Phosphorus and Potassium Fertilization for Corn and Soybean During 40 Years in Northeast Iowa - Final Study Report

September 2024

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Treatments and Procedures

Long-term experiments for phosphorus (P) and potassium (K) have been conducted Iowa State University (ISU) research farms to complement short-term trials on farmers' fields because they allow for the study of yield and soil-test values trends over time. A trial was established at the ISU Northeast Research and Demonstration Farm in 1979 by the late researcher Dr. John Webb and farm superintendent Ken Ross to study effects of P and K fertilization on soil-test values and grain yield of corn and soybean. This report summarizes results through the end of 2018 when the trial was discontinued.

The soil at the site was Kenyon loam and the 6-inch topsoil layer tested 28 ppm in P (Bray-1) and 213 ppm in K (ammonium-acetate), for which no P or K was recommended by ISU at the time. Both crops were grown each year by alternating adjacent trials with identical design and management. Nine annual treatments were the combinations of 0, 46, or 92 lb P_2O_5/acre and 0, 72, or 144 lb K_2O/acre. Two other treatments applied only once a mixture of 92 lb P_2O_5/acre and 144 lb K_2O/acre every other year before corn or soybean. Granulated triple superphosphate (0-46-0) and potassium chloride (0-0-62) were broadcast in the fall. Plots with cornstalks were chisel plowed in the fall after the fertilizers application and all plots were field cultivated in the spring. Annual nitrogen (N) rates for corn were 150 lb N/acre in the early years and were gradually increased up to 200 lb N/acre over time. Nonlimiting rates of sulfur and micronutrients began to be applied across all plots since 2010. Lime was applied periodically to maintain soil pH between 6.0 and 6.5. Grain yields were adjusted to 15% for corn and 13% for soybean.

Soil-Test Results

Figure 1 shows large effects of the P and K treatments on soil-test values (see figures and tables at the end). Soil-test P of plots receiving no P decreased from 28 ppm to a very low plateau at around 6 ppm after 30 years, was only slightly increased by the 46-lb rate, and was increased exponentially by the 92-lb rate to a final average around 120 ppm. Soil-test K of plots that received no K decreased from 213 ppm to a low plateau at around 100 ppm after 25 years, was slightly decreased by the 72-lb rate, and was increased exponentially by the 144-lb rate to a final average at around 400 ppm. These soil-test changes reflect the nutrient application rates and nutrient removal with grain harvest, which is significantly affected by the yield level. Grain P and K concentrations were analyzed occasionally in recent years only for some treatments (not shown).

Crop Grain Yield Results

Figure 2 shows corn and soybean grain yield trends over the 40 years of the study without P or K, both low P and K rates, and both high P and K rates. The graphs show well a large temporal yield variation due to weather. There were very small or no yield increases from P or K fertilization for either crop until around 1996. It took 17 years for the initial soil-test values of

the non-fertilized plots to decrease to levels between Low and Optimum according to current interpretations in extension publication PM 1688. The yield increases became larger over time as soil-test values of non-fertilized plots continued decreasing. Corn yield with the highest P and K rates began to be slightly higher than with the low rates since 2012. However, since around 2004 soybean yield with the highest rates often was lower than with the lower rates. The soybean yield decrease was due to the highest annual K rate of 144 lb K_2O/acre, which is demonstrated by yield averages in Fig. 3 for all annual rates since 1996.

Figure 3 also shows a clear P by K interaction for both crops because yield responses to one nutrient differed with the levels of the other. For both crops the lower overall yield without K increased linearly up to the highest annual P rate of 92 lb P_2O_5/acre but the 46-lb rate almost maximized yield. There were substantially different responses between crops for the low and high K rates. Corn yield was slightly higher with the 144-lb K rate than with the 72-lb K rates for both P rates, but soybean yield was reduced by the 144-lb K rate compared with the 72-lb rate for both P rates. Soybean is more susceptible to salt concentrations and chloride toxicity than corn so the combination of a very high potash rate and extremely high soil-test K may explain the yield decreases.

Another result from this study (not shown) was that grain yield for treatments that applied a mixture of 92 lb P_2O_5/acre and 144 lb K_2O/acre every other year either before corn or soybean have been similar to yields for treatments that have applied annually one-half these amounts. These results confirm similar results from other experiments at this farm and other farms in that the needed P or K rate for the two crops of the corn-soybean rotation can be applied only once either before corn or soybean.

Table 1 shows average annual net returns to investment in P and K fertilizers using current prevailing grain and fertilizer prices. Returns were calculated using the average grain yield responses for the last four years of the study. The cost of fertilization was subtracted from the value of additional grain produced in fertilized plots compared with non-fertilized plots. For both crops the net returns were highest with the low annual P and K rates used. Much lower and even negative returns with the highest fertilizer rates were explained by increased costs for approximately similar corn yield levels or lower soybean yield levels in recent years.

Conclusions

The study began with soil testing high in P and K, and 17 years were needed for soil-test values of nonfertilized plots to decrease sufficiently so corn and soybean grain yield responses resulted in economic returns from P and K fertilization. Annual rates of 92 lb P_2O_5/acre and 144 lb K_2O/acre (higher than removal) greatly increased soil-test values and by 40 years were around 100 ppm P and 400 ppm K. The high P rate and very high soil-test P never decreased yield of either crop. The high K rate did not affect corn yield but began decreasing soybean yield when soil-test K became around 300 ppm or higher. The profitability of crop production can be maintained by applying recommended P and K rates in low-testing soils and keeping soil-test values in the Optimum category based on prevailing yield and removal with harvest. There is no benefit from P or K fertilization in high-testing soils except for starter in some conditions.

Acknowledgements

We recognize support by the College of Agriculture and Life Sciences of ISU and contributions of seed by Monsanto/Bayer and fertilizers by PCS Corp/Nutrien Ltd.

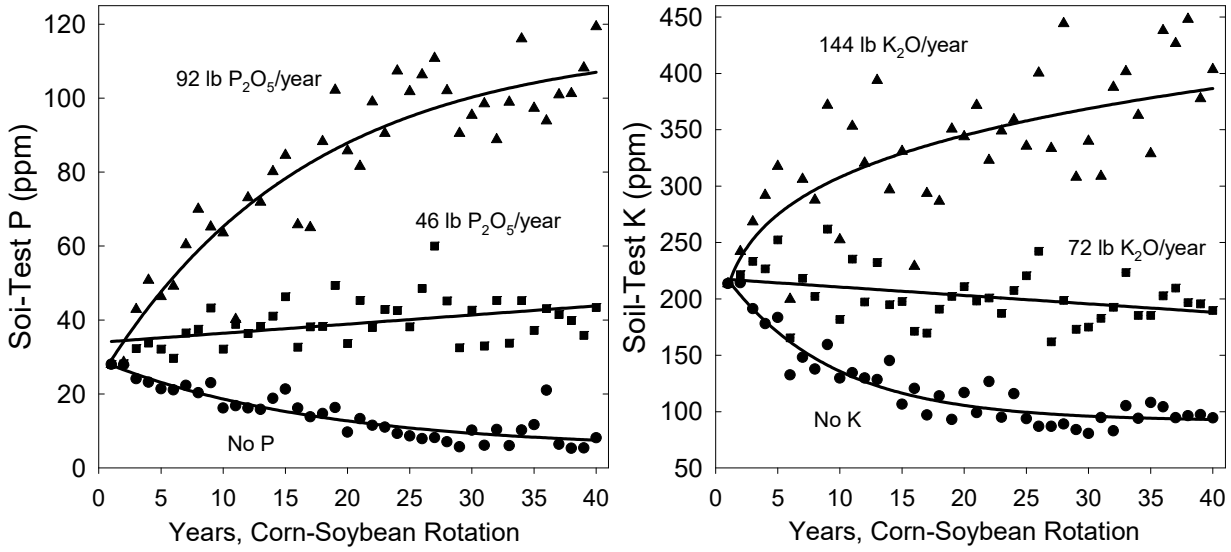

Figure 1. Soil-test P and K across the 40 years the study as affected by P and K fertilization.

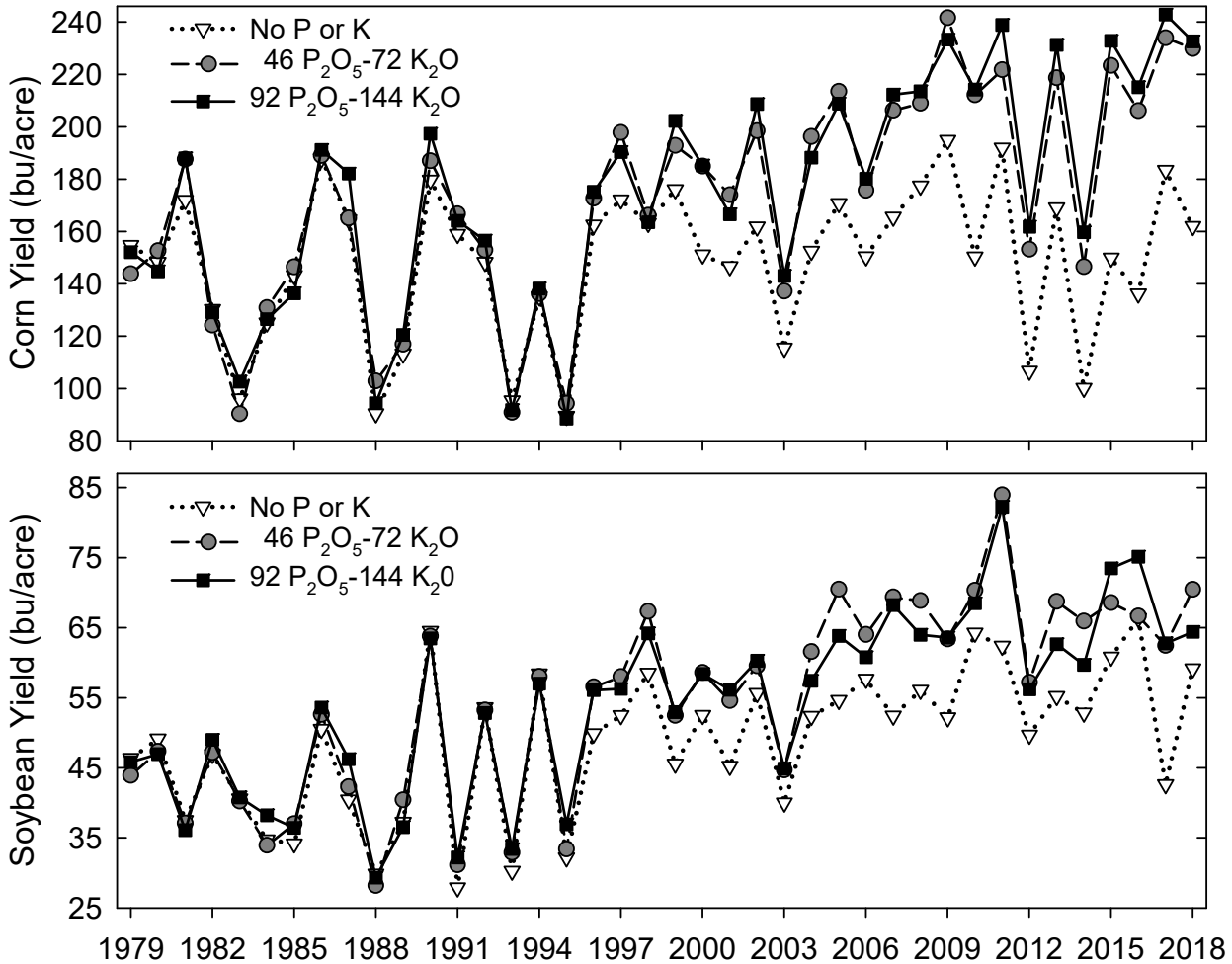

Figure 2. Corn and soybean grain yield across the 40 years the study as affected by P and K fertilization.

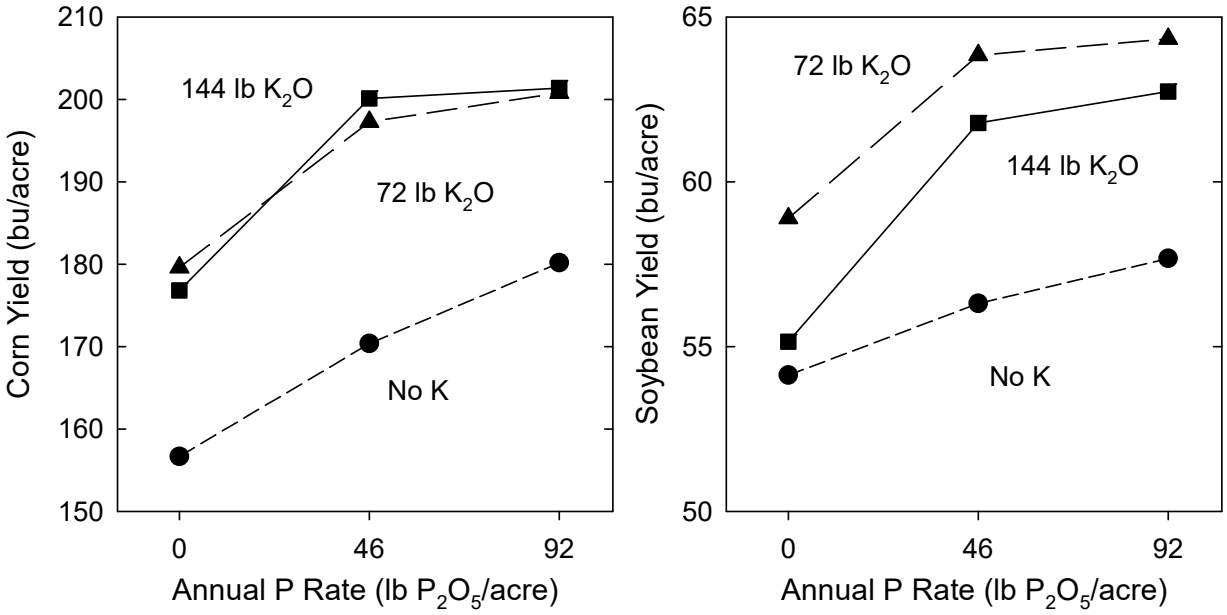

Figure 3. Effect of annual P and K fertilization rates on average crop yields from 1996 until 2018.

Table 1. Economic net returns to combinations of annual P and K fertilizer rates for average corn and soybean yields for the last four years of the study (2015, 2016, 2017, 2018). *

Corn				Soybean			
P rate	K rate (lb K_2O/acre)			P rate	K rate (lb K_2O/acre)		
lb P_2O_5/acre	0	72	144	lb P_2O_5/acre	0	72	144
	-------- $/acre/year --------				--------- $/acre/year --------		
0	-	119.87	86.90	0	-	19.42	-22.53
46	42.91	208.47	204.81	46	12.00	43.31	16.42
92	88.70	209.38	180.33	92	-43.00	70.18	11.19

* Assumed prices prevailing in Iowa in August were $4.00/bu of corn, $11.00/bu of soybean, $0.66/lb P_2O_5, and $0.41.00/lb K_2O. Application costs were not considered.