

Long-Term Nitrogen, Phosphorus, and Potassium 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 2018, N applied alone increased yields 44 bu/a, whereas N and P applied together increased yields up to 67 bu/a. Averaged across the past 10 years, N and P fertilization increased sorghum yields up to 75 bu/a. Application of 80 lb/a N (with P) produced the maximum yield in 2018, which is slightly less than the 10-year 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 31% for N, 65% for P, and 38% 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 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 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. Grain sorghum (Pioneer 85G46 in 2009–2011, Pioneer 84G62 in 2012–2014, Pioneer 86G32 in 2015, Pioneer 84G62 in 2016–2017, and Pioneer 85P44 in 2018) 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 mi-

nus 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 2018 were 5% lower than the 10-year average (Table 1). Nitrogen alone increased yields 44 bu/a, while P alone increased yields less than 10 bu/a. However, N and P applied together increased yields up to 67 bu/a. Averaged across the past 10 years, N and P applied together increased yields up to 75 bu/a. In 2018, 40 lb/a N (with P) produced about 88% of maximum yield, which is greater than the 10-year average of 85%. The 10-year average for 80 lb/a N (with P) and 120 lb/a N (with P) was 94 and 95% 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 22 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 22 to 26 lb/a. At the highest N, P, and K rate, apparent fertilizer recovery in the grain was 31% for N, 65% for P, and 38% for K.

Acknowledgment

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Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2009-2018

Fertilizer			Grain sorghum yield										Mean
N	P ₂ O ₅	K ₂ O	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
----- lb/a -----			----- bu/a -----										
0	0	0	64	51	75	78	62	90	89	80	70	77	74
0	40	0	70	51	83	90	77	94	102	91	79	87	83
0	40	40	76	55	88	93	72	96	97	91	80	83	83
40	0	0	84	66	106	115	94	115	122	106	87	93	99
40	40	0	118	77	121	140	114	144	160	142	120	126	126
40	40	40	109	73	125	132	110	142	155	137	118	131	123
80	0	0	115	73	117	132	102	120	133	120	104	103	112
80	40	0	136	86	140	163	136	151	173	154	123	144	141
80	40	40	108	84	138	161	133	164	178	160	129	140	140
120	0	0	113	70	116	130	100	116	127	108	93	91	106
120	40	0	130	88	145	172	137	162	177	164	121	128	142
120	40	40	136	90	147	175	142	170	178	170	131	143	148
160	0	0	108	74	124	149	117	139	150	135	120	107	122
160	40	0	128	92	152	178	146	171	181	173	137	134	149
160	40	40	140	88	151	174	143	176	179	161	131	139	148
200	0	0	110	78	128	147	119	139	155	151	123	121	127
200	40	0	139	84	141	171	136	165	177	167	131	134	145
200	40	40	129	87	152	175	138	170	179	170	131	130	146

continued

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Fertilizer			Grain sorghum yield										
N	P ₂ O ₅	K ₂ O	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
----- 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			0.324	0.892	0.278	0.826	0.644	0.117	0.806	0.943	0.727	0.549	0.833
N × P-K			0.053	0.229	0.542	0.186	0.079	0.012	0.002	0.001	0.084	0.003	0.007
MEANS													
Nitrogen, lb/a													
0			70 c	52 c	82 d	87 d	70 d	94 e	96 d	87 d	76 d	82 c	80 d
40			104 b	72 b	117 c	129 c	106 c	134 d	146 c	129 c	108 c	117 b	116 c
80			120 a	81 a	132 b	152 b	124 b	145 c	161 b	145 b	119 b	129 a	131 b
120			126 a	82 a	136 ab	159 ab	126 b	149 bc	161 b	147 b	115 bc	121 ab	132 b
160			125 a	84 a	142 a	167 a	135 a	162 a	170 a	156 a	129 a	127 a	140 a
200			126 a	83 a	141 a	165 a	131 ab	158 ab	170 a	163 a	129 a	128 a	139 a
LSD _(0.05)			11	5	8	9	8	9	8	8	9	9	6
P ₂ O ₅ -K ₂ O, lb/a													
0 - 0			99 b	68 b	111 b	125 b	99 b	120 b	129 b	117 b	99 b	99 b	107 b
40 - 0			120 a	80 a	130 a	152 a	124 a	148 a	162 a	149 a	119 a	126 a	131 a
40 - 40			116 a	79 a	133 a	152 a	123 a	153 a	161 a	148 a	120 a	128 a	131 a
LSD _(0.05)			7	4	6	6	5	6	5	6	6	6	4

ANOVA = analysis of variance.

LSD = least significant difference.

Table 2. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on grain N, P, and K content of irrigated grain sorghum, Tribune, KS, 2009-2018

Fertilizer			Grain						Grain removal					
N	P ₂ O ₅	K ₂ O	N	P	K	N	P	K	N	P	K	*AFNRg	*AFPRg	*AFKRg
----- lb/a -----			----- % -----			----- lb/bu -----			----- lb/a -----			----- % -----		
0	0	0	1.05	0.256	0.358	0.51	0.125	0.176	38	9	13	---	---	---
0	40	0	1.04	0.311	0.382	0.51	0.152	0.187	42	13	15	---	20	---
0	40	40	1.04	0.310	0.382	0.51	0.152	0.187	42	13	16	---	20	8
40	0	0	1.15	0.233	0.346	0.57	0.114	0.170	55	11	17	44	---	---
40	40	0	1.12	0.314	0.371	0.55	0.154	0.182	69	19	23	78	59	---
40	40	40	1.12	0.309	0.370	0.55	0.152	0.181	67	19	22	73	55	29
80	0	0	1.35	0.218	0.340	0.66	0.107	0.167	73	12	19	45	---	---
80	40	0	1.23	0.295	0.358	0.60	0.145	0.175	84	20	25	58	64	---
80	40	40	1.20	0.304	0.359	0.59	0.149	0.176	81	21	25	55	67	35
120	0	0	1.41	0.204	0.337	0.69	0.100	0.165	73	11	17	29	---	---
120	40	0	1.32	0.283	0.355	0.65	0.139	0.174	92	20	25	45	60	---
120	40	40	1.32	0.302	0.357	0.65	0.148	0.175	96	22	26	48	73	39
160	0	0	1.41	0.228	0.345	0.69	0.112	0.169	84	14	21	29	---	---
160	40	0	1.39	0.304	0.360	0.68	0.149	0.177	101	22	26	40	75	---
160	40	40	1.36	0.280	0.353	0.67	0.137	0.173	98	20	26	38	63	38
200	0	0	1.43	0.234	0.349	0.70	0.115	0.171	88	15	22	25	---	---
200	40	0	1.39	0.281	0.358	0.68	0.138	0.175	98	20	25	30	61	---
200	40	40	1.40	0.288	0.359	0.68	0.141	0.176	99	20	26	31	65	38

continued

Table 2. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on grain N, P, and K content of irrigated grain sorghum, Tribune, KS, 2009-2018

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/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	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	0.011	0.001	0.001	0.011	0.001	0.001	0.001	0.001	0.042	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	0.819	---
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			0.477	0.846	0.726	0.477	0.846	0.726	0.813	0.843	0.962	---	---	---
N × P-K			0.236	0.013	0.347	0.236	0.013	0.347	0.147	0.001	0.005	0.019	0.110	---
MEANS														
Nitrogen, lb/a														
0			1.04 e	0.292 a	0.374 a	0.51 e	0.143 a	0.183 a	40 e	11 c	15 d	---	20 c	8 c
40			1.13 d	0.286 a	0.362 b	0.55 d	0.140 a	0.178 b	63 d	16 b	21 c	65 a	57 b	29 b
80			1.26 c	0.272 b	0.353 c	0.62 c	0.133 b	0.173 c	80 c	18 ab	23 b	53 b	65 ab	35 a
120			1.35 b	0.263 b	0.350 c	0.66 b	0.129 b	0.172 c	87 b	17 ab	23 b	41 c	66 a	39 a
160			1.39 ab	0.271 b	0.353 c	0.68 ab	0.133 b	0.173 c	95 a	19 a	24 a	36 c	69 a	38 a
200			1.41 a	0.268 b	0.355 c	0.69 a	0.131 b	0.174 c	95 a	18 a	24 a	29 d	63 ab	38 a
LSD _(0.05)			0.04	0.012	0.006	0.02	0.006	0.003	5	1	1	6	8	5
P ₂ O ₅ -K ₂ O, lb/a														
0 - 0			1.30 a	0.229 b	0.346 b	0.64 a	0.112 b	0.170 b	69 b	12 b	18 b	35 b	---	---
40 - 0			1.25 b	0.298 a	0.364 a	0.61 b	0.146 a	0.178 a	81 a	19 a	23 a	50 a	56	---
40 - 40			1.24 b	0.299 a	0.363 a	0.61 b	0.146 a	0.178 a	81 a	19 a	23 a	49 a	57	---
LSD _(0.05)			0.03	0.009	0.004	0.01	0.004	0.002	3	1	1	5	5	---

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

ANOVA = analysis of variance.

LSD = least significant difference.