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Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Grain Sorghum

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Abstract

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 P_2O_5/bu) and grain K content reached a maximum of 0.19 lb/bu (0.23 lb K_2O/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.

Keywords

nitrogen fertilization, phosphorus fertilization, irrigated grain sorghum, long-term fertility, nutrient removal

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Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Grain Sorghum

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 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 P_2O_5/bu) and grain K content reached a maximum of 0.19 lb/bu (0.23 lb K_2O/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 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 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 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$_g$) 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 P$_2$O$_5$/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 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.

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

Fertilizer			Grain sorghum yield										Mean
N	P_2O_5	K_2O	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
----------- 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

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

Fertilizer			Grain sorghum yield										Mean
N	P_2O_5	K_2O	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
----------- 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
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_2O_5-K_2O, 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

N = nitrogen.
P = phosphorus.
K = potassium.
ANOVA = analysis of variance.
LSD = least significant difference.

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			*AFNR$_g$	*AFPR$_g$	*AFKR$_g$
N	P$_2$O$_5$	K$_2$O	N	P	K	N	P	K	N	P	K			
----------- 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

continued

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			Grain removal			*AFNR$_g$	*AFPR$_g$	*AFKR$_g$
N	P$_2$O$_5$	K$_2$O	N	P	K	N	P	K	N	P	K			
----------- lb/a -----------			----------------- % -----------------			-------------- lb/bu --------------			----------- lb/acre -----------			----------------- % -----------------		
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).
N = nitrogen.
P = phosphorus.
K = potassium.
ANOVA = analysis of variance.
LSD = least significant difference.