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Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Corn

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Abstract

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.

Keywords

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

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Cover Page Footnote

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Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Corn

A.J. 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 2017, N applied alone increased yields by 70 bu/a, whereas P applied alone increased yields by less than 10 bu/a. Nitrogen and P applied together increased yields up to 130 bu/a. This is 10 bu/a less than the 10-year average, where N and P fertilization increased corn yields up to 140 bu/a. Application of 120 lb/a N (with highest P rate) produced 93% of maximum yield in 2017, which is similar to the 10-year average. Application of 80 instead of 40 lb P_2O_5 /a increased average yields 10 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). At the highest N and P rate, apparent fertilizer nitrogen recovery in the grain (AFNR_g) was 42% and apparent fertilizer phosphorus recovery in the grain (AFPR_g) was 61%.

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 34B99 (2008); DeKalb 61–69 (2009); Pioneer 1173H (2010); Pioneer 1151XR (2011); Pioneer 0832 (2012–2013); Pioneer 1186AM (2014); Pioneer 35F48 AM1 (2015); Pioneer 1197 (2016); and Pioneer 0801 (2017)] were planted at about 32,000 seeds/a in late April or early May. Hail damaged the 2008, 2010, 2015, and 2017 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 har-

vested 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 ($AFPR_g$). Aerial application of insecticide was used for control of grasshoppers on July 18 and hail damage occurred on August 18.

Results

Corn yields in 2017 were 25% lower than the 10-year average (Table 1). Nitrogen alone increased yields 70 bu/a, whereas P alone increased yields less than 10 bu/a. However, N and P applied together increased corn yields up to 130 bu/a. Maximum yield was obtained with 200 lb/a N with 80 lb/a P_2O_5 . Corn yields in 2017 (averaged across all N rates) were 10 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 42% and $AFPR_g$ was 61%. 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 29 lb P/a at the highest yields.

Acknowledgment

The International Plant Nutrition Institute partially supported this research project.

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2008–2017

Fertilizer		Yield										
N	P ₂ O ₅	2008*	2009	2010*	2011	2012	2013	2014	2015*	2016	2017*	Mean
----- lb/a -----		----- bu/a -----										
0	0	36	85	20	92	86	70	86	92	74	44	68
0	40	57	110	21	111	85	80	95	103	78	47	79
0	80	52	106	28	105	94	91	98	104	86	52	82
40	0	62	108	23	114	109	97	106	113	105	60	90
40	40	105	148	67	195	138	125	153	164	145	92	133
40	80	104	159	61	194	135	126	149	162	135	90	132
80	0	78	123	34	136	128	112	117	131	118	70	105
80	40	129	179	85	212	197	170	187	195	196	132	168
80	80	139	181	90	220	194	149	179	193	193	129	167
120	0	65	117	28	119	134	114	115	124	109	62	99
120	40	136	202	90	222	213	204	213	212	212	142	185
120	80	151	215	105	225	211	194	216	216	223	162	192
160	0	84	139	49	157	158	122	128	144	142	84	121
160	40	150	210	95	229	227	199	211	215	226	154	192
160	80	146	223	95	226	239	217	233	216	238	165	200
200	0	99	155	65	179	170	139	144	162	159	114	139
200	40	152	207	97	218	225	198	204	214	216	148	188
200	80	157	236	104	231	260	220	238	221	235	174	208

continued

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2008–2017

Fertilizer		Yield										
N	P ₂ O ₅	2008*	2009	2010*	2011	2012	2013	2014	2015*	2016	2017*	Mean
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		48e	100e	23e	103d	88f	80e	93e	100e	79e	48e	76e
40		91d	138d	50d	167c	127e	116d	136d	146d	129d	81d	118d
80		115c	161c	70c	189b	173d	143c	161c	173c	169c	110c	146c
120		118c	178b	74bc	189b	186c	171b	181b	184b	182b	122b	158b
160		127b	191a	80ab	204a	208b	179ab	190ab	192ab	202a	134a	171a
200		136a	199a	89a	209a	218a	186a	196a	199a	203a	145a	178a
LSD _(0.05)		9	12	9	13	10	10	10	9	10	11	7
P ₂ O ₅ , lb/a												
0		71b	121c	36b	133b	131c	109b	116c	128b	118b	72c	103c
40		122a	176b	76a	198a	181b	163a	177b	184a	179a	119b	157b
80		125a	187a	81a	200a	189a	166a	186a	185a	185a	129a	163a
LSD _(0.05)		6	9	7	9	7	7	7	6	7	8	5

*Note: Hail events on 8/14/2008, 7/23/10, 5/28/15, and 8/18/17. ANOVA = analysis of variance. LSD = least significant difference.

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2008–2017

Fertilizer		Grain				Grain removal		*AFNR _g	*AFPR _g
N	P ₂ O ₅	N	P	N	P	N	P		
----- lb/a -----		----- % -----		----- lb/bu -----		----- lb/a -----		----- % -----	
0	0	0.98	0.232	0.47	0.110	31	7	---	---
0	40	0.95	0.313	0.45	0.148	34	12	---	25
0	80	0.95	0.322	0.45	0.152	36	12	---	15
40	0	1.17	0.184	0.55	0.087	49	8	45	---
40	40	0.97	0.304	0.46	0.144	60	19	73	67
40	80	0.98	0.324	0.46	0.153	60	20	73	36
80	0	1.26	0.181	0.60	0.085	62	9	38	---
80	40	1.05	0.259	0.50	0.122	83	20	65	73
80	80	1.02	0.312	0.48	0.148	79	25	61	49
120	0	1.26	0.175	0.60	0.083	58	8	23	---
120	40	1.13	0.230	0.54	0.109	98	20	56	70
120	80	1.10	0.299	0.52	0.141	99	27	57	55
160	0	1.25	0.179	0.59	0.085	71	10	25	---
160	40	1.18	0.245	0.56	0.116	106	22	47	82
160	80	1.17	0.283	0.55	0.134	110	27	49	54
200	0	1.24	0.188	0.59	0.089	80	12	25	---
200	40	1.19	0.241	0.56	0.114	105	21	37	78
200	80	1.18	0.297	0.56	0.140	115	29	42	61

continued

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2008–2017

Fertilizer		Grain				Grain removal		*AFNR _g	*AFPR _g
N	P ₂ O ₅	N	P	N	P	N	P		
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	0.035	0.088
MEANS									
Nitrogen, lb/a		----- % -----		----- lb/bu -----		----- lb/a -----		----- % -----	
0		0.96e	0.289a	0.46e	0.137a	34f	10e	---	20d
40		1.04d	0.271b	0.49d	0.128b	56e	16d	64a	52c
80		1.11c	0.250c	0.53c	0.118c	75d	18c	55b	61b
120		1.16b	0.235d	0.55b	0.111d	85c	18bc	45c	63ab
160		1.20a	0.236d	0.57a	0.111d	96b	19b	40d	68ab
200		1.20a	0.242cd	0.57a	0.115cd	100a	21a	35e	70a
LSD _(0.05)		0.02	0.011	0.01	0.005	4	1	5	8
P ₂ O ₅ , lb/a									
0		1.19a	0.190c	0.56a	0.090c	59b	9c	31b	---
40		1.08b	0.265b	0.51b	0.126b	81a	19b	56a	66a
80		1.07b	0.306a	0.50b	0.145a	83a	23a	56a	45b
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). ANOVA = analysis of variance. LSD = least significant difference.