WHAT CAN LONG TERM EXPERIMENTS PROVIDE FOR IMPROVING PHOSPHORUS AND POTASSIUM MANAGEMENT?

Antonio P. Mallarino
Department of Agronomy, Iowa State University
apmallar@iastate.edu

INTRODUCTION

Agricultural research utilizes both short-term and long-term experiments. Short-term experiments provide useful information on how a system is affected at the time of management changes, and evaluate short-term responses by the soil or crop. Agricultural systems are complex systems with multiple components that operate on different time scales of response, however. Therefore, the initial response of either the whole system or individual components may not necessarily indicate the direction or the magnitude of long-term changes. Long-term experiments that include key measurements are more likely to more correctly evaluate and interpret systems responses to management practices. Long-term experiments provide measurements of soil and crop changes and functioning across a time scale of years or decades that are critical for agronomic and environmental assessments of soil sustainability, productivity, and soil-environment interactions and also are useful for developing or validating models.

This article focuses on the value pf phosphorus (P) and potassium (K) long-term experiments. The prevailing P and K management and recommendation systems in the north-central region are based on soil testing, response-based fertilization of low-testing soils, and removal-based fertilization to maintain desirable soil-test levels. Important issues for effective management and recommendations include use of appropriate soil-test methods and field calibrations to determine optimum soil-test levels and fertilization rates, knowledge of fertilization and cropping impacts on soil-test values over time, reliable estimates of P and K removal with harvest, and use of efficient fertilizer placement methods among others. Short-term experiments are very useful to correlate soil- or tissue test values with crop yield response, calibrate test methods by finding the nutrient rates needed to attain maximum yield or a percentage of the maximum yield and both the magnitude and probability of yield responses, and to evaluate the short-term effect on yield or nutrient uptake of different placement methods or application times. Long-term P and K experiments also can provide some of this information, but most significantly add information about impacts of fertilization strategies on yield, nutrient uptake or removal, soil nutrient buildup or decline in topsoil and subsoil, and relationships between these measurements over time. This complementary information allows producers and nutrient management planners to make prudent management choices to profit from nutrient management while being mindful of soil sustainability and environmental impacts.

In most soils of the northcentral region, moderate soil-test P and K buildup happens with the rates usually recommended for low-testing soils and large soil-test increases occur with larger application rates. This is explained by nutrient uptake by crops, recycling with residues, and properties in most soils that keep applied P and K in crop-available forms over time. On the other hand, high soil test levels of naturally high-testing soils or those with histories of fertilizer or manure application in excess of crop removal and loss from fields with erosion and surface runoff decrease gradually over time. Research has shown high short-term and long-term variability of soil-test values mainly due to variation in uptake and recycling processes highly affected by variation in rainfall amounts.

Therefore, knowledge of long-term relationships between applied P or K, removal with harvest, and soil-test values is very useful for the management of these nutrients. As an example, the follow section summarizes results of three Iowa long-term studies.

LONG-TERM P AND K INTERACTION EXPERIMENT

An experiment established in northeast Iowa included measurements of grain yield of corn and soybean grown in rotations and soil-test values in the topsoil (6-inch depth) as affected by several combinations of P and K application rates. The soil at the site is Kenyon that initially tested high in P (28 ppm Bray-1) and K (213 ppm NH_4OAc), and has been managed with tillage and broadcast fertilization. Identical adjacent trials were established to grow both crops of the corn-soybean rotation each year. Annual fertilizer treatments have been the combinations of 0, 46, and 92 lb P_2O_5/acre and 0, 72, or 144 lb K_2O/acre. Two other treatments are applied every other year to corn or soybean at rates of 92 lb P_2O_5/acre and 144 lb K_2O/acre. The study has provided very useful information about long-term trends in yield responses, interactions between P and K, and soil-test values even though the funding level never allowed for measurements of P and K removed with harvest or management effects on subsoil P and K levels.

Figure 1 shows that soil-test P (STP) and K (STK) values of non-fertilized plots decreased curvilinearly from the initial value of 28 ppm to an almost plateau at 10 ppm, and from 213 ppm to a plateau at 96 ppm. The low application rates slightly increased STP and maintained STK, while the high rates increased values curvilinearly with decreasing increments up to 120 ppm STP and 390 ppm STK. Figure 2 shows that statistically significant small and occasional yield responses began to be observed after seven years, but consistent responses were not observed until after 18 years. On average across the responsive years, there were no yield differences between the application rates of each nutrient but there was a positive P by K interaction (not shown). Plots that received both P and K fertilizers yielded more than plots that received either P or K alone, but the yield response to P was proportionally greater when K was applied while the yield response to K was proportionally similar with or without P being applied. These results showed mainly that fertilization can be withheld for many years in high-testing soils, that P or K deficiency can significantly limit crop yield, and that a K deficiency also limits the relative response P. The long time that high STP took to decrease to optimum levels shows that the impact of excessive P levels on P loss to water resources would last for many years.

LONG-TERM P AND K TILLAGE BY PLACEMENT EXPERIMENTS

Separate studies for P and K have been conducted at five locations representative of major Iowa soil and crop production areas. The treatments at each P or K trials consisted of different application rates and placement methods for granulated fertilizers for corn-soybean rotations managed with no-tillage. The application rates evaluated since the establishment of the trials have been 0, 28 and 56 lb P_2O_5/acre/year and 0, 35, and 70 lb K_2O/acre/year, and double the highest rates applied every other year before corn or soybean. The placement methods evaluated in all years have been broadcast in the fall and banded with the planter attachments 2 inches besides 2 inches below the seeds. Only the two lowest application rates were applied with the planter. The STP and STK stratification as affected by the tillage and selected fertilizer treatments has been evaluated by annual soil sampling from depths of 0-3 and 3-6 inches.

This article summarizes only long-term relationships between P and K removal with harvest and soil-test values, only one of the many important outcomes of these trials. Partial results concerning effects of placement methods and P or K rates on crop yield and soil-test values have been partially summarized before and some articles have been posted in the ISU Soil Fertility web site (http://www.agronext.iastate.edu/soilfertility). Briefly, the yield response to P or K varied greatly across the five locations and years mainly as a result of differences in STP and rainfall. Sites initially testing high or very high in STP or STK according to Iowa State University interpretations showed very infrequent and small yield responses to P and K. The P or K placement methods have not differed, and occasional small differences were in favor or band or broadcast method. Large P and K stratification due to no-till management within the top 6 inches of the soils has not affected the response to fertilization and the correlation between yield response and soil-test values from samples taken from a 3-inch depth were not better than from 6-inch samples.

Figure 3 shows the long-term relationship between the cumulative P removed with harvested corn and soybean grain and STP (6-inch sampling depth) over 12 years for the non-fertilized plots at five locations and for the average across the locations. The averages smoothed larger variation at each location and there was a good general relationship between P removal and STP trends. On average across sites, removal of 37 lb P_2O_5/acre/year resulted in an average STP decrease of 0.78 ppm/year. These results imply an average removal of 47 lb P lb P_2O_5/acre/year to decrease 1 ppm STP/year. An equation (not shown) relating net P addition or removal and STP across fertilized and non-fertilized plots across all sites had a good fit for the drawdown portion but not for the buildup portion due to high variability in the data and relatively small P application rates. This equation showed that a net addition of 15 lb P_2O_5/acre increased STP 1 ppm, which was a value only slightly lower than the average value reported for the Midwest (16 to 18 lb P_2O_5/acre). Better predictions could be made with a longer study and with higher P application rates that would override effects introduced by P removal and STP variability. The data in Fig. 1 shows that there was no good relationship between P removal and STP change in the short term, probably because of variation in P recycling in residues and temporal STP variability. This is why producers should consider long-term trends and relationships when making decisions about STP maintenance.

Figure 4 shows the long-term relationship between the cumulative K removed with harvested corn and soybean grain and STK (6-inch sampling depth) over 10 years for the non-fertilized plots at five locations and for the average across the locations. The relationship between K removal and STK over a long time was relatively good, but was very poor for each year and much poorer than for P. Ongoing research is indicating that rainfall and soil moisture impacts on short-term nutrient recycling with crop residue and reactions between soil nutrient pools have a much higher impact on STK levels than on STP levels. In the long-term, and on average across all five locations, removal of 42 lb K_2O/acre/year resulted in an average STK decrease of 3.0 ppm/year. These results imply an average removal of 14 lb P lb K_2O/acre/year to decrease 1 ppm STK/year. In contrast to the P trials, the highest K rates applied resulted in little or no soil K buildup and much variability, so study of relationships when there is a K buildup is not possible.

ACKNOWLEDGEMENTS

Portions of the work for one or more of the studies summarized in this article have been supported by the International Plant Nutrition Institute, the Iowa Soybean Association, and the Leopold Center for Sustainable Agriculture.

FIGURES

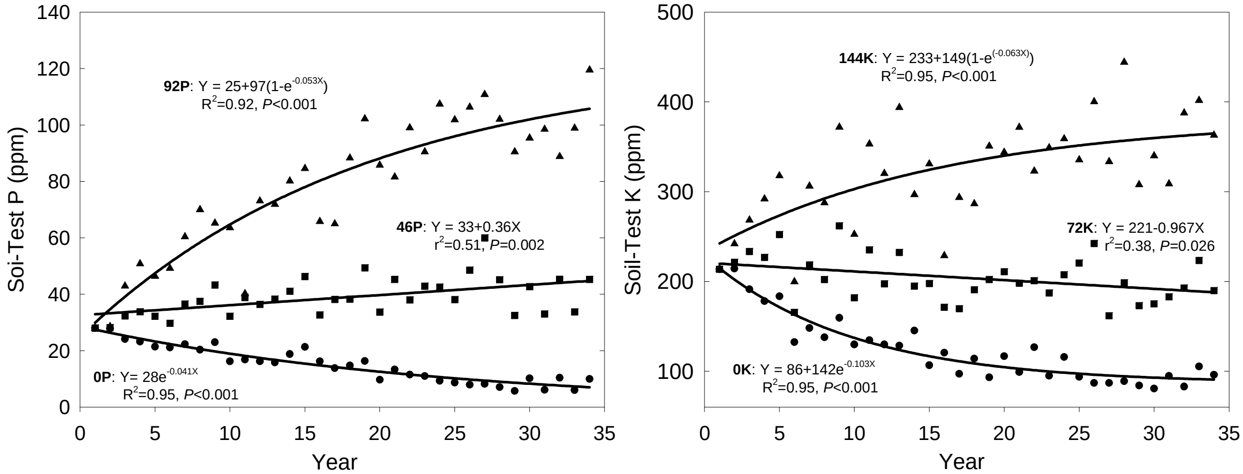

Fig. 1.Soil-test P and K trends over time from an Iowa long-term experiment with corn-soybean rotations that received 0, 46, and 92 lb P_2O_5/acre/year or 0, 72, and 144 lb K_2O/acre/year.

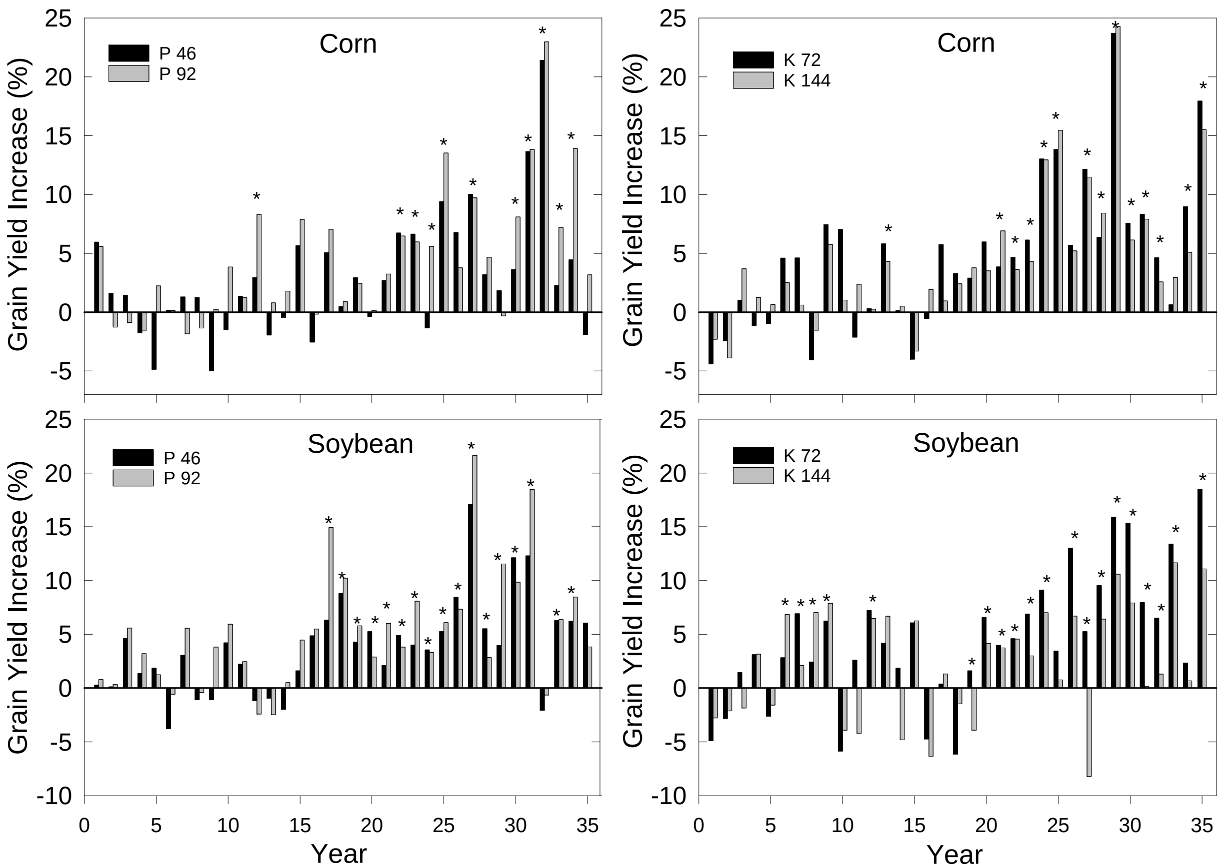

Fig. 2.Corn and soybean grain yields from an Iowa long-term experiment that received 0, 46, and 92 lb P_2O_5/acre/year or 0, 72, and 144 lb K_2O/acre/year. Yields for each nutrient are averages across the two rates of the other. Asterisks indicate significant differences ($P \leq 0.05$).

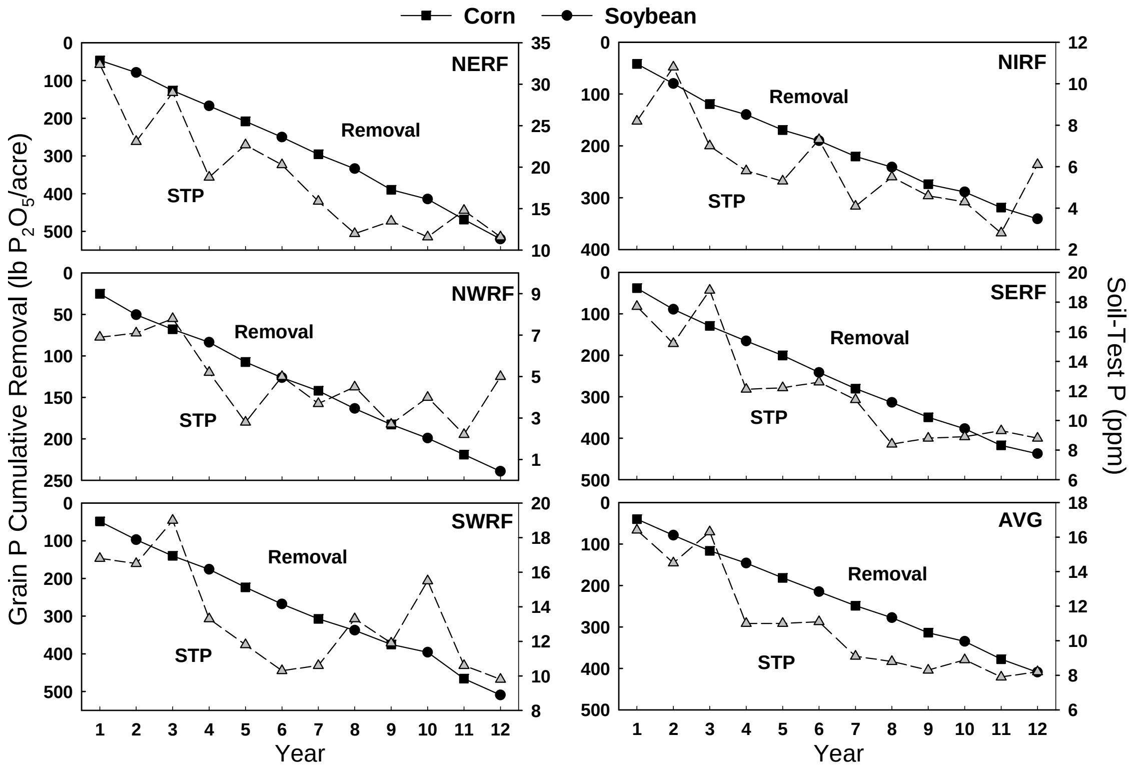

Fig. 3. Phosphorus removal with grain harvest and soil-test P trends over time for corn-soybean rotations at five Iowa long-term experiments for plots that were not fertilized with P.

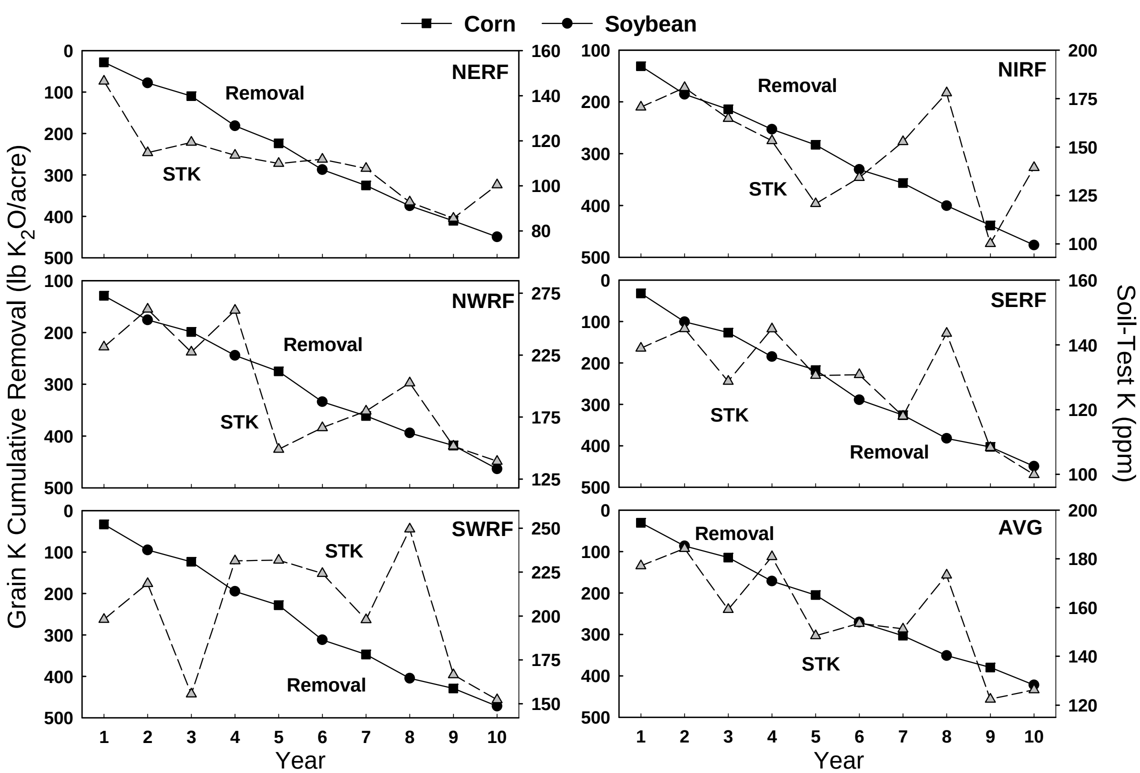

Fig. 4. Potassium removal with grain harvest and soil-test K trends over time for corn-soybean rotations at five Iowa long-term experiments for plots that were not fertilized with K.

PROCEEDINGS OF THE

46^{th}

NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 32

November 2-3, 2016
Holiday Inn Airport
Des Moines, IA

PROGRAM CHAIR:

Dorivar Ruiz Diaz
Kansas State University
Manhattan, KS 66506
(785) 532-7213
ruizdiaz@ksu.edu

PUBLISHED BY:

International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
Web page**: www.IPNI.net**

ON-LINE PROCEEDINGS:

http://extension.agron.iastate.edu/NCE/