

Long-Term Nitrogen, Phosphorus, and Potassium 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 2019, N applied alone increased yields by 66 bu/a, whereas N and P applied together increased yields up to 85 bu/a. Averaged across the past 10 years, N and P fertilization increased sorghum yields up to 78 bu/a. Application of 160 lb/a N (with P) produced the maximum yield in 2019, which is slightly more 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 0.16 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 were 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 2010-2011, Pioneer 84G62 in 2012-2014, Pioneer 86G32 in 2015, Pioneer 84G62 in 2016-2017, and Pioneer 85P44 in 2018-2019) 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 fer-

tilizer 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 2019 were 3% lower than the 10-year average (Table 1). Nitrogen alone increased yields by 66 bu/a while P alone increased yields 6 bu/a. However, N and P applied together increased yields up to 85 bu/a. Averaged across the past 10 years, N and P applied together increased yields up to 78 bu/a. In 2019, 40 lb/a N (with P) produced about 74% of maximum yield, which is less than the 10-year average of 83%. The 10-year average for 80 lb/a N (with P) and 120 lb/a N (with P) was 93 and 94% 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.

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Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2010–2019

Fertilizer			Yield										
N	P ₂ O ₅	K ₂ O	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
lb/a			bu/a										
0	0	0	51	75	78	62	90	89	80	70	77	68	74
0	40	0	51	83	90	77	94	102	91	79	87	74	83
0	40	40	55	88	93	72	96	97	91	80	83	67	82
40	0	0	66	106	115	94	115	122	106	87	93	94	100
40	40	0	77	121	140	114	144	160	142	120	126	113	126
40	40	40	73	125	132	110	142	155	137	118	131	114	124
80	0	0	73	117	132	102	120	133	120	104	103	109	111
80	40	0	86	140	163	136	151	173	154	123	144	145	141
80	40	40	84	138	161	133	164	178	160	129	140	139	143
120	0	0	70	116	130	100	116	127	108	93	91	102	105
120	40	0	88	145	172	137	162	177	164	121	128	139	143
120	40	40	90	147	175	142	170	178	170	131	143	150	150
160	0	0	74	124	149	117	139	150	135	120	107	129	124
160	40	0	92	152	178	146	171	181	173	137	134	153	152
160	40	40	88	151	174	143	176	179	161	131	139	142	148
200	0	0	78	128	147	119	139	155	151	123	121	134	130
200	40	0	84	141	171	136	165	177	167	131	134	140	145
200	40	40	87	152	175	138	170	179	170	131	130	149	148

continued

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Fertilizer			Yield										
N	P ₂ O ₅	K ₂ O	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	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			0.892	0.278	0.826	0.644	0.117	0.806	0.943	0.727	0.549	0.789	0.726
N × P-K			0.229	0.542	0.186	0.079	0.012	0.002	0.001	0.084	0.003	0.001	0.001
MEANS													
Nitrogen, lb/a													
0			52 c	82 d	87 d	70 d	94 e	96 d	87 d	76 d	82 c	70 d	80 d
40			72 b	117 c	129 c	106 c	134 d	146 c	129 c	108 c	117 b	107 c	116 c
80			81 a	132 b	152 b	124 b	145 c	161 b	145 b	119 b	129 a	131 b	132 b
120			82 a	136 ab	159 ab	126 b	149 bc	161 b	147 b	115 bc	121 ab	130 b	133 b
160			84 a	142 a	167 a	135 a	162 a	170 a	156 a	129 a	127 a	142 a	142 a
200			83 a	141 a	165 a	131 ab	158 ab	170 a	163 a	129 a	128 a	141 a	141 a
LSD _(0.05)			5	8	9	8	9	8	8	9	9	7	6
P ₂ O ₅ -K ₂ O, lb/a													
0 - 0			68 b	111 b	125 b	99 b	120 b	129 b	117 b	99 b	99 b	106 b	107 b
40 - 0			80 a	130 a	152 a	124 a	148 a	162 a	149 a	119 a	126 a	127 a	132 a
40 - 40			79 a	133 a	152 a	123 a	153 a	161 a	148 a	120 a	128 a	127 a	132 a
LSD _(0.05)			4	6	6	5	6	5	6	6	6	5	4

**Note: Hail events on 7/23/2010, 5/28/2015, 8/18/2017, and 9/20/2019.

ANOVA = analysis of variance. LSD = least significant difference.

Table 2. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on grain nutrient content and removal by irrigated grain sorghum, Tribune, KS, 2010–2019

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			%		
0	0	0	1.04	0.251	0.354	0.51	0.123	0.173	37	9	13	---	---	---
0	40	0	1.03	0.313	0.380	0.51	0.153	0.186	41	13	15	---	21	---
0	40	40	1.03	0.311	0.380	0.50	0.152	0.186	41	12	15	---	20	7
40	0	0	1.15	0.227	0.341	0.56	0.111	0.167	55	11	17	45	---	---
40	40	0	1.11	0.315	0.368	0.54	0.155	0.180	68	19	23	76	60	---
40	40	40	1.11	0.309	0.364	0.54	0.152	0.178	67	19	22	73	56	28
80	0	0	1.35	0.212	0.337	0.66	0.104	0.165	73	12	18	44	---	---
80	40	0	1.21	0.293	0.352	0.60	0.144	0.173	83	20	24	57	64	---
80	40	40	1.19	0.305	0.356	0.58	0.149	0.174	83	21	25	56	70	37
120	0	0	1.41	0.196	0.334	0.69	0.096	0.164	72	10	17	29	---	---
120	40	0	1.31	0.279	0.350	0.64	0.137	0.172	91	19	25	45	60	---
120	40	40	1.32	0.300	0.354	0.65	0.147	0.173	96	22	26	49	74	39
160	0	0	1.40	0.224	0.342	0.69	0.110	0.167	85	14	21	30	---	---
160	40	0	1.39	0.301	0.354	0.68	0.148	0.173	103	22	26	41	76	---
160	40	40	1.36	0.276	0.349	0.67	0.135	0.171	98	20	25	38	63	38
200	0	0	1.41	0.230	0.346	0.69	0.113	0.169	89	15	22	26	---	---
200	40	0	1.39	0.280	0.355	0.68	0.137	0.174	98	20	25	30	62	---
200	40	40	1.39	0.284	0.352	0.68	0.139	0.173	100	20	26	31	65	38

continued

Table 2. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on grain nutrient content and removal by irrigated grain sorghum, Tribune, KS, 2010–2019

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	0.007	0.001	0.001	0.007	0.001	0.001	0.001	0.001	0.050	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	0.736	---
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			0.589	0.876	0.758	0.589	0.876	0.758	0.985	0.779	0.823	---	---	---
N × P-K			0.060	0.013	0.082	0.060	0.013	0.082	0.120	0.001	0.001	0.045	0.041	---
MEANS														
Nitrogen, lb/a														
0			1.03 e	0.292 a	0.371 a	0.51 e	0.143 a	0.182 a	40 e	11 d	15 d	---	21 c	7 c
40			1.12 d	0.284 a	0.358 b	0.55 d	0.139 a	0.175 b	63 d	16 c	21 c	65 a	58 b	28 b
80			1.25 c	0.270 b	0.348 c	0.61 c	0.132 b	0.171 c	80 c	18 abc	23 b	53 b	67 a	37 a
120			1.35 b	0.258 b	0.346 c	0.66 b	0.127 b	0.169 c	86 b	17 bc	23 b	41 c	67 a	39 a
160			1.38 ab	0.267 b	0.348 c	0.68 ab	0.131 b	0.171 c	95 a	19 a	24 a	36 c	69 a	38 a
200			1.40 a	0.264 b	0.351 c	0.68 a	0.130 b	0.172 c	96 a	18 ab	24 a	29 d	64 ab	38 a
LSD _(0.05)			0.04	0.013	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			1.29 a	0.223 b	0.342 b	0.63 a	0.109 b	0.168 b	69 b	12 b	18 b	35 b	---	---
40 - 0			1.24 b	0.297 a	0.360 a	0.61 b	0.145 a	0.176 a	81 a	19 a	23 a	50 a	57	---
40 - 40			1.23 b	0.298 a	0.359 a	0.60 b	0.146 a	0.176 a	81 a	19 a	23 a	49 a	58	---
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.