To Paul - Larry
From Larry S
Re: More Buffalo Bones - HA Good Points

1991

PROJECT TITLE: EFFECT OF LONG TERM NITROGEN, PHOSPHORUS, AND POTASSIUM FERTILIZATION OF IRRIGATED CORN AND GRAIN SORGHUM

PROJECT LEADER:
Alan Schlegel
Southwest Research-Extension Center
Rt.1, Box 148
Tribune, KS 67879

PROJECT LOCATION: West-central Kansas at the Tribune Unit, Southwest Research-Extension Center.

OBJECTIVES:

1. Determine the optimum nitrogen rate for irrigated corn and grain sorghum.

2. Determine whether phosphorus fertilization is necessary for optimum grain production of irrigated corn and grain sorghum.

3. Determine whether potassium fertilization is necessary for optimum grain production of irrigated corn and grain sorghum.

4. Determine the effect of long term N and P applications on nitrate accumulation in the soil profile.

RESULTS:

1. Nitrogen fertilization is required for optimum production of irrigated corn and grain sorghum in western Kansas. Maximum corn yields in 1991 were obtained with 160 lb N/acre and maximum grain sorghum yields obtained with 80 lb N/acre.

2. Phosphorus fertilization increases grain yields of irrigated corn and grain sorghum. A yield response from P fertilizer has been observed for the last 25 years in this long term study. This response has increased with time and in 1991 corn yields were increased by over 100 bu/acre and sorghum yields increased 30 bu/acre by P fertilizer when adequate N was also applied.

3. Corn and grain sorghum yields are not increased by K additions due to inherently high K content of the soil.

4. Nitrate accumulation in the soil profile increased with increased N rate. The application of P with N reduced nitrate accumulation. With sorghum, N rates in excess of 120 lb N/acre significantly increased soil nitrate content, particularly deeper in the soil profile (5-10 ft depth).

The results of this study can be cited by PPI/FAR.

PROJECT CHANGES:

Several additional objectives are being added to the project. They are to 1.) determine the effect of long term NPK applications on soil chemical properties, 2.) determine the effect of P fertilization on crop utilization of N fertilizer.

ECONOMIC ANALYSIS:

Substantially higher grain yields of irrigated corn and grain sorghum can be obtained when both N and P fertilizer are applied than from N alone. Long term research with irrigated corn and grain sorghum has shown that economically optimal N rates are relatively constant across years. Grain yields vary from year to year even under irrigation due to a number of factors. Yields from the past 30 years were grouped into three categories (low, medium, and high yield potential years) and the economically optimum N rate calculated for each group. For corn, the optimum N rate was about 160 lb N/acre for all groups. The optimum N rate for sorghum was about 140 lb N/acre for medium and high yielding years and about 120 lb N/acre for low yielding years. Applying N in excess of these values resulted in reduced net return. For example, applying an excess of 20 lb N/acre on corn would reduce net return about $4.90/acre (corn at $2.50/bu and N at $0.15/lb) while applying an excess of 40 lb N/acre would reduce net return $16.10/acre. This demonstrates the fallacy of applying "insurance N", N applied in excess of optimum rate to insure adequate N in case of higher than expected yields.

INTERPRETIVE SUMMARY:

Long term research shows that phosphorus fertilizer must be applied for optimum grain yields of irrigated corn and grain sorghum in western Kansas. In 1991, P fertilizer (40 lb P_2O_5/acre) increased corn yields over 100 bu/acre and grain sorghum yields 30 bu/acre when adequate N was also applied. In this study, the optimum economic N rate (with P) for corn and sorghum remains relatively constant. When yields from the past 30 years were grouped into low, medium, and high yielding years, the economically optimum N rate for corn was about 160 lb N/acre for all three groups. With sorghum, the economically optimum N rate was about 140 lb N/acre for medium and high yielding years and about 120 lb N/acre for low yielding years. Nitrogen applied in excess of these amounts reduced net return and tended to increase nitrate movement deeper into the soil profile.

EFFECT OF NITROGEN, PHOSPHORUS, AND POTASSIUM FERTILIZATION OF IRRIGATED CORN AND GRAIN SORGHUM

Alan Schlegel

This study was initiated in 1961 to determine responses of continuous corn and grain sorghum grown under flood irrigation to nitrogen, phosphorus, and potassium fertilization.

Procedure

Corn and grain sorghum were grown on Ulysses silt loam in adjacent plot areas. Fertilizer treatments were N rates of 0, 40, 80, 120, 160, and 200 lb N $acre^{-1}$ without P and K; with 40 lb P_2O_5 $acre^{-1}$ and zero K; and with 40 lb P_2O_5 $acre^{-1}$ and 40 lb K_2O $acre^{-1}$. Fertilizers were broadcast by hand on 15 April 1990 for corn and 8 May 1990 for sorghum. Corn (Pioneer 3379) was planted on 23 April, and sorghum (Golden Acres TE Y-75) was planted on 22 May. Rainfall from planting to harvest was 13.56" for corn and 12.01" for sorghum. Both studies were furrow irrigated as needed during the growing season. All plots were machine harvested (2 October for corn and 21 October for sorghum). Grain yields were adjusted to 15.5% moisture for corn and 12.5% for sorghum.

Results

Corn yields in 1991 ranged from 64 to 206 bu $acre^{-1}$ (Table 1). Nitrogen applications increased yields for each increment of N up to 160 lb N $acre^{-1}$. Addition of phosphorus (40 lb P_2O_5 $acre^{-1}$) increased corn yields by 73 bu $acre^{-1}$ when averaged across N rates. The benefit from P addition increased with increased N rates to over 100 bu $acre^{-1}$ higher yields with P at optimum N rates.

Grain sorghum yields ranged from 59 to 146 bu $acre^{-1}$ in 1991 (Table 1). Grain yields increased with increased N up to 80 lb N $acre^{-1}$. When averaged across N rates, P increased yields by 24 bu $acre^{-1}$.

The benefit from P fertilization has increased with time. Phosphorus increased corn yields 24 bu/acre averaged over 31 years, 37 bu/acre averaged over the past 10 years, and 73 bu/acre in 1991. With grain sorghum, P increased yields 12 bu/acre averaged over 31 years, 18 bu/acre averaged over the past 10 years, and 24 bu/acre in 1991.

Potassium applications had no significant effect on corn or sorghum yields in 1991. The plot area is located on a soil inherently high in K, and the effect of K additions has always been negligible.

The amount of N and P contained in grain increased with

increased N rates and from P applications for both corn and sorghum in 1990 (Tables 2 and 3). Grain N and P content was about 50% more for corn than sorghum reflecting the higher corn yields. At optimum N rates, corn grain contained about 100 lb N/acre and sorghum grain about 70 lb N/acre. Phosphorus content of the grain was about 20 lb P/acre for corn and 14 lb P/acre for sorghum.

Soil nitrate levels after 30 years of N applications were quite variable but tended to increase with increased N rates (Tables 4 and 5).

Conclusions

Grain yields of irrigated corn and grain sorghum are increased by N and P applications but not by K additions. Averaged over the 31 years of this study, the optimal N rate is about 160 lb N $acre^{-1}$ for corn and about 135 lb N $acre^{-1}$ for sorghum. The addition of P, averaged over the past 10 years, has increased corn yields by approximately 50 bu $acre^{-1}$ and grain sorghum yields by about 20 bu $acre^{-1}$ at optimum N rates.

Table 1. Effect of nitrogen, phosphorus, and potassium on yield of irrigated grain sorghum and corn, Tribune, KS.

N	P_2O_5	K_2O	Sorghum			Corn		
			1991	1982-1991	1961-1991	1991	1982-1991	1961-1991
- lb/acre -			- - - - - - - - - bu/acre§ - - - - - - - - -					
0	0	0	67	72	72	64	82	70
0	40	0	59	72	73	78	87	73
0	40	40	71	74	74	75	90	75
40	0	0	91	87	93	82	109	107
40	40	0	121	109	107	119	131	119
40	40	40	123	106	107	117	131	119
80	0	0	100	95	105	82	115	121
80	40	0	138	111	114	158	150	143
80	40	40	138	116	117	148	150	142
120	0	0	97	91	103	90	114	124
120	40	0	135	115	118	180	166	159
120	40	40	137	115	120	196	172	160
160	0	0	109	93	103	89	120	131
160	40	0	134	118	121	206	177	169
160	40	40	132	113	119	202	167	164
200	0	0	110	97	105	92	119	132
200	40	0	134	117	121	196	173	166
200	40	40	146	118	120	205	173	168
MEANS								
Nitrogen								
0	lb/acre		66	73	73	73	86	73
40			112	101	102	106	124	115
80			125	107	112	129	139	136
120			123	107	114	156	151	148
160			125	108	114	166	155	155
200			130	111	116	164	155	155
LSD .05			10	4	3	10	8	4
P-K								
0-0	lb/acre		96	89	97	83	110	114
40-0			120	107	109	156	147	138
40-40			124	107	110	157	147	138
LSD .05			7	3	2	8	5	3

§ Grain sorghum yields adjusted to 12.5% moisture and corn yields adjusted to 15.5% moisture.

Table 2. Effect of nitrogen, phosphorus, and potassium on grain yield; grain N, P, and K content; and grain removal of N, P, and K of irrigated corn. Tribune, KS, 1990.

N	P_2O_5	K_2O	Grain				Grain Removal		
			Yield	N	P	K	N	P	K
- - -lb/a - -			bu/a	- - - - % - - - -			- - - - lb/a- - -		
0	0	0	71	0.89	0.22	0.26	30	7.4	8.5
0	40	0	73	0.81	0.31	0.30	28	10.6	10.3
0	40	40	80	0.84	0.29	0.29	32	10.8	10.7
40	0	0	94	0.95	0.18	0.22	42	8.0	9.7
40	40	0	125	0.83	0.28	0.28	49	16.6	16.5
40	40	40	125	0.83	0.29	0.29	49	17.4	17.4
80	0	0	124	1.08	0.18	0.20	63	10.3	11.8
80	40	0	160	0.89	0.25	0.26	67	18.7	19.6
80	40	40	161	0.87	0.26	0.27	66	20.0	20.5
120	0	0	120	1.14	0.17	0.20	65	9.8	11.3
120	40	0	195	0.96	0.21	0.23	88	19.5	21.4
120	40	40	199	0.97	0.24	0.25	91	22.3	23.5
160	0	0	118	1.20	0.17	0.19	67	9.7	10.5
160	40	0	212	1.04	0.22	0.24	104	22.3	23.6
160	40	40	207	1.04	0.21	0.22	102	20.2	21.3
200	0	0	130	1.14	0.17	0.19	71	10.7	12.0
200	40	0	207	1.08	0.22	0.23	105	21.3	22.2
200	40	40	209	1.06	0.22	0.22	104	21.4	21.9
ANOVA									
Nitrogen			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
N * P-K			0.001	0.032	0.001	0.001	0.001	0.001	0.001
MEANS									
Nitrogen									
0 lb/acre			75	0.85	0.27	0.28	30	9.6	9.9
40			115	0.87	0.25	0.26	46	14.0	14.5
80			149	0.94	0.23	0.24	66	16.3	17.3
120			171	1.02	0.21	0.23	81	17.2	18.7
160			179	1.09	0.20	0.21	91	17.4	18.5
200			182	1.09	0.20	0.21	93	17.8	18.7
LSD .05			8	0.04	0.01	0.01	5	1.2	1.0
P-K									
0-0 lb/acre			110	1.07	0.18	0.21	56	9.3	10.6
40-0			162	0.93	0.25	0.26	74	18.2	18.9
40-40			163	0.93	0.25	0.26	74	18.7	19.2
LSD .05			6	0.03	0.01	0.01	3	0.8	0.7

Table 3. Effect of N, P, and K fertilization on grain yield; grain N, P, and K content; and grain removal of N, P, and K of irrigated grain sorghum. Tribune, KS, 1990.

N	P_2O_5	K_2O	Grain				Grain removal		
			Yield	N	P	K	N	P	K
- - -lb/a - -			bu/a	- - - - - - % - - - - -			- - - lb/a - - -		
0	0	0	66	0.83	0.24	0.36	26	7.6	11.1
0	40	0	67	0.82	0.31	0.40	26	9.8	12.7
0	40	40	67	0.82	0.29	0.39	26	9.3	12.2
40	0	0	88	1.00	0.18	0.31	42	7.7	13.0
40	40	0	102	0.88	0.28	0.37	43	13.5	17.9
40	40	40	97	0.90	0.27	0.36	42	12.4	16.5
80	0	0	98	1.22	0.18	0.32	56	8.3	14.8
80	40	0	106	1.04	0.27	0.36	53	13.4	18.1
80	40	40	120	1.07	0.26	0.35	61	14.6	19.8
120	0	0	94	1.28	0.17	0.32	57	7.8	14.2
120	40	0	126	1.28	0.24	0.34	77	14.1	20.1
120	40	40	122	1.24	0.26	0.34	71	14.9	19.7
160	0	0	97	1.33	0.18	0.30	61	8.1	14.0
160	40	0	123	1.32	0.25	0.33	76	14.6	16.5
160	40	40	123	1.32	0.24	0.35	77	13.8	20.0
200	0	0	102	1.35	0.18	0.32	65	8.6	15.3
200	40	0	125	1.33	0.26	0.35	79	15.5	20.5
200	40	40	126	1.31	0.24	0.33	78	14.4	19.6
ANOVA									
Nitrogen			0.001	0.001	0.001	0.001	0.001	0.001	0.001
P-K			0.001	0.016	0.001	0.001	0.001	0.001	0.001
N * P-K			0.014	0.423	0.340	0.137	0.005	0.021	0.065
MEANS									
Nitrogen			Yield	N	P	K	N	P	K
lb/a			bu/a	- - - - - % - - - - -			- - - lb/a- - -		
0			67	0.82	0.28	0.38	26	8.9	12.0
40			96	0.93	0.24	0.35	42	11.2	15.8
80			108	1.11	0.23	0.34	56	12.1	17.5
120			114	1.27	0.22	0.33	68	12.3	18.0
160			114	1.32	0.22	0.33	72	12.2	17.8
200			117	1.33	0.23	0.33	74	12.8	18.4
$LSD_{.05}$			7	0.06	0.02	0.01	5	1.2	1.3
P-K (lb/a)									
0- 0			91	1.17	0.19	0.32	51	8.0	13.7
40- 0			108	1.11	0.27	0.36	59	13.5	18.1
40-40			109	1.11	0.26	0.35	59	13.2	18.0
$LSD_{.05}$			5	0.05	0.01	0.01	4	0.8	0.9

Table 4. Effect of 30 years of N and P applications for irrigated corn on soil NO_3-N content, Tribune, KS, 1990.

N Rate	P_2O_5 Rate	Depth, inches										
		0-6	6-12	12-24	24-36	36-48	48-60	60-72	72-84	84-96	96-108	108-120
- lb/a		- - - - - - - - - - - - lb NO_3-N/acre - - - - - - - - - - - -										
0	0	1.5	0.8	1.1	1.7	1.4	1.0	1.3	1.3	1.6	1.6	1.6
40	0	2.2	0.8	1.4	1.2	1.1	1.1	1.3	1.5	1.6	2.0	2.7
80	0	2.5	1.7	2.0	1.8	1.3	1.1	1.1	2.3	2.7	3.9	4.7
120	0	8.8	3.0	9.4	11.4	7.9	5.3	3.4	3.2	6.4	9.8	12.9
160	0	5.9	3.5	19.7	37.6	19.6	21.4	21.3	21.1	25.8	23.9	24.1
200	0	3.2	2.1	8.2	24.0	21.6	17.8	13.7	12.2	14.1	14.6	17.8
0	40	1.9	0.9	1.4	1.3	1.1	1.1	1.1	1.4	1.6	1.7	1.8
40	40	1.9	0.9	1.6	1.2	1.1	1.2	1.0	1.1	1.2	1.4	1.6
80	40	1.5	0.9	1.6	3.5	3.2	2.9	6.3	7.2	6.5	6.8	2.2
120	40	3.3	1.5	1.6	1.4	1.2	1.1	1.1	1.5	2.2	3.2	4.1
160	40	5.4	3.1	3.5	2.5	1.5	1.8	3.6	5.5	6.9	7.0	6.9
200	40	6.8	4.8	24.5	20.0	17.4	21.8	16.9	12.3	11.6	13.0	17.2

N Rate	P_2O_5 Rate	Depth, ft			
		0-2	2-5	5-10	0-10
lb/a		- - - - - - - lb NO_3-N/acre- - - - - - - -			
0	0	3	4	7	15
40	0	4	3	9	17
80	0	6	4	15	25
120	0	21	25	36	81
160	0	29	79	116	224
200	0	14	63	73	149
0	40	4	4	8	15
40	40	4	3	6	14
80	40	4	10	29	43
120	40	7	4	12	22
160	40	12	6	30	48
200	40	36	59	71	166
$LSD_{.05}$		20	52	58	119

Table 5. Effect of 30 years of N and P applications for irrigated grain sorghum on soil NO_3-N content, Tribune, KS, 1990.

N rate	P_2O_5 rate	Depth, inches										
		0-6	6-12	12-24	24-36	36-48	48-60	60-72	72-84	84-96	96-108	108-120
-lb/a-		- - - - - - - - - - -lb NO_3-N/acre- - - - - - - - - - -										
0	0	1.5	0.9	1.2	0.9	0.5	0.2	0.6	0.7	1.3	1.2	2.9
40	0	5.1	2.1	1.7	0.8	0.9	0.6	1.4	0.7	0.8	1.2	1.7
80	0	10.7	11.4	13.4	2.1	1.3	2.5	5.0	7.8	12.8	21.6	29.3
120	0	14.8	12.8	23.1	8.8	8.1	17.4	15.8	21.6	24.1	23.7	22.8
160	0	25.5	27.7	45.9	39.5	56.4	79.3	114.9	11.3	99.7	85.7	64.4
200	0	18.6	24.2	62.1	67.8	49.9	38.2	25.8	37.6	78.0	129.3	111.0
0	40	2.2	1.2	1.2	1.5	0.5	0.5	1.1	1.1	1.8	1.6	1.5
40	40	1.6	0.7	1.2	0.8	0.4	0.8	0.6	0.9	1.2	1.6	2.4
80	40	4.2	3.3	3.8	1.1	0.8	1.8	2.6	1.7	1.6	1.4	2.2
120	40	5.3	2.8	4.2	2.9	1.4	1.8	4.7	7.4	6.1	6.9	8.3
160	40	12.0	9.5	23.7	17.3	9.4	7.9	13.6	19.6	24.1	28.3	29.3
200	40	6.9	11.6	26.7	15.7	13.9	19.9	20.9	31.8	36.9	45.3	30.0

N rate	P_2O_5 rate	Depth, ft			
		0-2	2-5	5-10	0-10
-lb/a-		- - - - - - - lb NO_3-N/acre- - - - - - - -			
0	0	4	2	7	12
40	0	9	2	6	17
80	0	35	6	76	118
120	0	51	34	108	193
160	0	99	175	476	750
200	0	105	156	382	643
0	40	5	2	7	14
40	40	4	2	7	12
80	40	11	4	10	25
120	40	12	6	33	52
160	40	45	35	115	195
200	40	45	50	165	260
$LSD_{.05}$		53	45	82	136