EFFECT OF LONG-TERM N AND P FERTILIZATION ON SOIL CHEMICAL PROPERTIES

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ABSTRACT

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated corn and grain sorghum in western Kansas. Averaged across the past 50 years, N and P fertilization increased corn yields more than 100 bu/a and grain sorghum yields more than 50 bu/a. Application of 160 lb N/a was sufficient to maximize corn yields while 80 to 120 lb N/a was sufficient for grain sorghum. Soil organic matter was increased by N and P fertilization. Soil pH was decreased by increased N rates and not affected by P fertilization. Application of 40 lb P_2O_5/a was not sufficient to maintain soil test P levels for corn but was for grain sorghum. Residual soil NO_3-N was increased by increasing N rates for both corn and sorghum. Soil NO_3-N accumulated below 5 ft particularly at N rates of 160 lb N/a or greater. Phosphorus fertilization had an inconsistent effect on residual NO_3-N for corn and no effect for sorghum.

INTRODUCTION

This study was initiated in 1961 to determine responses of continuous corn and grain sorghum grown under irrigation to N, P, and K fertilization. The study was conducted on a Ulysses silt loam soil with an inherently high K content. No yield benefit to corn from K fertilization was observed in 30 years and soil K levels remained high so the K treatment in the corn study was discontinued in 1992 and replaced with a higher P rate. After 30 years, the optimal N rate for corn was about 160 lb N/a with an increasing benefit from P fertilization (Schlegel and Havlin, 1995). At that time, profile nitrate-N content was relatively low and essentially the same when N was applied with P at the economic optimal rate or less (Schlegel, et al., 1996). The objectives of this study were to determine the effect of an additional 20 years of fertilization on soil chemical properties.

MATERIALS AND METHODS

Initial fertilizer treatments in 1961 to corn and grain sorghum in adjacent fields were N rates of 0, 40, 80, 120, 160, and 200 lb N/a without P and K; with 40 lb P_2O_5/a and zero K; and with 40 lb P_2O_5/a and 40 lb K_2O/a. In 1992, the treatments for the corn study were changed with the K variable being replaced by a higher rate of P (80 lb P_2O_5/a). All fertilizers were broadcast by hand in the spring and incorporated prior to planting. The soil is a Ulysses silt loam. Corn was planted in late April to early May while sorghum was planted in late May to early June. Both studies were irrigated to minimize water stress. Furrow irrigation was used through 2000 and sprinkler irrigation since 2001. The center 2 rows of each plot were machine harvested after physiological maturity. Grain yields were adjusted to 15.5% moisture for corn

and 12.5% for sorghum. Soil samples (0-6 inches and 0 to 10 ft) were taken in both studies following harvest in 2010. All chemical analyses were done by Harris Laboratories, Lincoln, NE. Soil test phosphorus was determined by two methods; Bray-1 because the historical analyses used this method and Olsen because of the high pH in some treatments

RESULTS AND DISCUSSION

Nitrogen alone increased corn yields by 60 bu/a while P alone increased yields only 6 bu/a when averaged across the 50 years of the study (Table 1). A combination of N and P increased corn yields by more than 100 bu/a. Only 120 lb N/a with P was required to obtain ~95% of maximum corn yields. With grain sorghum, N alone increased grain yields 37 bu/a while P alone increased yields only 3 bu/a. Similar to corn, a combination of N and P increased yields 53 bu/a, considerably more than from either applied alone. An N rate of 80 lb/a with P produced >90% of maximum grain sorghum yield.

Soil organic matter was increased by N and P fertilization of corn from 2.1% in the non-fertilized control to a maximum of 2.5% with 200 lb/a of N with P (Table 2). Soil test P averaged across N rates was higher with 40 lb/a P_2O_5 than without P (15 vs. 8 ppm Bray-1 P), but still slightly less than at the start of the study (17 ppm Bray-1 P in 1961). Application of 80 lb/a P_2O_5 since 1992 to corn resulted in a build-up of soil test P to 26 ppm by 2010. Soil test P based on the Olsen test showed similar trends to that using the Bray-1 P test. Long-term N applications decreased soil pH while P fertilization had no effect on soil pH.

Soil NO_3-N concentrations were increased throughout the 10 ft profile by application of N fertilizers to corn (Tables 3 and 4). The effect of P fertilization on soil NO_3-N concentrations was inconsistent. In the surface soil (0 to 2 ft), P fertilization had no effect on soil NO_3-N concentrations. Below 2 ft at moderate N rates (80 to 160 lb N/a), P fertilization tended to reduced soil NO_3-N concentrations; however, at low N rates (40 lb N/a or less) and at the highest rate (200 lb N/a) soil NO_3-N concentrations were unaffected by P fertilization.

Similar to corn, soil organic matter was increased by N and P fertilization of grain sorghum from 2.1% in the unfertilized control up to 2.6% with N and P fertilization (Table 5). Soil test P was increased by P fertilization from an initial value of ~17 ppm up to >30 ppm. Without P fertilization, soil test P was reduced with N rates of 120 lb N/a or less. However, at higher N rates, soil test P actually increased to 25 to 28 ppm. This increase in soil test P without P additions is surprising. This trend was also noticed with the Olsen test. Soil pH was reduced by N fertilization from 7.8 in the unfertilized control to 6.6 with 200 lb N/a. Similar to corn, P applications had no effect on soil pH.

Soil NO_3-N concentrations were increased throughout the 10 ft profile by application of N fertilizers to grain sorghum (Tables 6 and 7). Soil NO_3-N concentrations below 5 ft increased considerably when N rates exceeded 120 lb N/a, which is greater than the N rate required to produce maximum yield. Phosphorus fertilization had no significant effect on soil NO_3-N concentrations.

REFERENCES

Schlegel, A.J., K.C. Dhuyvetter, and J.L. Havlin. 1996. Economic and environmental impacts of long-term nitrogen and phosphorus fertilization. J. Prod. Agric. 9:114-118.

Schlegel, A.J. and J.L. Havlin. 1995. Corn response to long-term nitrogen and phosphorus fertilization. J. Prod. Agric. 8:181-185.

Table 1. Effect of long term (50 yr) applications of N and P fertilizers on grain yield of irrigated corn and grain sorghum, Tribune, KS, 1961-2010.

N	P_2O_5	Corn	Grain Sorghum
- - - -lb/acre - - -		- - - - - - bu/acre - - - - -	
0	0	65	70
	40	71	73
40	0	95	90
	40	118	109
80	0	109	102
	40	146	116
120	0	109	98
	40	161	119
160	0	119	103
	40	170	123
200	0	125	107
	40	169	123
ANOVA (P>F)			
Nitrogen		0.001	0.001
Linear		0.001	0.001
Quadratic		0.001	0.001
P_2O_5		0.001	0.001
N x P		0.001	0.008
MEANS			
0		68	72
40		107	99
80		128	109
120		135	109
160		144	113
200		147	115
$LSD_{0.05}$		5	5
	0	104	95
	40	139	111
	$LSD_{0.05}$	3	3

Table 2. Selected soil properties (0-6 inch) after long term (50 yr) applications of N and P fertilizers to irrigated corn, Tribune, KS, 2010.

N	P_2O_5	Soil OM	Bray 1 P	Olsen P	Soil pH
- - - -lb/acre - - -		%	- - - - - - ppm - - - - - -		
0	0	2.1	7	4	7.8
	40	2.1	23	14	7.8
	80†	2.1	25	15	7.7
40	0	2.1	8	5	7.8
	40	2.4	15	9	7.7
	80	2.3	27	16	7.6
80	0	2.2	7	4	7.6
	40	2.3	10	6	7.6
	80	2.4	23	14	7.6
120	0	2.2	8	5	7.7
	40	2.4	12	7	7.6
	80	2.5	23	13	7.5
160	0	2.3	8	5	7.4
	40	2.4	14	7	7.2
	80	2.4	23	13	7.4
200	0	2.4	8	4	6.9
	40	2.5	15	8	7.2
	80	2.5	34	17	7.1
ANOVA (P>F)					
Nitrogen		0.001	0.017	0.008	0.001
Linear		0.001	0.868	0.071	0.001
Quadratic		0.279	0.001	0.001	0.007
P_2O_5		0.001	0.001	0.001	0.786
Linear		0.001	0.001	0.001	0.591
Quadratic		0.078	0.136	0.070	0.664
N x P		0.338	0.044	0.035	0.485
MEANS					
0		2.1	19	11	7.8
40		2.3	17	10	7.7
80		2.3	13	8	7.6
120		2.3	14	8	7.6
160		2.4	15	8	7.3
200		2.5	19	10	7.1
$LSD_{0.05}$		0.1	4	2	0.2
	0	2.2	8	4	7.5
	40	2.3	15	8	7.5
	80	2.4	26	15	7.5
	$LSD_{0.05}$	0.1	3	1	0.1

† The 80 lb/a rate of P_2O_5 was applied starting in 1992, prior to then it was 40 lb/a.

Table 3. Soil NO_3-N concentration after long-term (50 yr) N and P fertilization of irrigated continuous corn, Fall 2010, Tribune, KS.

		Depth, ft									
N	P_2O_5	1	2	3	4	5	6	7	8	9	10
- - - - lb/ acre - - - -		- - - - - - - - - - - - - - - - - NO_3-N, ppm - - - - - - - - - - - - - - - - -									
0	0	2	2	2	2	2	2	2	2	2	2
	40	2	2	2	2	2	1	2	2	2	2
	80	2	2	2	2	1	2	2	2	2	2
40	0	3	2	2	2	2	2	2	2	2	2
	40	4	2	2	2	2	2	2	2	2	2
	80	3	2	2	2	2	2	2	2	2	2
80	0	7	4	4	5	7	8	5	5	6	4
	40	4	2	2	2	2	2	2	2	2	2
	80	5	2	2	2	2	2	2	2	2	2
120	0	5	4	7	8	5	5	9	9	7	5
	40	11	5	5	3	3	3	2	2	2	2
	80	10	4	3	2	2	3	3	2	2	2
160	0	12	11	20	16	17	12	13	16	19	20
	40	12	6	7	5	7	8	8	8	9	8
	80	11	7	8	5	3	4	4	4	4	5
200	0	13	9	16	17	14	12	10	9	12	12
	40	13	13	10	16	18	16	12	10	8	8
	80	20	11	16	17	17	11	11	10	10	9

Note: The 80 lb/a rate of P_2O_5 was applied starting in 1992, prior to then it was 40 lb/a. All other rates were applied annually since 1961.

Table 4. Profile soil NO_3-N following long-term (50 yr) N and P fertilization to irrigated corn, fall 2010, Tribune, KS.

N	P_2O_5	Profile Depth 0-2’	2-5’	5-10’	0-10’
- - - - - - -lb/acre - - - - - -		- - - - - - - - - - - - - NO_3-N, lb/a - - - - - - - - - - - - -			
0	0	14	17	33	64
	40	13	16	29	57
	80	12	14	27	53
40	0	21	20	28	69
	40	21	19	28	68
	80	19	16	27	63
80	0	37	56	94	187
	40	25	19	29	72
	80	28	18	31	77
120	0	32	65	116	213
	40	58	37	37	132
	80	49	24	40	113
160	0	83	175	269	527
	40	63	64	135	262
	80	63	54	69	186
200	0	80	156	185	421
	40	91	147	182	421
	80	112	166	170	448
ANOVA (P>F)					
Nitrogen		0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001
Quadratic		0.006	0.001	0.010	0.001
P_2O_5		0.881	0.010	0.001	0.001
Linear		0.632	0.007	0.001	0.001
Quadratic		0.883	0.146	0.218	0.123
Nitrogen x P_2O_5		0.190	0.108	0.048	0.006
MEANS					
0		13	16	30	58
40		20	19	27	67
80		30	31	51	112
120		46	42	64	153
160		70	98	158	325
200		94	156	179	430
$LSD_{0.05}$		15	33	46	69
	0	45	82	121	247
	40	45	50	73	169
	80	47	49	61	157
	$LSD_{0.05}$	11	23	32	49

Note: The 80 lb/a rate of P_2O_5 was applied starting in 1992, prior to then it was 40 lb/a.

Table 5. Selected soil properties (0-6 inch) after long term (50 yr) applications of N and P fertilizers to irrigated grain sorghum, Tribune, KS, 2010.

N	P_2O_5	OM	Bray 1 P	Olsen P	pH
- - - - - - lb/acre - - - -		%	- - - - - - - ppm - - - - - - -		
0	0	2.1	11	6	7.8
	40	2.3	36	21	7.7
40	0	2.2	13	7	7.7
	40	2.4	43	23	7.5
80	0	2.3	14	7	7.1
	40	2.4	35	19	7.4
120	0	2.4	9	5	7.2
	40	2.5	19	10	7.2
160	0	2.5	28	14	7.1
	40	2.6	37	21	6.6
200	0	2.6	25	12	6.6
	40	2.6	35	17	6.5
ANOVA (P>F)					
Nitrogen		0.001	0.109	0.113	0.001
Linear		0.001	0.361	0.658	0.001
Quadratic		0.821	0.219	0.226	0.435
Phosphorus		0.001	0.001	0.001	0.128
N x P		0.485	0.444	0.392	0.035
MEANS					
Nitrogen	0 lb/a	2.2	24	13	7.8
	40	2.3	28	15	7.6
	80	2.4	24	13	7.2
	120	2.4	14	7	7.2
	160	2.5	32	17	6.9
	200	2.6	30	15	6.6
	$LSD_{0.05}$	0.1	13	7	0.2
P_2O_5	0 lb/a	2.3	16	8	7.2
	40	2.5	34	18	7.2
	$LSD_{0.05}$	0.1	8	4	0.1

Table 6. Soil NO_3-N concentration after long-term (50 yr) N and P fertilization of irrigated continuous grain sorghum, Fall 2010, Tribune, KS.

		Depth, ft									
N	P_2O_5	1	2	3	4	5	6	7	8	9	10
- - - - - lb/acre - - - - -		- - - - - - - - - - - - - - - NO_3-N, ppm - - - - - - - - - - - - - - -									
0	0	3	2	2	2	2	2	2	2	2	2
	40	3	3	2	2	2	2	2	2	2	2
40	0	3	2	2	2	2	2	2	2	2	2
	40	4	3	2	3	2	3	2	2	2	2
80	0	18	6	6	6	7	9	7	7	6	8
	40	5	3	3	3	3	3	3	3	3	4
120	0	6	6	9	5	4	6	12	14	10	9
	40	7	6	5	5	6	6	6	5	6	9
160	0	15	8	10	9	10	15	20	27	31	28
	40	12	6	7	8	7	13	14	13	13	12
200	0	17	11	15	13	11	11	7	11	20	23
	40	31	19	23	18	15	30	20	20	18	19

Table 7. Profile soil NO_3-N following long-term (50 yr) N and P fertilization to irrigated grain sorghum, fall 2010, Tribune, KS.

		Profile Depth			
N	P_2O_5	0-2 ft	2-5 ft	5-10 ft	0-10 ft
- - - - - lb/acre - - - - - -		- - - - - - - - - - - - - NO_3-N, lb/a - - - - - - - - - - - - -			
0	0	19	22	36	76
	40	21	23	37	81
40	0	19	22	36	78
	40	24	25	41	90
80	0	89	60	122	270
	40	29	29	54	112
120	0	44	62	172	278
	40	48	54	103	205
160	0	83	99	409	591
	40	67	76	216	359
200	0	102	129	243	474
	40	179	187	361	727
ANOVA (P>F)					
Nitrogen		0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001
Quadratic		0.050	0.001	0.165	0.015
Phosphorus		0.880	0.999	0.225	0.410
N x P		0.092	0.106	0.060	0.016
MEANS					
Nitrogen	0 lb/a	20	22	36	79
	40	22	24	39	84
	80	59	45	88	191
	120	46	58	138	242
	160	75	88	313	475
	200	141	158	302	601
	$LSD_{0.05}$	44	32	97	136
P_2O_5	0 lb/a	59	66	170	295
	40	61	66	135	262
	$LSD_{0.05}$	26	18	56	78