Phosphorus and Potassium Recommendations for Illinois Crops

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INTRODUCTION

Corn (*Zea mays* L.), soybean (*Glycine max* [L.] Merr.), and wheat (*Triticum aestivum* L.) are the three most extensively-grown crops in the state. Large amounts of phosphorus (P) and potassium (K) are required to attain high yields in these crops. Phosphorus is an essential structural element (integral part of DNA), responsible for energy transfer, photosynthesis efficiency, and shoot growth. Likewise, K is a multi-tasking nutrient that increases the ability of these crops to withstand biotic and abiotic stresses, and helps in overall plant health. High requirements for these nutrients typically results in the need to fertilize the soil to provide these crops with an adequate supply of P and K. Application of P and K represents a multi-billion dollar investment for Illinois farmers.

To determine the proper rate of application of these nutrients, and ensure maximum yields, producers are advised to follow university recommendations listed in the Illinois Agronomy Handbook (Fernández and Hoeft, 2009). This recommendation system for P and K applications is based on yield response to soil test levels. These yield response curves were used to determine 1) the critical soil test level, or point at which near maximum yields could be obtained; and 2) the soil test level at which additional fertilization is very unlikely to increase yields. The range of soil test values between these two points is defined as the maintenance level. Fertilizer application rates at the maintenance level are determined by the amount of P and K removed by the crop. When soil test values are below the critical level, in addition to the maintenance rate, a rate of 9 lb P_2O_5 $acre^{-1}$ for P or 4 lb K_2O $acre^{-1}$ for K is normally added to increase soil test levels by 1 lb $acre^{-1}$.

While the new 24th edition of the Illinois Agronomy Handbook was published in 2009, P and K recommendations values are based on work conducted during the 1960's. Obviously, much has changed since this set of recommendations were established, not only in terms of yield, but also other factors such as economics, greater awareness of environmental sustainability, hybrids, nutrient distribution and nutrient status of the soil, climate, and management. The fact that these values were generated more than 40 years ago, during what could be considered a different era of agricultural production in Illinois, calls into question the validity of the recommendations for current production systems.

Re-evaluating the P and K recommendation system is an ambitions endeavor that requires strategic planning and considerable amounts of time, but must be done to ensure conscientious management of these nutrients. Thus, our project was established to address the need to re-evaluate P and K recommendations for the state. This work will include determination of P and K removal rates in grain, soil P and K correlation and calibration studies, and evaluation of new soil P and K extraction and analysis methods.

Soil test values without proper correlation and calibration studies are meaningless (similar to a number without units). Establishing long-term P and K rate plots at the University Of Illinois Research Centers is extremely important for the correlation, and most importantly, for the calibration work needed to re-evaluate current soil-test-based fertilizer recommendations. These research plots will also provide data on incline and decline of soil fertility levels based on nutrient inputs and outputs over the long term. These data are important in determining fertilization rates needed to build up or draw down fertility. Additionally, over time these plots can become assets to Illinois to address future questions on the effect of long-term management on soil and crop production.

Another important aspect of this work is that we propose to evaluate several different extraction and analysis methods currently being used by commercial soil testing labs for which the necessary correlation and calibration studies have not been conducted in Illinois. The traditional extractions and analytical colorimetric methods are being quickly displaced by multi-nutrient extractions and analysis by Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP). However, the interpretation of results for P from ICP should be based on field calibrations rather than conversions based on the data from the traditional methods (Mallarino, 2003). Similarly, it is well known that wetting and drying of soils can have important and unpredictable effects on soil K levels (Haby et al. 1990). The use of a field-moist soil sample has been shown to be a more reliable approach by early Iowa work. However, just as with colorimetric vs. ICP data, the values of the field-moist method cannot be interpreted as those obtained by standard methods.

Determination of removal rates, the soil P and K correlation and calibration work, and the analysis of soil samples using new methodologies are of critical importance to Illinois growers. The information collected from this study will provide timely and much needed information to help assist producers with their P and K management decisions. Currently the recommendations are based solely on maximum yield and there are no means to calculate economical optimum rates. This work will allow us to start viewing recommendations in terms of economics. Even if this project shows that current recommendations are adequate for Illinois, this project will help restore or improve confidence in the current recommendation system. This can result in greater adoption of the recommendations by producers; the benefits of which would be improved management of resources, greater profitability, and greater protection of the environment.

MATERIALS AND METHODS

In order to evaluate the of removal rates of P and K in seed of corn and soybean samples collected by the University of Illinois Variety Testing trials around the state were analyzed with funds received from FREC. Additional corn and soybean grain samples were evaluated for

removal rates from an established P and K study. This study is located in East Central Illinois in three different farmer's fields. Treatments were established in 2007 on a corn-soybean rotation and have remained in the same location since that time.

Funding from FREC also allowed us to establish a seven year Lo Farm P and K rate trial in corn and soybeans in rotation with both crops present each year. All treatments were randomly assigned in 3 replications blocked by tillage practice. The study consists of three tillage practices and fertilizer placement methods; No-till broadcast (NT-BC), No-till deep-placement (NT-DP), and Strip-till deep-placement (ST-DP). The treatments stayed in place for the duration of the experiment. Four P levels: 0, 25, 50, 75 lbs. P_2O_5/acre/yr and four K levels: 0, 45, 90, 180 lbs. K_2O/acre/yr were applied. From this study we are able to look at the changes in soil P and K tests at different soil depths, yield information and grain removal of nutrients over six years. Plant samples have also been analyzed allowing us to look closely at plant uptake of P and K. This established trial produced valuable information and leads us to the need to further evaluate the phosphorus and potassium recommendations for Illinois crops.

Objective 1 of the Phosphorus and Potassium Recommendations for Illinois Crops Project is to establish long-term P and K rate studies at the University of Illinois Research and Education Centers around the state. The goal is to set up plots that can be used for the other objectives of this project as well as to provide future research opportunities related to re-evaluation of P and K recommendations. In 2012 P and K rate studies were established at the 6 Crop Sciences Research & Education Centers located throughout Illinois (Brownstown, Monmouth, Perry, Shabbona, Simpson, and Urbana). In order to generate response curves, fields with low to medium starting P or K levels were selected at each location to conduct P and K fertilizer rate studies. Sites were select for soils that are most important and representative for agriculture in the state. A continuous corn and corn-soybean rotation was established with no-till and conventional tillage components at Urbana and Monmouth; a continuous corn and corn-soybean rotation was established at Perry and Shabbona; and a continuous corn and corn-soybean-wheat rotation was established at Brownstown and Simpson. Each crop is present each year for each of the rotation studies. The P-rate studies consist of six P-fertilizer rates (0, 30, 60, 90, 120 lb P_2O_5 $acre^{-1}$ $year^{-1}$) and the K-rate studies have six K-fertilizer rates (0, 30, 60, 90, 120 lb K_2O $acre^{-1}$ $year^{-1}$). Due to field area limitations at Perry, the treatments were reduced to three P-fertilizer rates (0, 60,120 lbs. P_2O_5 $acre^{-1}$ $year^{-1}$) and three K-fertilizer rates (0, 60, 120 lbs. K_2O $acre^{-1}$ $year^{-1}$). Fertilizer treatments will remain in the same plot during successive years. The P or K rates are arranged in a randomized complete block design replicated 4 times for each of the crop rotations. This setup will allow accomplishing the objectives of this proposal, and will establish research plots that can provide opportunities for studies in the future. Except for P and K, all cultural practices are designed to obtain the highest possible yields. For all crop rotations, the rates on each P and K study will be broadcast-applied each fall prior to chisel plowing.

Pretreatment soil samples were collected in Urbana from the 0-3, 3-7, 7-12, 12-24, and 24-36 inch soil depth increments to establish baseline information for P and K levels. Soil samples were collected prior to treatment at the remaining 5 research centers from the 0-3, 3-7, 7-12 inch soil depth increments. Time constraints and soil conditions prohibited the sampling of the 12-24, and 24-36 inch soil depth increments at the remaining 5 research centers during spring 2012.

The second objective of the project is to improve soil-test-based fertilizer recommendations by correlating soil test nutrient levels to crop response and by calibrating P and K fertilization rates to maximize productivity and economic returns. At each of the six research centers in 2012 and 2013 yield was collected from the center portion of each plot. Grain samples collected from each plot are ready to be analyzed for P and K concentration. Following harvest in 2013 soil samples were collected at the 0-7 inch depth for all treatments at Perry, Shabbona, Brownstown and Simpson. Samples from Monmouth and Urbana will be collected early spring 2014. The soil samples will be analyzed for P by Bray-1 and Mehlich-3 ICP and for K by ammonium acetate and Mehlich-3.

This objective includes evaluation of the traditional soil analysis methods (colorimetric analysis of Bray P-1 for P and atomic absorption spectroscopy analysis of ammonium acetate for K) and new methodologies being used by commercial testing labs for which there is no correlation and calibration work done in Illinois. These new methodologies include Mehlich-3 extractions of P and K analyzed by Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP) and moist soil extraction of K (slurry method.) Following harvest in 2013, field moist 0-7 inch soil depth samples were collected from 2 established long-term P and K studies in central Illinois. The field moist samples were analyzed for K determination by the slurry method and will be further analyzed by standard testing methods.

The third objective of the project is to establish strip trials throughout the state and create a central repository of existing geo-referenced data. In the fall of 2013 six strip trials were established; three trials will be established in the spring of 2014. Additional strip trials will be established in the fall of 2014. A repository of geo-referenced seed yield and soil test data will be collected from the trials. Measures will be taken to ensure the database is populated with high quality data. Before incorporating new data we will obtain as much information as possible to determine the soundness of the approach used during data collection. Sites have adequate P and K levels (within maintenance range as suggested by current recommendations). Fields with lower P or K fertility will be considered. Cooperators can conducted this study for both corn and soybean. Information on the previous two crops will also be reported.

The treatments consisted of replicated strips (4 to 8 times) with no P or no K applied in the fall and strips with fall applications equal to at least 1.5 times the removal rate of P or K in grain. The strips were normally as wide as the width of the applicator and harvest was done in the center of the strip. The length of the strip was at least 300 ft. Cooperators used cultural practices that are representative of the cultural practices being used in their area of the state. Geo-referenced soil P and K tests information from the top 7 inches was collected on a maximum of one sample/acre density before treatment application. Yield data was collected with yield monitor or weigh wagon from each treatment and replication. The GPS coordinates were recorded to obtain soil map information for each field using the NRCS Web Soil Survey database (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm).

RESULTS AND DISCUSSION

Crop Yield

A study at the Lo Farm was started in 2007 with soil P and K near critical levels (40 lb.P/acre and 330 lb. K/acre. Averaged over seven years there was significant corn yield response to tillage/placement (Figure 1.) The mean yields for corn were 134.3, 136.7, and 144.6 for No-till/Broadcast (NT-BC), No-till /Deep Placement (NT-DP), and Strip-till/Deep Placement (ST-DP) respectively. The overall low yields are the result of delayed planting in some of the years. Corn also showed a significant response to P rate with a 7 bushel $acre^{-1}$ advantage with 75 lbs. P_2O_5 $acre^{-1}$ over the 0 lbs. P_2O_5 $acre^{-1}$ treatment (Figure 2.) Figure 3 illustrates the interaction between P rate and tillage/placement on corn yield. The tillage effect of ST-DP over shadows the corn response to P rate obtained with NT-BC and NT-DP. In the NT treatments, additional P was needed to increase yield, but yields at the highest P rate remained at least numerically lower than those at the 0 lbs P_2O_5 $acre^{-1}$ treatment in ST-DP. It is likely that tillage in ST-DP allow better crop establishment and growth and improved soil exploration for nutrients by the roots. Further, the data clearly show that deep banding the fertilizer (NT-DB) produced no difference in yield relative to a broadcast application (NT-BC). The seven year project also revealed a corn yield response to K rate. Relative to the check plot, corn yield increased 3 bushel per acre with 45 and 90 lbs. K_2O/acre, and gained another 3 bushel per acre with 180 lbs. K_2O/acre (Figure 4.)

The Lo Farm P and K study also shows significant soybean response to tillage/placement (Figure 5.) Strip-till had a 3.4 bushel per acre advantage over NT-BC. The seven years of soybean yield data showed a slight response to P rate with a 2.8 bushel/acre increase between the 0 lbs. P_2O_5/acre and 75 lbs. P_2O_5/acre treatment (Figure 6.) The response of soybean yields to fertilizer rate appears to be different under different tillage and fertilizer placement (Figure 7.) The seven years of data showed that K_2O application had little effect on soybean yield (Figure 8.)

Yield data has also been analyzed from the Urbana P and K Recommendation trials in 2012 and 2013. A consistent corn yield increase was gained from conventional tillage over no-till in the P study (Figure 9) as well as the K study (Figure 10). Soybeans demonstrated a slight response to tillage in the K study (Figure 11). These data show similar results to the Lo farm study where tillage improved yield over no-till. In contrast to the Lo farm (where treatment application over time has created a large range of soil P and K testing values), in this new study, regardless of tillage practice, no differences in corn or soybean yields by P or K rate occurred in 2012 or 2013 (data not shown). The lack of response to P or K in this new study illustrates the fact that starting fertility levels are sufficiently high to maximize yield and indicate a need to continue to conduct the study for additional years in order to develop the needed range in soil test values to evaluate crop response to fertilizers. Once an adequate range of P and K fertility is developed in this and other long-term sites under this project, we will be able to conduct in-depth analysis for the much needed work of evaluation of current P and K recommendations.

Reference

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Haby, V.A., M.P. Russelle, and E.O. Skogley. 1990. Testing soils for potassium, calcium, and magnesium. p. 181-227, *In* SSSA Book Series: 3, Soil Testing and Plant Analysis, R.L. Westerman (ed.).

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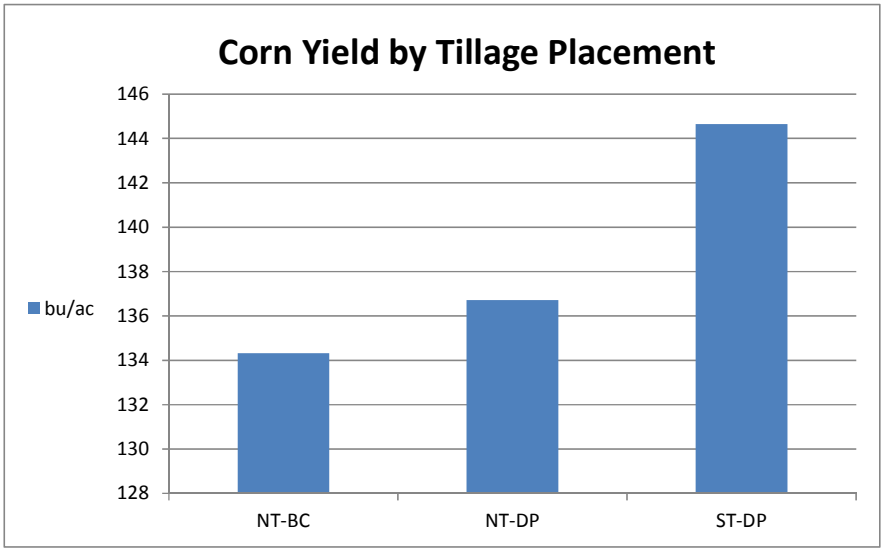
Corn Yield by Tillage Placement
146
144
142
140
138
136
134
132
130
128
bu/ac
NT-BC
NT-DP
ST-DP

Figure 1. Results from Lo Farm P and K Research 2007-2013 show corn yield response to tillage/fertilizer placement.

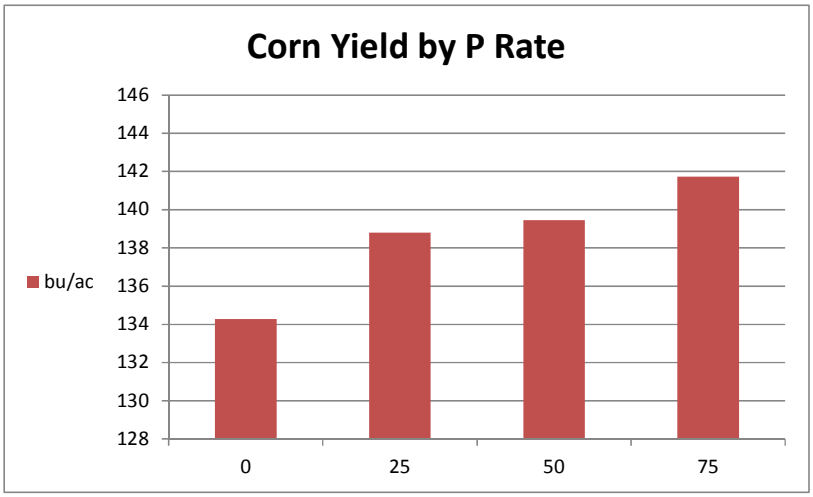

Figure 2. Results from Lo Farm P and K Research 2007-2013 show corn yield response to P rate (lbs per acre.)

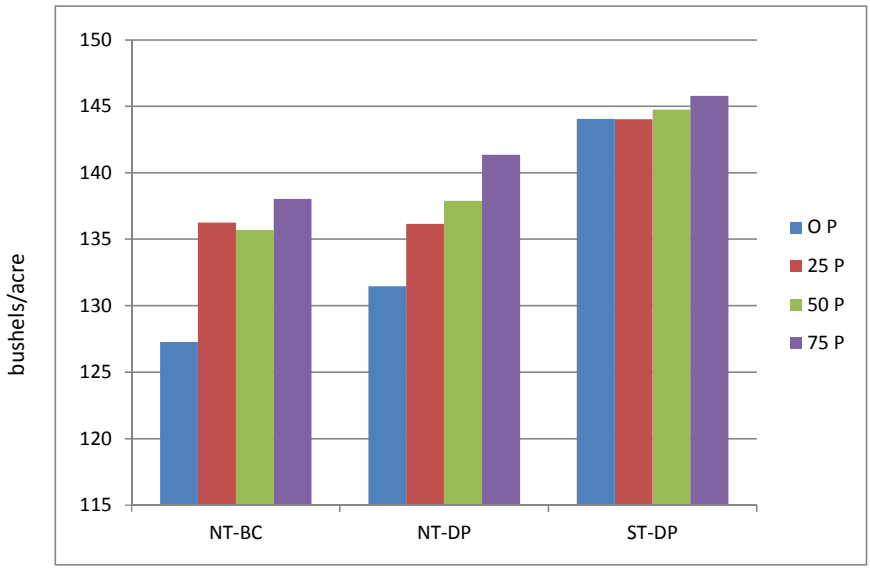

Figure 3. Corn Yield by Tillage Placement and P Rate (lbs per acre) from Lo Farm P and K Research 2007-2013.

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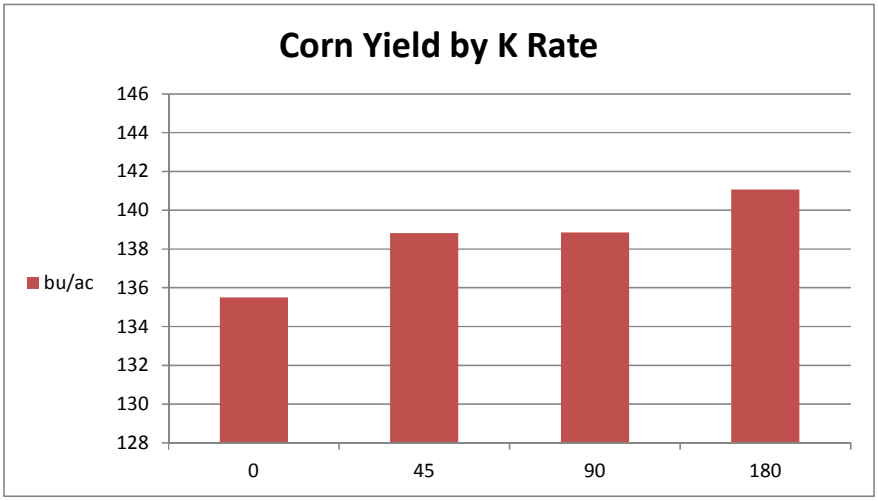

Figure 4. Results from Lo Farm P and K Research 2007-2013 show corn yield response to ~~P~~ K rate (lbs per acre.)

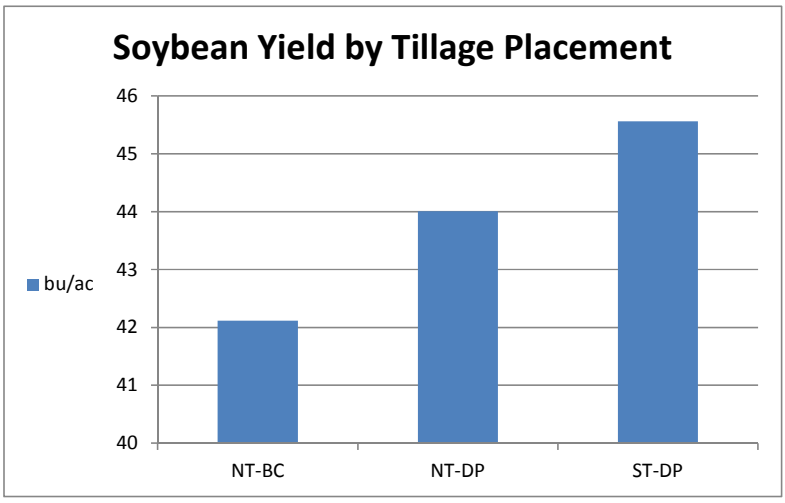

Figure 5. Results from Lo Farm P and K Research 2007-2013 show soybean yield response to the tillage/fertilizer placement.

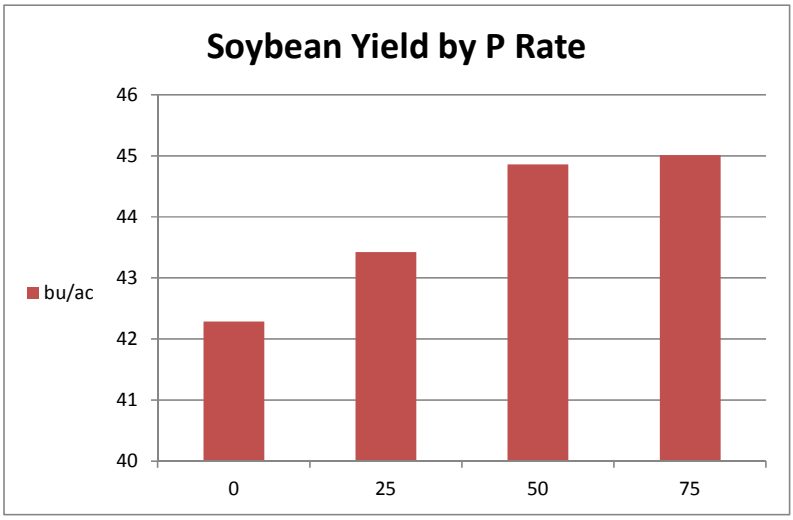

Figure 6. Results from Lo Farm P and K Research 2007-2013 show soybean yield response to P rate (lbs per acre.)

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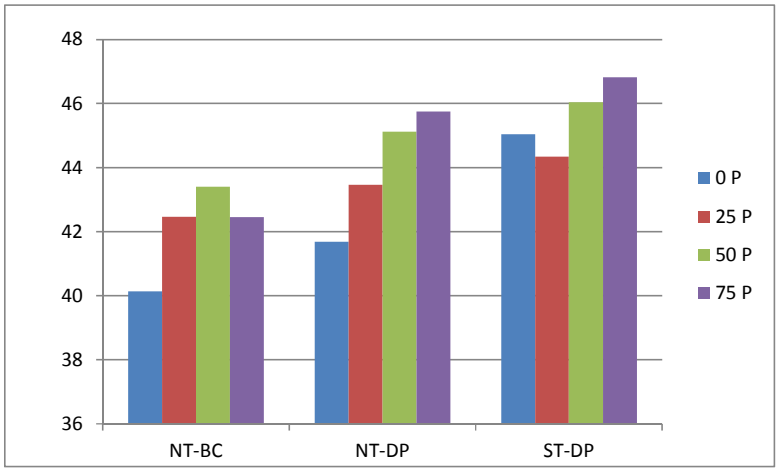

Figure 7. Soybean Yield by Tillage Placement and P Rate from Lo Farm P and K Research 2007-2013.

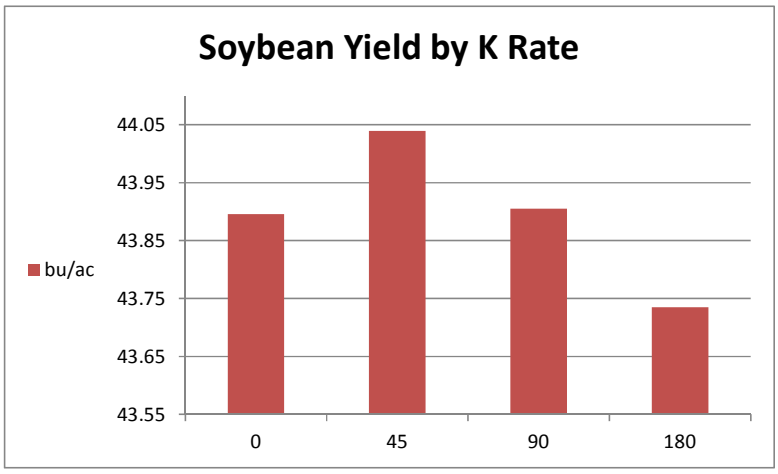

Figure 8. Results from Lo Farm P and K Research 2007-2013 show soybean yield response to K rate (lbs per acre.)

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Bushels/Acre
200
180
160
140
120
100
80
60
40
20
0
CC
2012
SC
2012
CC
2013
SC
2013
No-Till
Conventional Tillage

Figure 9. Urbana Recommendation P study corn yield by tillage and crop rotation.
CC – Continuous Corn
SC – Corn following Soybeans

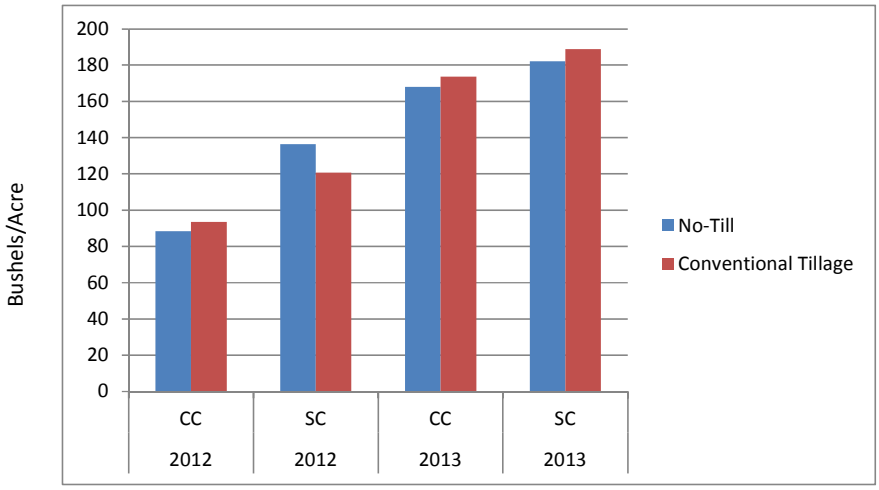

Figure 10. Urbana Recommendation K study corn yield by tillage and crop rotation.

CC- Continuous Corn
SC- Corn following Soybeans

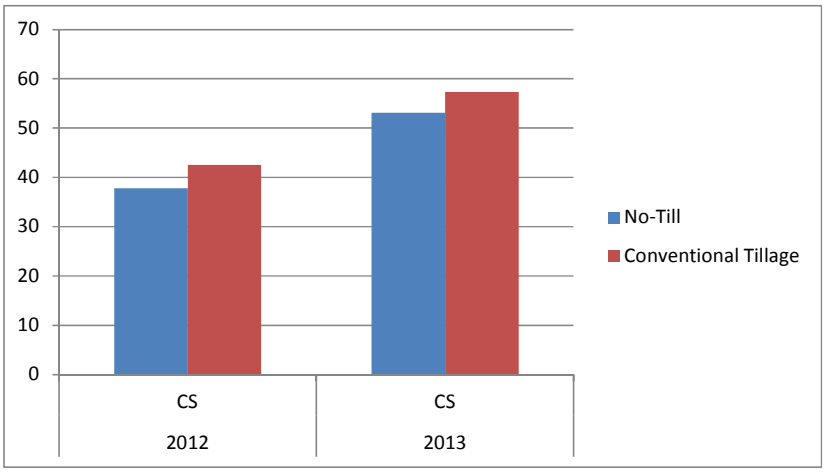

Figure 11. Urbana Recommendation K Study soybean response to tillage.

CS- Soybeans following corn.