Phosphorus Runoff from Surface and Subsurface Fertilizer Applications in No-till and Strip-till Fields with Minimal Slope Gradient in Central Illinois

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In addition farmer cooperators with this project include:
Eric Rund, Field Equipment Operator, Pesotum, IL
David Schaefer, Farmer, Pesotum, IL
Denny Reifsteck, Farmer, Pesotum, IL
Jerry Christian, Farmer, Tolono, IL

INTRODUCTION

Many studies have been focused on determining the effect of conservation vs. conventional tillage systems on P runoff. Relatively less has been done to compare differences in P runoff within different conservation tillage practices. Specifically, studies that compared no-till to strip till are scarce. The few available studies have been done in sandy soils or for productions systems that are very different from Illinois agriculture (Franklin et al., 2007; Truman et al., 2007). The only studies done in Illinois to compare no-till and strip-till were done in fields with substantial slope gradients and to study only the effect of tillage as no fertilizer treatments were applied (Harschi, et al., 1995; McIssac et al., 1991). A substantial portion of agricultural land in Illinois is in the 0 to 2% slopes category. While the potential for runoff is lower in "flat" landscapes, the effect of conservation tillage practices (no-till and strip-till) along with P application rate and placement method has not been evaluated for such landscapes. Also, in the last few years we have observed firsthand that large precipitation events can cause substantial soil erosion and water runoff even in very "flat" ground. These facts would indicate that research in this "flat" landscapes should be a priority. A few manuscripts recently published from our work in Illinois (Farmaha et al., 2011, 2012a, 2012b; Fernández and White, 2012) indicate some of the benefits associated with strip-till over no-till for corn and soybean production. In addition, in another publication (Fernández and Schaefer, 2012) we discussed the benefits of deep banding fertilizer to reduce surface P levels without negatively impacting corn and soybean yields. In all these recent studies, we have mentioned as a possible hypothesis that the potential for P runoff may be reduced with deep banding of fertilizer in no-till and strip-till systems. Obviously, research is needed to quantify the effect of conservation tillage and P fertilizer placement on P runoff.

MATERIALS AND METHODS

Original study setup

The study was conducted in commercial fields at three locations near Pesotum, Illinois (East Central Illinois). The fields were in a corn-soybean rotation with 30-inch row spacing in all sites and for both crops. All three sites had soybeans during the 2007 growing season before the start of the study, thus corn was the first crop planted after treatment establishment. Plot size was 20 x 500 ft and treatments remained in the same plot for the duration of the study. The study was set up as a split-plot arrangement in a randomized complete-block design with two replications. The main (whole) plot included three tillage/fertilizer placement treatments: no-till/broadcast (NTBC); strip-till/broadcast (STBC); and strip-till/deep-placed (STDP). The split-plot treatments were blends of P_2O_5 and K_2O made to create seven P-K fertilizer treatments with a control receiving no P or K (0-0 or check). The six additional rates were established in 23 lb P_2O_5 and K_2O / ac increments starting with a blend of 46 lb P_2O_5 / ac and 46 lb K_20 / ac. Triple Superphosphate was applied at the P source each year. The benefit of ongoing treatment application since 2007, by fall 2013 the plots had a large gradient of soil surface P test levels, which made these plots ideal to accomplish the objectives of this study.

Strip-till operations were done always in the fall and the crop was planted on the location of the strips the following spring.

Photo caption: left~~a~~) DMI Model 4300 Strip-till tool bar with Gandy Orbit-Air dry fertilizer box, right~~b~~) Strip-till ridges following fall application.

P Runoff ~~P runoff study setup~~

Fall 2013

Following harvest soil samples were collected at 0-4, 4-8 and 8-12 inch depths for Bray-P analysis to assess nutrient levels in the soil profile. ~~Yield data w collected from the crop in the fall of 2014. application of~~ Potassium and Phosphorus treatments were applied using the three tillage/fertilizer placement methods: no-till/broadcast (NTBC); strip-till/broadcast (STBC); and strip-till/deep-placed (STDP). Three fertilizer rates from the original study (0, 92, and 161 lb P_2O_5 $acre^{-1}$ and K_2O $acre^{-1}$) were selected for Phosphorus runoff measurements. We followed similar procedures to Daverede et al. (2003) for rainfall simulation and runoff sample collection

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and analysis. In the center of each treatment area a microplot (5 x 6.5 ft) was established by installing metal borders on 3 sides with a collection tray on the 4th side. The microplots were installed to be representative of the field with the long sides placed in the middle of a strip-till track.

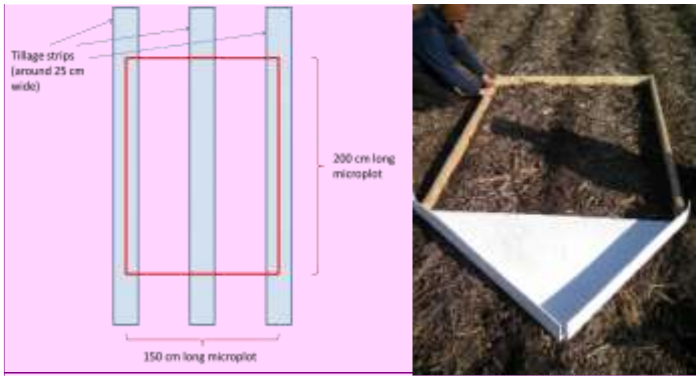

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Photo caption: left~~a~~) Orientation of microplot over tillage strips, right~~b~~) microplot frame constructed on 3 sides of angle-iron in ground attached to lumber above ground with 4th side collection tray with plot edge inserted into ground.

Rainfall simulation started in early November 2013 but was disrupted by inclement weather until December. Thus, samples were collected only in one of the three locations. Runoff water from a 30-minute runoff event was collected from each micro-plot at 5 minute intervals (up to 500 ml) with an additional 1-liter sample collected after the rainfall simulation event. The runoff samples were analyzed for three forms of phosphorus. Dissolve Reactive Phosphorus (DRP) includes the dissolved or soluble forms of P captured when samples were filtered through a 0.45µm filter. This gives the distinction from Total Phosphorus (TP) that includes the particulate or soil bound P. Algal-available Phosphorus (AAP) (sometimes called Bio-available or plant-available) is measured by the Iron Oxide method. The test was designed to withdraw AP from soils in a similar manner to plant roots, without mobilizing unavailable P. (R.G. Myers et al. 1997).~~)~~ Sediment content of each sample was quantified. The length of rainfall simulation to initial runoff was recorded. The entire volume of runoff generated per event was recorded to calculate P load of the event.

Village of Tolono water supply was used for rainfall simulation. Water samples were collected from each source tank load for contaminant analysis. During the rainfall simulation event 0-1 inch depth soil sample composites consisting of 12 cores were collected adjacent to the microplot for Bray-P analysis to quantify soil available P at the surface.

Photo caption: top left~~a~~) rainfall towers and microplots oriented over treatment areas, top right~~b~~) collection tray with splash guard directing runoff to collection point, bottom left~~c~~) plumbing system with pressure tank to feed 4 rain towers, bottom right~~d~~) rainfall towers in place with water transporting equipment.

P Runoff Spring 2014

Prior to planting, new micro-plots were established in an undisturbed area within the treatment areas that were established the previous fall. During April and May rainfall simulation was performed and runoff samples were collected at two locations. The third field was not sampled to prevent delay of corn planting in hopes that a timely harvest would allow Runoff sampling in the fall. ~~At the Christian and Schaefer~~Spring~~ fields~~ runoff water was collected for a~~from~~ 30-minute~~ runoff~~ event.~~s were collected in total and e~~ The entire runoff volume was recorded from each micro-plot. The runoff that continued after the ~~rainfal~~rainfall ended~~l event~~ was collected until~~ runoff~~ flow ~~diminished~~ stopped (referred to as the End Runoff sample). The duration of End runoff ~~flow~~ was timed and entire volume collected.~~, the volume was recorded, and a subsample was analyzed.~~ A subsample of the 30 minute Runoff and the End Runoff subsample were analyzed for DRP, TP, and AAP. S~~Runoff s~~ediment content was also quantified for each sample. Following the spring sample collection corn was planted in each field.

P Runoff Fall 2014

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As in the previous year, ~~F~~after~~ollowing~~ harvest soil samples were collected at 0-4, 4-8 and 8-12 inch depths for Bray-P analysis to assess fertilizer movement down the soil profile. ~~ Yield data w collected from the crop in the fall of 2014.~~ In October, ~~application of~~ Potassium and Phosphorus treatments were again applied using the three tillage/fertilizer placement methods: no-till/broadcast (NTBC); strip-till/broadcast (STBC); and strip-till/deep-placed (STDP). Soon after fertilizer applications, new ~~in the fall of 2014,~~ microplot borders were installed at the first location. R~~r~~ainfall simulation was conducted during October and November at this site~~.will be repeated at each site. Runoff samples were collected from the 30-minute runoff event .~~. Rainfall was initiated and continued until a 30-minute runoff event occurred. Runoff water from event was collected and the entire volume was recorded from each micro-plot. A one liter subsample was collected from the total volume. An End-Runoff sample was collected in the same manner as the spring sampling. A subsample of the 30 minute Runoff and the End Runoff subsample were analyzed for dissolved reactive phosphorus (DRP) and total phosphorus (TP) and ~~Due to nightly temperatures well below freezing for the weeks following no rainfall was simulated at the Schaefer or Reifsteck locations. Total Phosphorus and Dissolved Reactive Phosphorus from the Christian Runoff samples have been an~~algal available phosphorus (AAP).~~)~~ ~~in January~~ Sediment content was also quantified for each sample. As the previous fall and spring, c~~C~~omposite ~~Appropriate statistical analysis will be used to analyze the data from each event.~~ soil samples at 0-1 inch depth from each microplot were analyzed for Bray-P . Due to nightly temperatures well below freezing during the weeks following work at the first location we were unable to simulate rainfall at the two other locations.

Comment [R4]: Was this done like in the first year? Cores taken outside the microplot? I would suggest mentioning the same information or indicating "soil samples at 0-1 inch depth were collected for P analysis as in the previous year" or something similar.

PRELIMINARY ~~CONCLUSION~~DISCUSSION:

~~To put the result concentrations into perspective, it only takes .015-.03 mg P/L to cause a body of water to become eutrophic. Illinois has standard set for 20 acre lakes at 0.05 mg P/L. Wisconsin standard for lakes and reservoirs is 0.015-.04 mg P/L with standard for rivers and streams at 0.075-0.1 mg P/L.~~

Data from the three sampling events (fall 2013, spring 2014, and fall 2014) were combined and statistically analyzed ~~and yielded the following results~~. ~~When looking at the~~ Runoff generated ~~P~~phosphorus loss ~~loss by treatment~~ was not significantly different between 0 or 92 lbs/acre P rates for either DRP and TP ~~both showed no significant differences between 0 or 92 lbs/acre P rates~~. However the P loss from 161 ~~lbs/ac P205~~ lb P_2O_5 acre^{-1} ~~w~~was significantly ~~higher~~ greater (Fig 1).~~)~~ ~~both forms?~~

DRP levels were significantly reduced in STDP when compared to ~~STBC and NTBC~~broadcast applications in both NT and ST (Fig. 2). However in TP analysis there are no differences in P runoff, likely due to the increased soil bound P contribution from the ST loosened soil.

~~Relative to other research these values are on low side. Two reasons for this are the average 2 week delay in rainfall following application and the slope of our fields is less that the majority of research previously conducted. Research has demonstrated that P loss 24 hours after application is significantly higher than loss 10 days after application. Therefore avoiding fertilizer application 24-48 hours before a significant precipitation is predicted can help reduce loss. Mallarino?~~

P loss concentrations were combined with the volume of runoff events to calculate the P load in ~~lbs/acre~~lb P_2O_5 acre^{-1}. STDP generated a lower P l~~L~~oad for the three rates of 0, 90 and 161 ~~lbs P205/acre~~lb P_2O_5 acre^{-1} relative to the broadcast treatments (Fig. 3). It is important to n~~N~~ote that a ~~the~~ significant increase in P load took place when broadcast P rates increase from 92 to 161 ~~lbs/ac.~~lb P_2O_5 acre^{-1}, which for this situation it would be considered an over application of P fertilizer.
Figure 4 shows the different levels of P runoff in fall after application compared to collection runoff in the spring. Spring runoff produced much lower and less variable P loss when the fertilizer had time to move down into the soil profile.

~~Researchers have noted that a key strategy in reducing P loss is to apply in either early fall or spring, and NOT during winter months fertilizer is more vulnerable to movement across soil surface. Ref?~~

Soil available P was assessed from s~~S~~urfac~~e~~e 0-1" cores ~~were~~ collected during the runoff events. ~~and the deeper cores were collected after harvest.~~ S~~As expected s~~oil available P increases with P rate ~~and there are~~with no significant differences between NT & ST broadcast methods (Fig 5). Following harvest soil samples were collected at 0-4, 4-8 and 8-12 inch depths for Bray-P analysis to assess fertilizer movement down the soil profile. ~~STDP over~~ Six ~~the 6~~ years of STDP has created a drawdown of available P at the surface. ~~The~~ In STDP the post-harvest sampling showed ~~reveal~~ the majority of soil available P in the 4-8" zone from deep placement at 6 inch depth (Fig 6). This drawdown was observed by Fernandez and Shaefer (2012) and was attributed to the combined effect of subsurface band application of P and disproportionately greater P removal by the crop from the surface layer than deeper layers of the soil. This reduction of P in the soil surface proved to be beneficial to reducing P loss from runoff. Conversely, ~~The six 6 years of continual~~ broadcast applications after six years in both no-till and strip-till created a P rich layer with greater potential for P loss ~~via~~ from runoff.
~~STDP fertilizer saw a drawdown of P available at the surface proved to be beneficial to reducing P loss from runoff.. This and other research show that DRP and TP are relative to Soil P and the Bray P1 test is good tool for predicting loss potential.~~
~~The benefit of ongoing treatment application since 2007, by fall 2013 the plots had a large gradient of soil surface P test levels, which made these plots ideal to accomplish the objectives of this study.~~

Yield data was analyzed for one crop each year. In 2013 the soybean crop had no significant yield differences between treatments. The c~~C~~orn crop of 2014 ~~showed~~ had significant yield benefit in strip-till over no-till. ~~increase between NT and ST but~~However, no significant yield difference existed between the two strip-till~~ST~~ application methods of ~~BC~~ broadcast and~~or~~ ~~DP~~ deep placement (Fig 7). These findings are consistent with previous observations by Fernandez and Schaefer (2012) during earlier years of this study.
Data analysis of yields among~~by~~ P rates of 0, 92, and 161 lb P_2O_5 acre^{-1} had no significant differences in soybeans. ~~The corn~~H~~h~~owever, corn benefited from 92 ~~lbs/ac~~ lb P_2O_5 acre^{-1}, but showed no additional yield increase when P rate increased to 161 lb~~/a~~ P_2O_5 acre^{-1} ~~c~~ (Fig 8). ~~A comparison of yields across all treatment combinations.~~ All strip-till treatment~~ST~~ combinations out yielded no-till treatments.~~NT and again, no benefit from increasing P rate from 92 to 161 lbs/ac~~ (Fig 9).

PRELIMINARY CONCLUSIONS:

Deep placement of P fertilizer over a six-year period generated reduced surface soil available P and reduced potential P loss via runoff. Deep placement ~~gives us~~provides the opportunity to significantly reduce P loss via r~~R~~unoff on fields with minimal slope gradient ~~a large area of~~ in Illinois. ~~that is relatively flat. While this project did not have an incorporated treatment, work by Antonio Mallarino at Iowa shows incorporation does not simply reduce P loss. Certain situations actually can have P loss increased from incorporation due to increased soil particle movement.~~ Moderate application rates such as 92 lb ~~lbs~~ P_2O_5 acre^{-1} ~~P2O5/acre~~ generate significantly lower P loss while maintaining crop yield relative to the 161 lb P_2O_5 acre^{-1} rate.

~~RESULTS AND DISCUSSION~~

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Preliminary analysis of fall 2013 data reveals dissolved reactive P (DRP) concentrations combined over the 30-minute rainfall simulation runoff period (Figure 1) showed greater DRP concentrations for broadcast P applications regardless of the tillage method (no-till or strip-till) compared to when the P fertilizer is banded in the subsurface (ST DP). For both DRP combined over the 30-minute rainfall simulation runoff period (Figure 1) and for DRP from runoff during the 30 minute period after rainfall simulation (Figure 2) when P is broadcast on the soil surface, soil disturbance with strip-till appeared to increase DRP concentrations relative to the no-till system where no soil disturbance occurred.

Concentrations of DRP increased with increasing P fertilizer rate (Figures 3 and 4). This finding illustrates the importance of P management, both in terms of soil P level and P fertilization rate, in minimizing the negative impact of P to the environment when runoff occurs. These data show that it is possible to reduce the amount of DRP by not applying more fertilizer (92 lb P_2O_5/acre over two years for this particular location) than what is needed to maintain an adequate fertility level. However, equally important it is to point out that even when an appropriate P fertilizer rate is used to maintain adequate fertility, in a runoff event the amount of P exiting the field will be higher than if no P fertilizer is applied. This illustrates that even when the best possible management practices are used, it is not reasonable to expect no negative impact on the environment if runoff events occur. Interaction of tillage/fertilizer placement and P fertilizer rate shows that instead of broadcast applications, sub-surface banding P fertilizer with strip-till can be a viable alternative to minimize P runoff when P fertilizer applications are needed.

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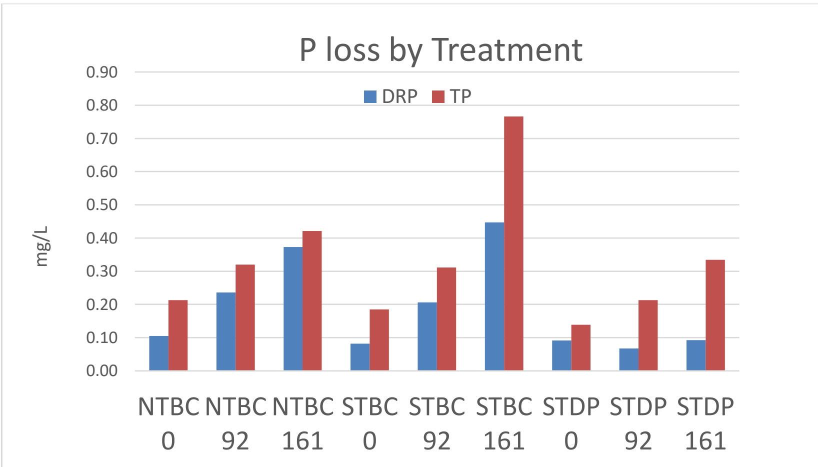


Figure 1. ~~Analysis for DRP (soluble P) & TP (including sediment) both showed no significant difference between 0 and 92 P rates. However the P loss from 161 lbs/ac P205 was significantly higher.~~

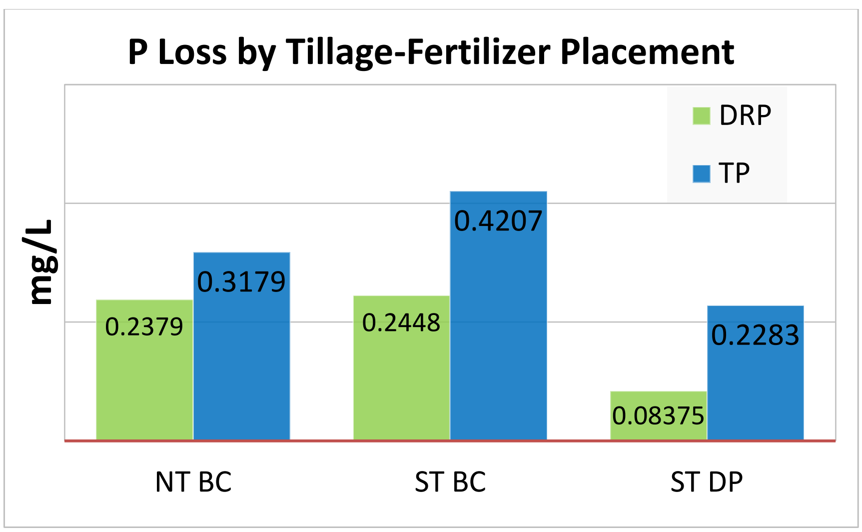


Figure 2. ~~benefit from STDP. In DRP , STDP has loss significantly lower than both NT & ST Broadcast. Yet in TP analysis there are no differences.~~

Comment [R5]: This figure and Fig 3 are not mentioned in the discussion

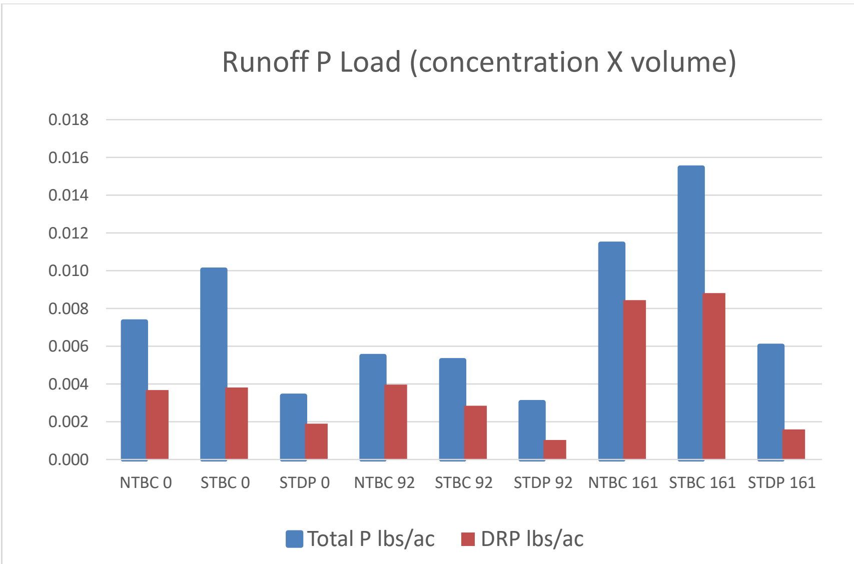


Figure 3.

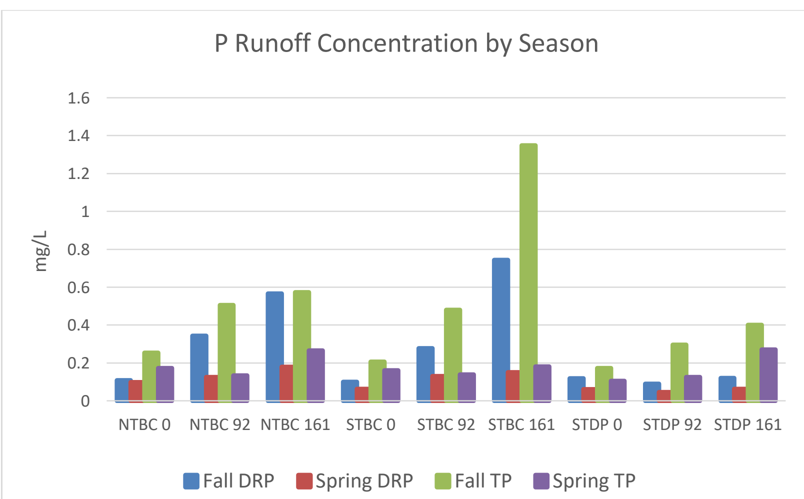


Figure 4.

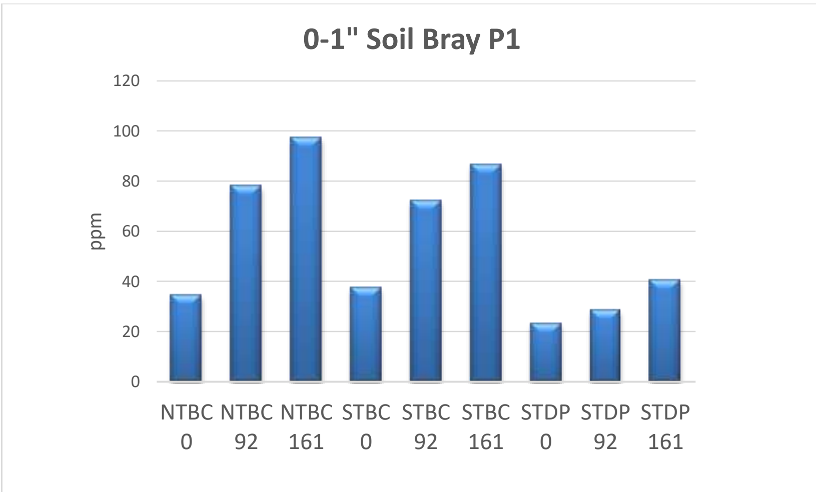


Figure 5.

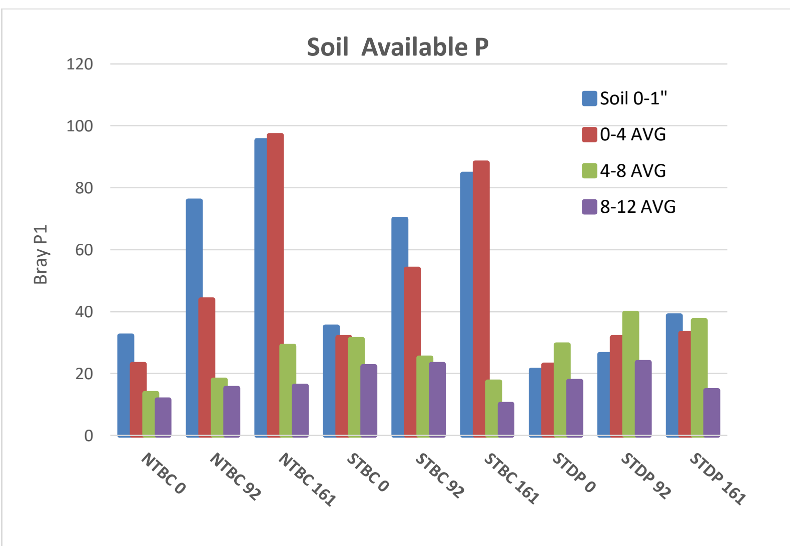
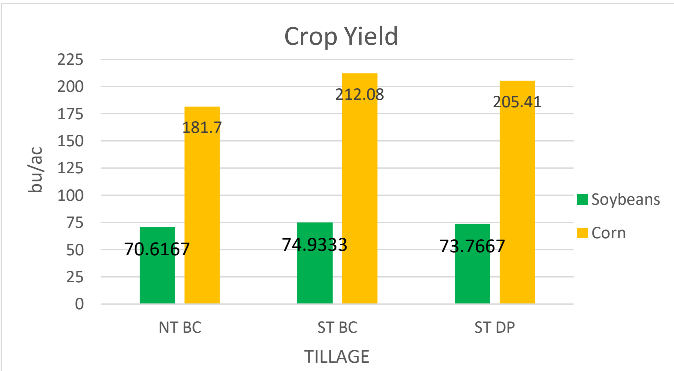


Figure 6.



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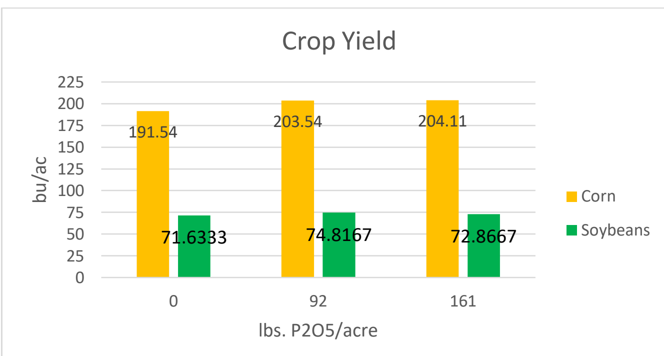

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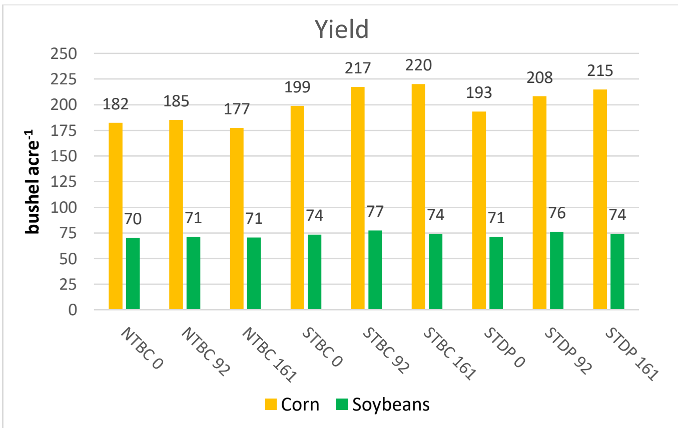
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74
71
76
74
NTBC 0
NTBC 92
NTBC 161
STBC 0
STBC 92
STBC 161
STDP 0
STDP 92
STDP 161
Corn
Soybeans

Figure 9.