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Macronutrient Fertility on an Irrigated Corn/Soybean in Rotation

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Summary

Effects of nitrogen (N), phosphorus (P), and potassium (K) fertilization on a corn/soybean cropping sequence were evaluated from 2013 to 2020 (corn planted in odd years) from a study initiated in 1983. Corn yield was near optimum at 160 lb/a N. Phosphorus and K fertilization alone increased corn yield 31 and 7 bu/a, respectively; and soybean yields 22 and 1.7 bu/a, respectively. As N fertilization increased, the response to P increased corn yield from 13 to 40 bu/a. The best return on fertilizer investment was when the N and P needs were met for both crops.

Introduction

A study was initiated in 1972 at the Topeka Unit of the Kansas River Valley Experiment Field to evaluate the effects of N, P, and K on furrow-irrigated soybean. In 1983, the study was changed to a corn/soybean rotation with corn planted and fertilizer treatments applied in odd years. Study objectives were to evaluate the effects of N, P, and K applications to a corn crop on grain yield of corn, yield of the following soybean crop, and soil test values.

Procedures

The initial soil test in March 1972 on this silt loam soil was 47 lb/a available P and 312 lb/a exchangeable K in the top 6 in. of the soil profile. All fertilizer treatments were applied pre-plant before corn planting and incorporated. Nitrogen rates included a factorial arrangement of 0, 120, and 160 lb/a of N (with single treatments of 80 and 240 lb/a N). Three rates of P were 0, 30, and 60 lb/a of P_2O_5, and K treatments were 0 and 150 lb/a of KCl.

The planting date average was April 22 for corn and May 14 for soybean for the last four rotations, with herbicides applied pre-plant and postemergence each year. Plots were sprinkler irrigated with a linear move irrigation system. A plot combine was used for harvesting grain yields from the middle two rows of 15 (6 rows) × 30-ft plots.

The soil P ppm has decreased from the initial sampling when the study began as a corn/soybean rotation in 1983, with a study average of 55 ppm to 16 ppm in 2018. Soil K ppm has dropped from 320 to 242 K ppm, which is not as drastic as the P levels. For this reason, yield data from both crops for the last four rotation sequences are presented here to give a picture of the current yield level. Additionally, the seed planted in the last four crop rotations better represent the yield potential of current hybrids and varieties.

The income from fertilizer was calculated for each treatment in a crop rotation. Average yields of corn and soybeans were multiplied by the current grain price (January 2021) at \$5.00 for corn and \$13.60 for soybeans. Fertilizer cost was calculated using the following prices, N at \$0.42/lb, P_2O_5 at \$0.44/lb, KCl at \$0.32/lb. The fertilizer cost of each treatment was subtracted from the gross income of a rotation of corn and soybeans since the fertilizer was applied only before corn. Then the gross of the check plot with no fertilizer was subtracted from each treatment in each replication for each year. This resulted in the income returned over fertilizer cost for comparison of fertilizer treatments.

Results

The average yield response of corn and soybean yields from 2013–2019 and 2014–2020, respectively, to the fertilizer treatments applied prior to corn planting are shown in Table 1. There were differences between the treatments for both crops. The factorial analysis at the bottom of the table explains the crops' response to each nutrient.

All three macronutrients increased corn yield, with corn responding most to N and P (Table 1). Yield responses of corn to N rates are shown in Figure 1, where the P and K rates were 30 and 150 lb/a, respectively, for all N rates. Nitrogen rate had the greatest influence on corn yield, as shown in Figure 1, especially to the first 80 lb of N. The yield response curve began to flatten as the N rate increased above 80 lb. The optimum economic N rate would probably be approximately 160 lb, which could vary depending on the price of corn and the cost of N.

Similarly, the first 30 lb of P_2O_5 resulted in the greatest yield increase (23 bu/a) for corn and continued to increase (8 bu/a) with an additional 30 lb of P_2O_5 (Table 1). The addition of 150 lb of KCl did increase the corn yield 6 bu/a, though probably not enough to be cost effective.

Soybean yields showed most response to the P left over after the corn, with a 13 bu/a increase for the first 30 lb of P_2O_5, with an additional increase of 9 bu/a at the 60-lb rate. A previous report from this study (Adee et al., 2016) showed that the severity of Sudden Death Syndrome (SDS) and subsequent yield loss in soybeans were related to lower soil P values. Long-term grain removal will reduce soil P levels, especially when fertilizer P levels do not meet maintenance levels. The severity of SDS and soybean yield response were very similar in 2016 and 2018. A variety more tolerant to SDS that was treated with ILeVO seed treatment greatly reduced the foliar symptoms of SDS in 2020. There was no significant yield benefit to the soybeans from additional N and K applied to the corn.

There was a significant return on fertilizer investment for N and P fertilizer and for the treatments that provided a more balanced fertility. The 150 lb of KCl (K) did not pay for itself, though a lower rate may have been more profitable. The highest income was with treatments of 120-60-0, 120-60-150, 160-60-0, and 160-60-150 of N-P-K (Table 1).

There was a significant interaction between N and P for both crops (Table 2). Basically, as corn yields increase with the increased N rate, more P is removed from the soil, as shown by the soil test data. As a result, both crops showed an increased yield response to

P as the N rate increased, and an increased income over both years of the corn/soybean rotation (Table 1).

Conclusions

As was well documented for years, these data from a long-term study show that N is the most critical fertilizer for corn. The curve representing corn's yield response to N still shows that the optimum N rate is approximately 160 lb N/a. Phosphorus follows closely behind as a critical fertilizer for both crops. The best return for fertilizer investment is a balanced program that meets the needs of both crops in the rotation, and over the long term helps maintain or build fertility levels as needed.

Reference

Adee, E., Ruiz Diaz, D.A. and Little, C.R. (2016), Effect of Soil-Test Phosphorus and Phosphorus Fertilization on the Severity of Soybean Sudden Death Syndrome. Crop, Forage & Turfgrass Management, 2: 1-4 cftm2015.0193. *https://doi.org/10.2134/cftm2015.0193*.

Table 1. Effects of nitrogen (N), phosphorus (P), and potassium (K) applications on corn yields in a corn/soybean cropping sequence, Kansas River Valley Experiment Field, Topeka Unit

Fertilizer[1]			Corn yield		Soybean yield		2-year Income return over fertilizer cost[4]	
N	P_2O_5[2]	K_2O	2013–2019		2014–2020			
-------------- lb/a --------------			------------------- bu/a -------------------				$/a	
0	0	0	96.0	g[3]	37.7	f	0.00	j
0	0	150	99.8	g	38.1	ef	-66.49	j
0	30	0	122.2	f	53.6	c	326.43	efgh
0	30	150	98.1	g	55.7	bc	137.58	i
0	60	0	109.8	gf	62.8	a	363.57	efg
0	60	150	112.0	gf	65.5	a	314.72	efgh
120	0	0	157.2	e	43.8	ed	323.7	efgh
120	0	150	164.7	de	44.2	c	241.02	ghi
120	30	0	174.3	d	50.6	c	445.65	de
120	30	150	197.4	c	56.4	bc	544.02	cd
120	60	0	195.7	c	63.1	a	694.91	a
120	60	150	206.4	bc	64.1	a	667.26	ab
160	0	0	171.7	de	41.6	ed	302.72	fgh
160	0	150	169.5	de	43.5	ed	220.57	h
160	30	0	199.0	bc	55.7	bc	604.44	abc
160	30	150	205.8	bc	53.1	c	507.02	cd
160	60	0	200.5	bc	60.8	ab	654.02	ab
160	60	150	223.2	a	64.5	a	721.82	a
80	30	150	173.2	de	54.2	c	425.75	def
200	30	150	214.4	ab	55.4	bc	546.99	bcd
Prob>F			<0.0001		<0.0001		<0.0001	

continued

Table 1. Effects of nitrogen (N), phosphorus (P), and potassium (K) applications on corn yields in a corn/soybean cropping sequence, Kansas River Valley Experiment Field, Topeka Unit

Fertilizer[1]			Corn yield	Soybean yield	2-year Income return over fertilizer cost [4]	
N	P_2O_5[2]	K_2O	2013–2019	2014–2020		
-------------- lb/a --------------			------------------- bu/a -------------------		$/a	
Nitrogen means						
0			106.3	52.2	179.30	b
120			182.6	53.7	486.09	a
160			195.0	53.2	501.77	a
Prob>F			<0.0001	0.38	<0.0001	
Phosphorus means						
	0		143.2	41.4	170.25	c
	30		166.2	54.2	427.52	b
	60		174.6	63.5	569.38	a
Prob>F			<0.0001	<0.0001	<0.0001	
Potassium means						
		0	158.5	52.2	412.83	
		150	164.1	53.9	365.28	
Prob>F			0.045	0.059	0.029	

[1] Fertilizer applied to corn in odd years from 1983 to 2019.
[2] Phosphorus treatments not applied in 1997. Starter fertilizer of 10 gal/a of 10-34-0 was applied to all treatments in 1997 and 1998 (corn and soybean). Nitrogen and K treatments were applied to corn in 1997.
[3] Numbers followed by different letters are different at $P = 0.05$.
[4] 2-year income calculated using corn at $5.00, soybeans at $13.60, N at $0.42/lb, P_2O_5 at $0.44/lb, and KCl at $0.32/lb.

Table 2. Interaction of nitrogen (N) and phosphorus (P) fertilizer applied before corn in a corn-soybean rotation on soil phosphorus, corn and soybean yield at the Kansas River Valley Experiment Field, Topeka[1]

Nutrient		2018 soil test	Yield average	
			2013–2019	2014–2020
N	P	P ppm	Corn	Soybean
---------------- lb/a ----------------		0–6 in. depth	-------------------- bu/a --------------------	
0	0	7.0	97.9 e[2]	37.7 d
0	30	16.7	110.1 d	54.7 b
0	60	42.9	110.9 d	64.2 a
120	0	4.2	161.0 c	44.0 c
120	30	13.2	185.9 b	53.5 b
120	60	32.8	201.0 a	63.6 a
160	0	3.9	170.6 c	42.5 c
160	30	8.4	202.4 a	54.4 b
160	60	24.3	211.8 a	62.6 a
Pr>F			0.005	0.03

[1] Fertilizer applied to corn in odd years from 1983 to 2019.

[2] Numbers followed by different letters are different at $P = 0.05$.

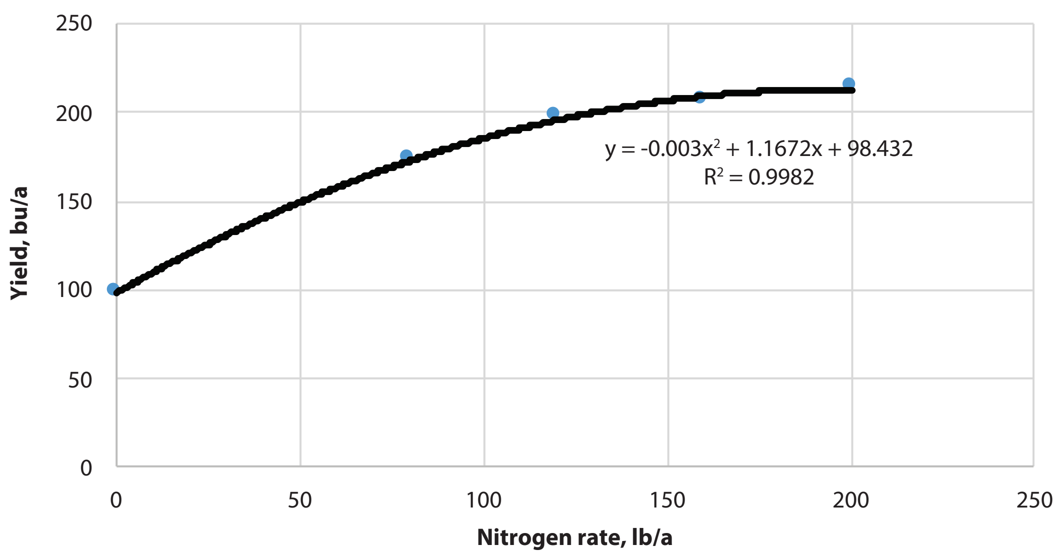

Figure 1. Average corn yield response from 2013 to 2019 to nitrogen rates applied with 30 and 150 lb of P_2O_5 and KCl, respectively, prior to the corn crop in long-term macronutrient fertility study at the Kansas River Valley Experiment Field, Topeka.