Kansas Agricultural Experiment Station Research Reports

Volume 2
Issue 6 *Kansas Fertilizer Research*

Article 10

January 2016

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

Keywords

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

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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-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 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.

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_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.

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

continued

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 ----------										
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/a		
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

continued

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/a ----------		
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