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Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Grain Sorghum

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Abstract
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.

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

Cover Page Footnote
The International Plant Nutrition Institute partially supported this research project.

Long-Term Nitrogen and Phosphorus 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 2017, N applied alone increased yields 53 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 77 bu/a. Application of 80 lb/a N (with P) was sufficient to produce almost 90% of maximum yield in 2017, 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 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 32% for N, 66% for P, and 39% 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 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 85G46 in 2008–2011, Pioneer 84G62 in 2012–2014, Pioneer 86G32 in 2015, and Pioneer 84G62 in 2016–2017) 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 ($AFKR_g$).

Aerial application of insecticide was used for control of grasshoppers on July 18 and hail damage occurred on August 18.

Results

Grain sorghum yields in 2017 were 8% lower than the 10-year average (Table 1). Nitrogen alone increased yields 53 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 77 bu/a. In 2017, 40 lb/a N (with P) produced about 88% of maximum yield, which is greater 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 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 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 removal ranging from 18 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 32% for N, 66% for P, and 39% for K.

Acknowledgment

The International Plant Nutrition Institute partially supported this research project.

Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2008–2017

Fertilizer			Grain sorghum yield										
N	P_2O_5	K_2O	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Mean
lb/a			bu/a										
0	0	0	66	64	51	75	78	62	90	89	80	70	73
0	40	0	60	70	51	83	90	77	94	102	91	79	80
0	40	40	65	76	55	88	93	72	96	97	91	80	81
40	0	0	92	84	66	106	115	94	115	122	106	87	99
40	40	0	111	118	77	121	140	114	144	160	142	120	125
40	40	40	105	109	73	125	132	110	142	155	137	118	121
80	0	0	114	115	73	117	132	102	120	133	120	104	113
80	40	0	128	136	86	140	163	136	151	173	154	123	139
80	40	40	126	108	84	138	161	133	164	178	160	129	138
120	0	0	106	113	70	116	130	100	116	127	108	93	108
120	40	0	131	130	88	145	172	137	162	177	164	121	143
120	40	40	136	136	90	147	175	142	170	178	170	131	147
160	0	0	105	108	74	124	149	117	139	150	135	120	122
160	40	0	138	128	92	152	178	146	171	181	173	137	150
160	40	40	133	140	88	151	174	143	176	179	161	131	147
200	0	0	120	110	78	128	147	119	139	155	151	123	127
200	40	0	137	139	84	141	171	136	165	177	167	131	145
200	40	40	135	129	87	152	175	138	170	179	170	131	147

continued

Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2008–2017

Fertilizer			Grain sorghum yield										
N	P_2O_5	K_2O	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
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			0.745	0.324	0.892	0.278	0.826	0.644	0.117	0.806	0.943	0.727	0.932
N × P-K			0.005	0.053	0.229	0.542	0.186	0.079	0.012	0.002	0.001	0.084	0.006
MEANS													
Nitrogen, lb/a			---------- bu/a ----------										
0			64d	70c	52c	82d	87d	70d	94e	96d	87d	76d	78d
40			103c	104b	72b	117c	129c	106c	134d	146c	129c	108c	115c
80			123b	120a	81a	132b	152b	124b	145c	161b	145b	119b	130b
120			124ab	126a	82a	136ab	159ab	126b	149bc	161b	147b	115bc	133b
160			125ab	125a	84a	142a	167a	135a	162a	170a	156a	129a	140a
200			131a	126a	83a	141a	165a	131ab	158ab	170a	163a	129a	140a
$LSD_{(0.05)}$			7	11	5	8	9	8	9	8	8	9	6
P_2O_5-K_2O, lb/a													
0 - 0			101b	99b	68b	111b	125b	99b	120b	129b	117b	99b	107b
40 - 0			117a	120a	80a	130a	152a	124a	148a	162a	149a	119a	130a
40 - 40			117a	116a	79a	133a	152a	123a	153a	161a	148a	120a	130a
$LSD_{(0.05)}$			5	7	4	6	6	5	6	5	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, 2008–2017

Fertilizer			Grain			Grain removal					
N	P_2O_5	K_2O	N	P	K	N	P	K	*$AFNR_g$	*$AFPR_g$	*$AFKR_g$
lb/a			%			lb/bu			lb/a			%		
0	0	0	1.02	0.263	0.361	0.50	0.129	0.177	36	9	13	---	---	---
0	40	0	1.01	0.315	0.385	0.50	0.154	0.189	39	12	15	---	18	---
0	40	40	1.01	0.312	0.382	0.50	0.153	0.187	40	12	15	---	18	7
40	0	0	1.13	0.239	0.345	0.55	0.117	0.169	54	11	17	45	---	---
40	40	0	1.09	0.318	0.373	0.53	0.156	0.183	66	19	23	76	58	---
40	40	40	1.10	0.311	0.370	0.54	0.152	0.181	64	18	22	70	52	27
80	0	0	1.33	0.223	0.339	0.65	0.109	0.166	73	12	19	47	---	---
80	40	0	1.22	0.298	0.357	0.60	0.146	0.175	82	20	24	58	63	---
80	40	40	1.18	0.306	0.360	0.58	0.150	0.176	79	21	24	54	66	35
120	0	0	1.39	0.210	0.336	0.68	0.103	0.164	73	11	18	31	---	---
120	40	0	1.32	0.286	0.354	0.65	0.140	0.174	92	20	25	46	61	---
120	40	40	1.32	0.306	0.358	0.64	0.150	0.175	95	22	26	49	73	39
160	0	0	1.41	0.233	0.345	0.69	0.114	0.169	84	14	21	30	---	---
160	40	0	1.38	0.307	0.361	0.68	0.150	0.177	101	22	26	41	76	---
160	40	40	1.35	0.286	0.353	0.66	0.140	0.173	97	20	25	38	64	38
200	0	0	1.42	0.238	0.349	0.70	0.117	0.171	88	15	22	26	---	---
200	40	0	1.39	0.285	0.357	0.68	0.140	0.175	98	20	25	31	63	---
200	40	40	1.39	0.291	0.359	0.68	0.143	0.176	99	21	26	32	66	39

continued

Table 2. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on grain N, P, and K content of irrigated grain sorghum, Tribune, KS, 2008–2017

Fertilizer			Grain			Grain removal					
N	P_2O_5	K_2O	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	0.005	0.001	0.001	0.005	0.001	0.001	0.001	0.001	0.094	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	0.911	---
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			0.363	0.900	0.680	0.363	0.900	0.680	0.614	0.922	0.925	---	---	---
N × P-K			0.285	0.009	0.231	0.285	0.009	0.231	0.080	0.001	0.003	0.029	0.093	---
MEANS														
Nitrogen, lb/a														
0			1.01e	0.297a	0.376a	0.50e	0.146a	0.184a	38e	11d	14d	---	18c	7c
40			1.11d	0.289a	0.363b	0.54d	0.142a	0.178b	61d	16c	20c	64a	55b	27b
80			1.24c	0.276b	0.352c	0.61c	0.135b	0.172c	78c	18ab	22b	53b	64a	35a
120			1.34b	0.267b	0.349c	0.66b	0.131b	0.171c	86b	18bc	23b	42c	67a	39a
160			1.38ab	0.275b	0.353c	0.68ab	0.135b	0.173c	94a	19a	24a	36d	70a	38a
200			1.40a	0.272b	0.355c	0.68a	0.133b	0.174c	95a	19ab	24a	29e	64a	39a
$LSD_{(0.05)}$			0.04	0.012	0.006	0.02	0.006	0.003	4	1	1	6	8	5
P_2O_5-K_2O, lb/a														
0 - 0			1.28a	0.234b	0.346b	0.63a	0.115b	0.169b	68b	12b	18b	36b	---	---
40 - 0			1.24b	0.302a	0.365a	0.61b	0.148a	0.179a	80a	19a	23a	50a	56	---
40 - 40			1.22b	0.302a	0.364a	0.60b	0.148a	0.178a	79a	19a	23a	48a	56	---
$LSD_{(0.05)}$			0.03	0.008	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.