28	105	94	91	98	104	**80**
40	0	56	77	62	108	23	114	109	97	106	113	**87**
40	40	129	112	105	148	67	195	138	125	153	164	**133**
40	80	123	116	104	159	61	194	135	126	149	162	**133**
80	0	79	107	78	123	34	136	128	112	117	131	**104**
80	40	162	163	129	179	85	212	197	170	187	195	**168**
80	80	171	167	139	181	90	220	194	149	179	193	**168**
120	0	68	106	65	117	28	119	134	114	115	124	**99**
120	40	176	194	136	202	90	222	213	204	213	212	**186**
120	80	202	213	151	215	105	225	211	194	216	216	**195**
160	0	84	132	84	139	49	157	158	122	128	144	**120**
160	40	180	220	150	210	95	229	227	199	211	215	**194**
160	80	200	227	146	223	95	226	239	217	233	216	**202**
200	0	115	159	99	155	65	179	170	139	144	162	**139**
200	40	181	224	152	207	97	218	225	198	204	214	**192**
200	80	204	232	157	236	104	231	260	220	238	221	**210**
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		61e	50f	48e	100e	23e	103d	88f	80e	93e	100e	**75f**
40		103d	102e	91d	138d	50d	167c	127e	116d	136d	146d	**118e**
80		137c	146d	115c	161c	70c	189b	173d	143c	161c	173c	**147d**
120		149bc	171c	118c	178b	74bc	189b	186c	171b	181b	184b	**160c**
160		155ab	193b	127b	191a	80ab	204a	208b	179ab	190ab	192ab	**172b**
200		167a	205a	136a	199a	89a	209a	218a	186a	196a	199a	**180a**
$LSD_{(0.05)}$		15	11	9	12	9	13	10	10	10	9	**8**
P_2O_5, lb/a												
0		74c	105b	71b	121c	36b	133b	131c	109b	116c	128b	**102c**
40		149b	160a	122a	176b	76a	198a	181b	163a	177b	184a	**159b**
80		162a	168a	125a	187a	81a	200a	189a	166a	186a	185a	**165a**
$LSD_{(0.05)}$		11	8	6	9	7	9	7	7	7	6	**6**

*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, 2006-2015.

Fertilizer		Grain				Grain Removal	
N	P_2O_5	N	P	N	P	N	P
- - - - - - - - - lb/a - - - - - - - - -		- - - - - - - - - - - - % - - - - - - - - - - -		- - - - - - - - lb/bu - - - - - - - -		- - - - - - - - lb/acre - - - - - - - -	
0	0	1.02	0.233	0.48	0.110	31	7
0	40	0.97	0.310	0.46	0.147	35	11
0	80	0.97	0.318	0.46	0.151	36	12
40	0	1.16	0.185	0.55	0.087	47	7
40	40	0.99	0.298	0.47	0.141	62	19
40	80	1.00	0.321	0.47	0.152	62	20
80	0	1.26	0.178	0.60	0.084	62	9
80	40	1.07	0.257	0.51	0.121	84	20
80	80	1.05	0.306	0.50	0.145	83	24
120	0	1.25	0.173	0.59	0.082	58	8
120	40	1.15	0.228	0.54	0.108	101	20
120	80	1.12	0.296	0.53	0.140	103	27
160	0	1.26	0.178	0.60	0.084	70	10
160	40	1.19	0.243	0.57	0.115	109	22
160	80	1.19	0.282	0.56	0.133	113	27
200	0	1.26	0.185	0.60	0.088	82	12
200	40	1.21	0.240	0.57	0.114	109	22
200	80	1.20	0.296	0.57	0.140	119	29
ANOVA (P>F)							
Nitrogen		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
Quadratic		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
Linear		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
N × P		0.001	0.001	0.001	0.001	0.001	0.001
MEANS							
Nitrogen, lb/a							
0		0.99e	0.287a	0.47e	0.136a	34f	10e
40		1.05d	0.268b	0.50d	0.127b	57e	16d
80		1.13c	0.247c	0.53c	0.117c	76d	18c
120		1.17b	0.232d	0.56b	0.110d	87c	18bc
160		1.21a	0.234d	0.57a	0.111d	97b	20b
200		1.22a	0.240cd	0.58a	0.114cd	103a	21a
$LSD_{(0.05)}$		0.02	0.012	0.01	0.006	5	1
P_2O_5, lb/a							
0		1.20a	0.189c	0.57a	0.089c	58b	9c
40		1.10b	0.263b	0.52b	0.124b	83a	19b
80		1.09b	0.303a	0.52b	0.143a	86a	23a
$LSD_{(0.05)}$		0.01	0.008	0.01	0.004	3	1

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 2015, N applied alone increased yields 66 bu/a, whereas N and P applied together increased yields up to 92 bu/a. Averaged across the past 10 years, N and P fertilization increased sorghum yields up to 76 bu/a. Application of 40 lb/a N (with P) was sufficient to produce 88% of maximum yield in 2015 which is slightly above 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 P_2O_5/bu) and grain K content reached a maximum of 0.19 lb/bu (0.23 lb K_2O/bu).

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 P_2O_5 and zero K; and with 40 lb/a P_2O_5 and 40 lb/a K_2O. All fertilizers are broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. Sorghum (Pioneer 8500/8505 from 2006–2007, Pioneer 85G46 in 2008–2011, Pioneer 84G62 in 2012-2014, and Pioneer 86G32 in 2015) 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.

Results

Grain sorghum yields in 2015 were 22% greater than the 10-year average (Table 1). Nitrogen alone increased yields 66 bu/a while P alone increased yields 13 bu/a. However, N and P applied together increased yields up to 92 bu/a. Averaged across the past 10 years, N and P applied together increased yields up to 76 bu/a. In 2015, 40 lb/a N (with P) produced about 88% of maximum yield, which is slightly above the 10-year average of 84%; 120 lb/a N (with P) and 160 lb/a N (with P) produced 98% and 100% of maximum yield, respectively. Sorghum yields were not affected by K fertilization, which has been the case throughout the study period.

Ten-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 P_2O_5/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 applications 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.

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, 2006-2015.

Fertilizer			Grain sorghum yield										
N	P_2O_5	K_2O	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	**Mean**
lb/a			bu/a										
0	0	0	84	80	66	64	51	75	78	62	90	89	**74**
0	40	0	102	97	60	70	51	83	90	77	94	102	**83**
0	40	40	95	94	65	76	55	88	93	72	96	97	**83**
40	0	0	102	123	92	84	66	106	115	94	115	122	**102**
40	40	0	133	146	111	118	77	121	140	114	144	160	**126**
40	40	40	130	145	105	109	73	125	132	110	142	155	**123**
80	0	0	111	138	114	115	73	117	132	102	120	133	**116**
80	40	0	132	159	128	136	86	140	163	136	151	173	**140**
80	40	40	142	166	126	108	84	138	161	133	164	178	**140**
120	0	0	101	138	106	113	70	116	130	100	116	127	**112**
120	40	0	136	164	131	130	88	145	172	137	162	177	**144**
120	40	40	139	165	136	136	90	147	175	142	170	178	**148**
160	0	0	123	146	105	108	74	124	149	117	139	150	**123**
160	40	0	145	170	138	128	92	152	178	146	171	181	**150**
160	40	40	128	167	133	140	88	151	174	143	176	179	**148**
200	0	0	134	154	120	110	78	128	147	119	139	155	**128**
200	40	0	143	168	137	139	84	141	171	136	165	177	**146**
200	40	40	143	170	135	129	87	152	175	138	170	179	**148**
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			0.004	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			0.578	0.992	0.745	0.324	0.892	0.278	0.826	0.644	0.117	0.806	**0.951**
N × P-K			0.210	0.965	0.005	0.053	0.229	0.542	0.186	0.079	0.012	0.002	**0.035**
MEANS													
Nitrogen, lb/a													
0			93d	91d	64d	70c	52c	82d	87d	70d	94e	96d	**80d**
40			121c	138c	103c	104b	72b	117c	129c	106c	134d	146c	**117c**
80			128bc	155b	123b	120a	81a	132b	152b	124b	145c	161b	**132b**
120			125bc	156ab	124ab	126a	82a	136ab	159ab	126b	149bc	161b	**134b**
160			132ab	161ab	125ab	125a	84a	142a	167a	135a	162a	170a	**140a**
200			140a	164a	131a	126a	83a	141a	165a	131ab	158ab	170a	**141a**
$LSD_{(0.05)}$			11	9	7	11	5	8	9	8	9	8	**6**
P_2O_5-K_2O, lb/a													
0 - 0			109b	130b	101b	99b	68b	111b	125b	99b	120b	129b	**109b**
40 - 0			132a	151a	117a	120a	80a	130a	152a	124a	148a	162a	**132a**
40 - 40			130a	151a	117a	116a	79a	133a	152a	123a	153a	161a	**132a**
$LSD_{(0.05)}$			7	6	5	7	4	6	6	5	6	5	**4**

Table 2. Nitrogen, phosphorus, and potassium fertilizers on grain N, P, and K content of irrigated grain sorghum, Tribune, KS, 2006-2015.

Fertilizer			Grain						Grain Removal		
N	P_2O_5	K_2O	N	P	K	N	P	K	N	P	K
lb/a			%			lb/bu			lb/acre		
0	0	0	1.07	0.267	0.372	0.52	0.131	0.182	39	10	13
0	40	0	1.05	0.315	0.393	0.51	0.154	0.192	42	13	16
0	40	40	1.04	0.312	0.391	0.51	0.153	0.191	42	13	16
40	0	0	1.18	0.240	0.345	0.58	0.117	0.169	59	12	17
40	40	0	1.14	0.317	0.378	0.56	0.156	0.185	70	20	23
40	40	40	1.14	0.311	0.376	0.56	0.152	0.184	68	19	23
80	0	0	1.36	0.227	0.339	0.67	0.111	0.166	77	13	19
80	40	0	1.27	0.301	0.361	0.62	0.147	0.177	86	21	25
80	40	40	1.24	0.312	0.369	0.61	0.153	0.181	84	21	25
120	0	0	1.41	0.215	0.335	0.69	0.105	0.164	77	12	18
120	40	0	1.36	0.288	0.356	0.67	0.141	0.174	96	20	25
120	40	40	1.36	0.311	0.363	0.67	0.153	0.178	98	22	26
160	0	0	1.45	0.236	0.345	0.71	0.115	0.169	88	14	21
160	40	0	1.41	0.311	0.365	0.69	0.152	0.179	104	23	27
160	40	40	1.39	0.292	0.358	0.68	0.143	0.176	100	21	26
200	0	0	1.45	0.242	0.349	0.71	0.119	0.171	91	15	22
200	40	0	1.42	0.294	0.365	0.70	0.144	0.179	101	21	26
200	40	40	1.43	0.297	0.363	0.70	0.146	0.178	103	21	26
ANOVA (P>F)											
Nitrogen			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
Quadratic			0.001	0.009	0.001	0.001	0.009	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
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			0.502	0.718	0.876	0.502	0.718	0.876	0.659	0.890	0.986
N × P-K			0.705	0.014	0.221	0.705	0.014	0.221	0.118	0.002	0.019
MEANS											
Nitrogen, lb/a											
0			1.05e	0.298a	0.385a	0.52e	0.146a	0.189a	41e	12c	15d
40			1.15d	0.289ab	0.367b	0.57d	0.142ab	0.180b	66d	17b	21c
80			1.29c	0.280bc	0.356cd	0.63c	0.137bc	0.175cd	82c	18a	23b
120			1.38b	0.272c	0.351d	0.68b	0.133c	0.172d	90b	18a	23b
160			1.42ab	0.280bc	0.356cd	0.69ab	0.137bc	0.174cd	97a	19a	25a
200			1.43a	0.278bc	0.359c	0.70a	0.136bc	0.176c	98a	19a	25a
$LSD_{(0.05)}$			0.04	0.012	0.007	0.02	0.006	0.003	4	1	1
P_2O_5-K_2O, lb/a											
0 - 0			1.32a	0.238b	0.348b	0.65b	0.117b	0.170b	71b	13b	19b
40 - 0			1.27b	0.304a	0.370a	0.62a	0.149a	0.181a	83a	19a	24a
40 - 40			1.27b	0.306a	0.370a	0.62a	0.150a	0.181a	83a	20a	24a
$LSD_{(0.05)}$			0.03	0.008	0.005	0.01	0.004	0.002	3	1	1