Macronutrient Fertility on 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 2015 to 2023 (corn planted in odd years) from a study initiated in 1983. Corn yields responded most to N, followed by P fertilization, and soybean yields were most influenced by P fertilization. The highest return on fertilizer investment averaged over both crops was when N, P, and K were more closely meeting the needs of the 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 soybeans. In 1983, the study was changed to a corn/soybean rotation with corn planted and fertilizer treatments applied in odd years, and in 2000, sprinkler irrigation was initiated. The 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 inches 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 200 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 K_2O.

Planting dates averaged April 21 for corn for the last five corn crops and May 16 for soybeans for the last three soybean crops, with herbicides applied preplant and postemergence herbicides 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) by 30-foot plots.

As the yield potential of hybrids and varieties improve over years, the fertility needs for the crops increase. For this reason, yield data from both crops for the last several rotation sequences are presented here to give a picture of the current yield level. Prior to 2020, the soybean varieties were susceptible to Sudden Death Syndrome (SDS), therefore, were not included in this analysis with the yield data of SDS tolerant varieties with seed treatment for control of SDS.

The income from fertilizer was calculated for each treatment in a crop rotation sequence. Average yields of corn and soybeans were multiplied by current grain price (January 2025) at $4.65 for corn and $10.07 for soybeans. Fertilizer cost was calculated using the following prices, N at $0.445/lb, phosphorus (P_2O_5) at $0.611/lb, and potassium chloride (KCl) at $0.375/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. For additional comparison of fertilizer treatments, the gross income of the check plot with no fertilizer was subtracted from each treatment in each replication for each year.

Results

Average yield response of corn and soybean yields from 2015 to 2023 and 2020 to 2024, 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 helps sort out each crop's response to each nutrient.

All three macro-nutrients increased corn yield, with corn responding most to N and P (Table 1). Nitrogen rate had the greatest influence on corn yield, as also demonstrated in Figure 1, especially to the first 120 lbs of N. The yield response curve begins to flatten as the N rate increases above 120 lbs. When P and K were more adequate, the optimum N rate would probably be over 160 lbs. This study will be modified for the 2025 season and beyond to have five N rates with 60 lbs of P and 150 lbs of K, which this study has shown would more closely meet the needs of the higher-yielding crops.

Similarly, the first 30 lbs of P_2O_5 resulted in the greatest yield increase (26 bu/a) for corn, and continued to increase (14 bu/a) with an additional 30 lbs of P_2O_5 (Table 1). The addition of 150 lbs of KCl increased the corn yield by 3.3 bu/a.

Soybean yields showed a significant response to the P left over after the corn, with a 14 bu/a increase for the first 30 lbs of P_2O_5, with an additional increase of 10.3 bu/acre at the 60 lb rate. Across all N and P rates, average yield increased by 2.8 bu/a of soybeans with the application of 150 lb of K_2O. There was a 4.7 bu/a increase in soybeans following the N applied to corn.

The highest return on fertilizer investment over a corn/soybean rotation was with the 160-60-150 treatment (Table 1). The treatments that had more balanced fertility that more closely met the needs of the crops had the highest incomes (Table 1).

As corn yields increased with higher N rates, more P and K were removed from the soil, as shown by the soil test data (Table 2). As a result, corn showed a greater increase in yield with N when the P and K were closer to meeting the crop's needs. (Figure 1, Table 2).

The soil P ppm has been dropping from the initial sampling when the study began as a corn/soybean rotation in 1983, with a study average of 55 ppm then compared to 44 ppm in 2022 with 60 lb/a P_2O_5 and 16 ppm with 30 lb/a P_2O_5, averaged across N and K rates. Soil K ppm has dropped from 320 to 307 K ppm, averaged across N and P rates, for the same time period.

The P and K removed by both crops in a corn/soybean rotation averaging 225 bu/acre corn and 72 bu/acre soybeans would be 132 and 158 lbs/acre, respectively.

Summary

As well documented for years, the data from a long-term study showed that N is the most critical fertilizer for corn. Phosphorus follows closely behind as a critical fertilizer for both crops. However, the addition of K allowed for corn yield to respond more as N rates increased. 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.

Table 1. Average yield response of corn and soybean yields from 2015 to 2023 and 2020 to 2024, respectively, to the fertilizer treatments applied prior to corn planting.

Fertilizer[1]			Corn yield	Soybean yield	2 year Income return over fertilizer cost [4]	2 Year net income over check (0-0-0)
N	P_2O_5 [2]	K_2O	2015-2023	2020-2024		
lb/a			bu/a		$/acre	
0	0	0	95.8 h[3]	38.9 i	838	0
0	0	150	97.6 h	43.7 hi	838	0
0	30	0	120.6 f	58.5 ef	1132	294
0	30	150	101.2 gh	58.9 ef	989	151
0	60	0	112.0 fg	69.2 ab	1181	343
0	60	150	114.0 fg	74.5 a	1187	350
120	0	0	157.1 e	50.6 ed	1186	348
120	0	150	165.5 de	53.1 gh	1195	357
120	30	0	181.7 c	59.2 def	1369	531
120	30	150	201.2 b	66.9 bc	1481	643
120	60	0	204.9 b	69.2 ab	1559	722
120	60	150	206.7 b	71.5 a	1535	697
160	0	0	170.8 cde	47.5 gh	1202	364
160	0	150	168.5 cde	48.3 gh	1142	304
160	30	0	202.5 b	60.9 cde	1465	628
160	30	150	206.0 b	61.4 cde	1430	593
160	60	0	209.7 b	71.0 ab	1583	745
160	60	150	223.8 a	72.1 ab	1603	765
80	30	150	175.3 cd	58.0 ef	1289	451
200	30	150	209.3 b	65.6 bcd	1470	632
Prob>F			<0.0001	<0.0001		

continued

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Fertilizer[1]			Corn yield	Soybean yield	2 year Income return over fertilizer cost [4]	2 Year net income over check (0-0-0)
N	P_2O_5 [2]	K_2O	2015-2023	2020-2024		
---------- lb/a ----------			---------- bu/a ----------		---------- $/acre ----------	
Nitrogen means						
0			106.9 c	57.3 b		
120			186.2 b	61.7 a		
160			196.9 a	60.2 a		
Prob>F			<0.0001	0.008		
Phosphorus means						
	0		142.6 c	47.0 c		
	30		168.9 b	60.9 b		
	60		178.5 a	71.2 a		
Prob>F			<0.0001	<0.0001		
Potassium means						
		0	161.7	58.3 b		
		150	165.0	61.1 a		
Prob>F			0.17	0.02		

[1] Fertilizer applied to corn in odd years from 1983 to 2023.
[2] P 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). N and K treatments were applied to corn in 1997.
[3] Numbers followed by different letters are different at Prob. = 0.05.
[4] 2 year income calculated using corn at $4.65, soybeans at $10.07, N at $0.445/lb, P_2O_5 at $0.611/lb, KCl at $0.375/lb.

Table 2. Interaction of nitrogen, phosphorous and potassium fertilizer applied before corn in a corn-soybean rotation on soil fertility, corn and soybean yield at Kansas River Valley Experiment Field-Topeka.[1]

Nutrient			2022 soil test		2015-2023 corn yield average	2020-2024 soybean yield average
N	P_2O_5	K_2O	P ppm	K ppm		
lb/a			0-6 inch depth		bu/a	
0	0	0	12	193	95.8	38.9
0	0	150	12	330	97.6	43.7
0	30	0	22	187	120.6	58.5
0	30	150	22	300	101.2	58.9
0	60	0	55	178	112.0	69.2
0	60	150	58	306	114.0	74.5
120	0	0	5	176	157.1	50.6
120	0	150	7	310	165.5	53.1
120	30	0	18	169	181.7	59.2
120	30	150	12	296	201.2	66.9
120	60	0	39	170	204.9	69.2
120	60	150	49	297	206.7	71.5
160	0	0	5	191	170.8	47.5
160	0	150	5	331	168.5	48.3
160	30	0	12	158	202.5	60.9
160	30	150	9	304	206.0	61.4
160	60	0	34	160	209.7	71.0
160	60	150	32	289	223.8	72.1
80	30	150	12	309	175.3	58.0
200	30	150	9	294	209.3	65.6

[1] Fertilizer applied to corn in odd years from 1983 to 2023.

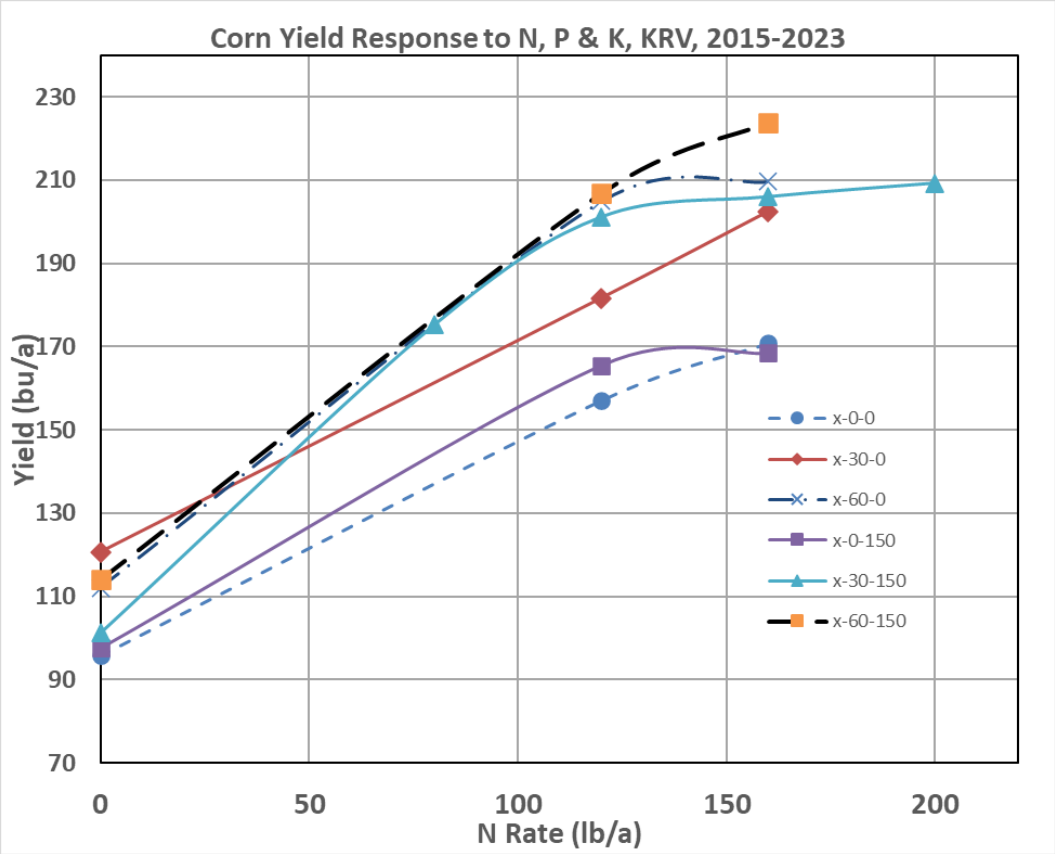

Figure 1. Corn yield response to N at different levels of P and K from corn planted in annual rotation with soybeans from 2015-2023 at Kansas River Valley Experiment Field. The "x" = N rate in legend, followed by P and K rates.