FINAL REPORT TO TEXAS CORN PRODUCER"S BOARD - DEC 16, 2016

PROJECT TITLE: MAXIMIZING CORN YIELD THROUGH IMPROVED PHOSPHORUS FERTILIZATION

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EXECUTIVE SUMMARY:

Banding liquid phosphorus fertilizer allows crop plants to make more efficient use of the relatively insoluble soil nutrient. Plant roots have been shown to respond physiologically to chemical gradients in soil. When roots access a concentrated zone of nutrients, it allow for less energy to be expended by the whole plant by reducing the need to explore a large volume of soil. However, when nutrients are placed too near the surface, periods of limited water will result in limited nutrient availability as well. Crop plants must shift energy to producing more root mass to explore deeper portions of the soil volume for nutrients and water. By placing banded liquid phosphorus fertilizer more deeply, it is possible that root growth may be stimulated to concentrate near the banded zone where both water and nutrients are more likely to be available during periods of water stress. Thus, the plant may conserve energy required for stress response mechanisms other than root growth. This study examined the response of corn rooting patterns, nutrient uptake, and yield to the placement of three rates of liquid phosphorus fertilizer at three depths.

MAXIMIZING CORN YIELD THROUGH IMPROVED PHOSPHORUS FERTILIZATION

Introduction

Corn planted in two locations (Thrall & Snook, TX) was fertilized with banded liquid phosphorus (P) applied at different rates and depths to investigate the effect on rooting patterns. Banded P was applied 15 cm off the seed row. Root crowns were excavated along with all top plant matter at the V10 - V12 growth stage prior to tasseling. Photo-images of washed crowns were analyzed for spatial density of roots relative to the zone of concentrated P fertilizer. Images were processed using the free-ware application 'ImageJ' (image processing and analysis in Java). The analyses indicated decreased root densities associated with the volume of soil nearest the banded zone. However, there was positive relationship between both rate of phosphorus and depth of application to concentration of P in corn leaf tissue collected at the same time. Additionally, the highest yielding plots in both locations were associated with P fertilizer placed below the surface of the soil, demonstrating improved P-use efficiency in subsurface banded applications.

Materials and Methods

Sites:

Two sites were planted with corn (*Zea mays*, var. Terral REV 25BHR26) seed-drilled into a default no-till system. The site at Thrall, TX (Blacklands) was preceded by a corn/fallow rotation. The site at Snook, TX (Post Oak Savannah) was preceded by a corn/oat rotation. The soil types at the research plots are Weswood silt loam and Burleson clay respectively. Due to unfavorable weather conditions for strip tillage in late winter and early spring, corn was planted without tillage into terminated oats on 3/4/16 at Snook and into corn stubble at Thrall on 3/7/16.

Yield goals were based on historic data. At the Snook site, a 180 bushel yield goal was used to estimate fertilizer needs based on soil test results. For the Thrall site, a 120 bushel yield goal was used. 11-37-0 fertilizer was used to deliver phosphorus as liquid fertilizer on 3-23-16 at Snook and 3-28-16 at Thrall. Liquid P fertilizer was applied in all plots except the control (trt 1) as ammonium polyphosphate (11-37-0). The remaining required nitrogen (N) was supplied as per soil test recommendation as liquid UAN (32-0-0) at the same depth as P, except in trt 1 and trt 2, where N was knifed into the soil to 6". Regardless of depth, all liquid fertilizers were placed 4" off the seed row shortly after planting (V2 - V4).

Experimental Design

Study Detail (Snook):

Five randomized complete blocks; 4-row plots with length 70 feet (75 to alley center); 5 foot alleys; 30-inch rows; Terral 25BHR26-CW0J planted on 3/4/16, planting population 24,000 seeds/A; corn seed planted into a half-grown, terminated oat crop; treatments initiated on 3/23 and 3/25 (had 0.5 inch rain in between); side dress band applied 210 lb N/A using liquid 32-0-0 to six inch depth; applicator knives positioned 6 inches from each seed row on “driver” side (from behind shanks, left side of row) . Area planted is 72 rows wide with unplanted, 8-row border around all study plots; study area to receive soil test recommended N for rain-fed corn production; Winter 2015 crop was oats, burn-down herbicide applied late February, no additional pre-emerge herbicide used

Treatments:

1. Control (no addition of P)
2. Granular P at recommended rate (60 lb P_2O_5/A), broadcast surface-applied
3. Liquid P at half recommended rate (30 lb P_2O_5/A), side dress banded to six inch depth
4. Liquid P at recommended rate (60 lb P_2O_5/A), side dress banded to six inch depth
5. Liquid P at 1.5x recommended rate (90 lb P_2O_5/A), side dress banded to six inch depth
6. Liquid P at half recommended rate (30 lb P_2O_5/A), side dress banded to nine inch depth
7. Liquid P at recommended rate (60 lb P_2O_5/A), side dress banded to nine inch depth
8. Liquid P at 1.5x recommended rate (90 lb P_2O_5/A), side dress banded to nine inch depth

Study Detail (Thrall):

Six randomized complete blocks; 4-row plots with length 70 feet (75 to alley center); 5 foot alleys; 38-inch rows; Terral 25BHR26-CW0J planted on 3/7/16, planting population 24,000 seeds/A; treatments initiated on 3/29, exception - applied 90 lb P_2O_5/A in plot 202; side dress band applied 180 lb N/A using liquid 32-0-0 to six inch depth; applicator knives positioned 6 inches from each seed row on “driver” side (from behind shanks, on left side of seed row). Area planted is 56 rows wide with 24 rows extra; study area to receive soil test recommended N for rain-fed corn production; previous, 2015 crop was corn

Treatments:

1. Control (no addition of P)
2. Liquid P at recommended rate (45 lb P_2O_5/A), band, surface-applied
3. Liquid P at half recommended rate (23 lb P_2O_5/A), side dress banded to six inch depth
4. Liquid P at recommended rate (45 lb P_2O_5/A), side dress banded to six inch depth
5. Liquid P at 1.5x recommended rate (68 lb P_2O_5/A), side dress banded to six inch depth
6. Liquid P at half recommended rate (23 lb P_2O_5/A), side dress banded to nine inch depth
7. Liquid P at recommended rate (45 lb P_2O_5/A), side dress banded to nine inch depth
8. Liquid P at 1.5x recommended rate (68 lb P_2O_5/A), side dress banded to nine inch depth

Crown Root Collection was performed in three replicates per site by excavating a 30 cm diameter by 35 cm deep cylinder surrounding 1 plant from the center two rows in each plot. Wooden skewers were inserted through the base of the stalk and perpendicular to the band and seed row to maintain orientation for imaging. Excavated soil and crown roots were allowed to soak for 2-5 days in 18.9 L plastic buckets saturated with tap water to soften soil for removal. Roots were gently washed free of soil using a garden hose shower attachment and immediately imaged. Imaging and Processing were managed by placing intact corn plants on a black felt sheet with the ‘fertilizer band’ side to the right (Image 2). Images were captured with a Nikon digital camera with a ruler and sample ID tag in the frame. ImageJ software was used to analyze 2-dimensional root density by separating the images into quadrants corresponding to proximity to the P-fertilizer band (Figures 1 -4).

Tissue Concentration (early & late) was sampled as upper most unfolded leaf (10 per plot) collected at V10-V14 & ear-leaf collected at grain-fill P content and determined using microwave assisted acid digestion and analysis by ICP-AES. Results are expressed on a dry-weight basis. Yield was determined by hand-harvesting the center two rows of each plot at Thrall, TX and by yield monitor-equipped combine harvesting the center two rows of each plot at Snook, TX. Results are expressed on a 15.5 % moisture basis. Statistical Analysis was performed using SAS software. Multiple linear regression using PROC REG and comparison of means (Fisher’s protected LSD adjustment) was performed using PROC GLM at the $\alpha = 0.05$ significance level.

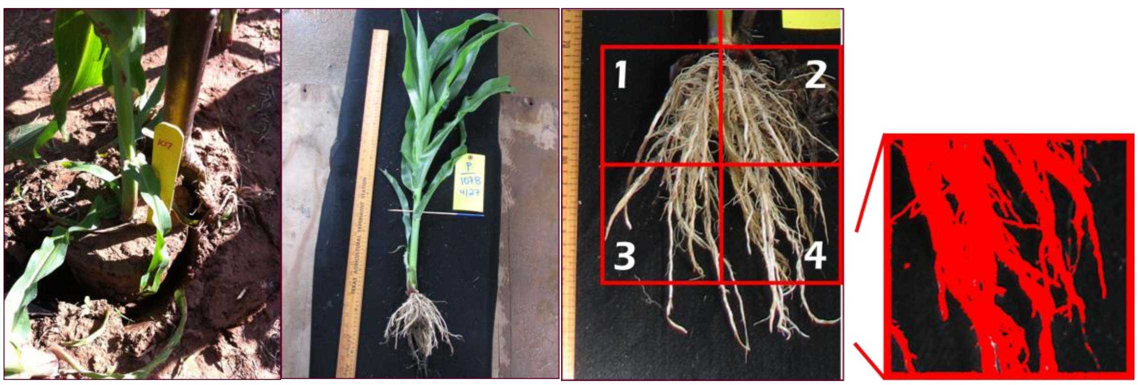


Figure 1-4 (l-r): 1. Crown root excavation. 2. Imaging against black felt background. 3. Division of root into quadrants of 4x4” each. 4. Software analysis of 2-dimensional density of roots in the 4th quadrant nearest the fertilizer band.

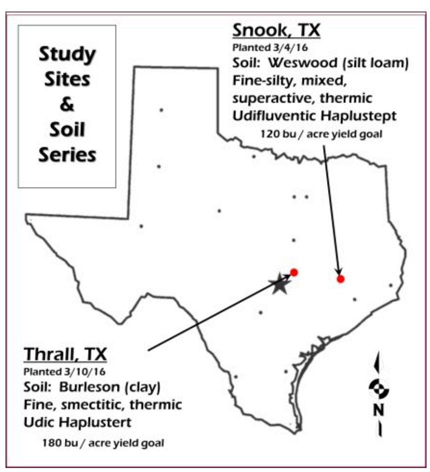


Figure 5. Location of study sites and soil properties associated with each.

Results and Discussion

Root Imaging:

ImageJ was found to be highly suitable for the simple approach of estimating 2-dimensional root density following separation of the area into four quadrants. Manual manipulation was required for processing. In the future it may be possible to enable more rapid processing via more careful preparation in the image collection phase.

Rooting Density:

There were significant differences in rooting density in quadrant 4 nearest the 6" and 21" P fertilizer placement depths (Figures 6a & 6b). At the Snook TX site, treatments 4, 5, & 8 resulted in decreased rooting densities nearest the band. At the Thrall TX site, treatments 6 & 7 resulted in decreased rooting densities as compared to the control and to surface applied P fertilizer (Trt. 2).

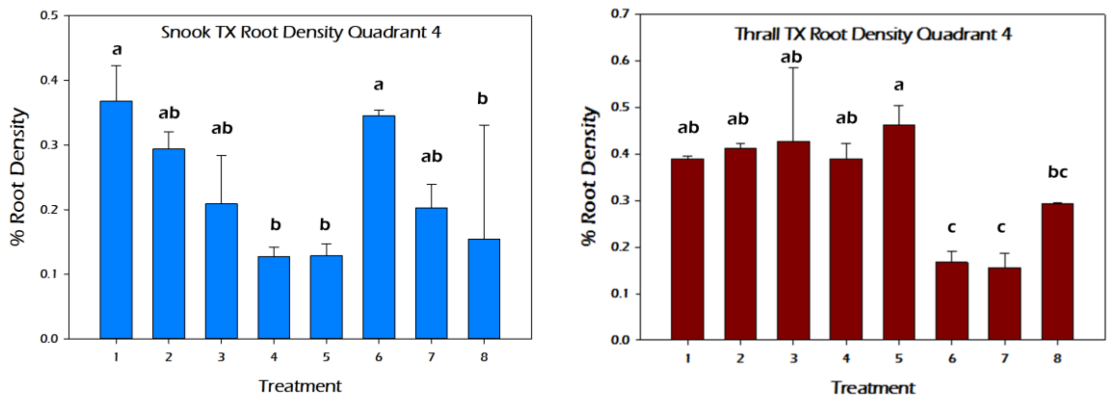
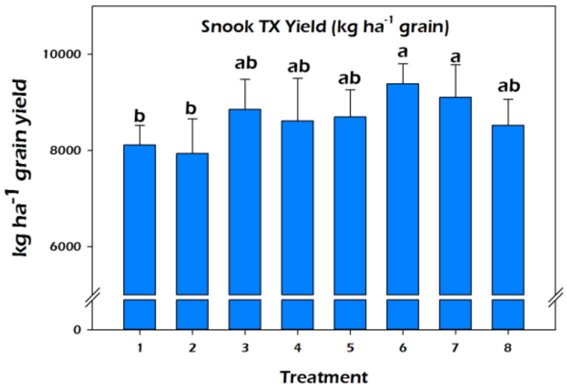


Figure 6a & 6b: results of root density analysis by ImageJ software.

Grain Yield:

Significantly higher yields were observed at the Snook TX site associated with the 21 cm placement of liquid P fertilizer as compared to the control but were not significantly separable any of the other treatments. At the Thrall TX site, no single treatment receiving fertilizer was significantly different from the control (Figures 7a & 7b). High rainfall events that caused prolonged ponding of water on the field at Thrall between the root excavation event and grain harvest may have led to overall poor yields at this site, and a poor distinction between yield differences between treatments.



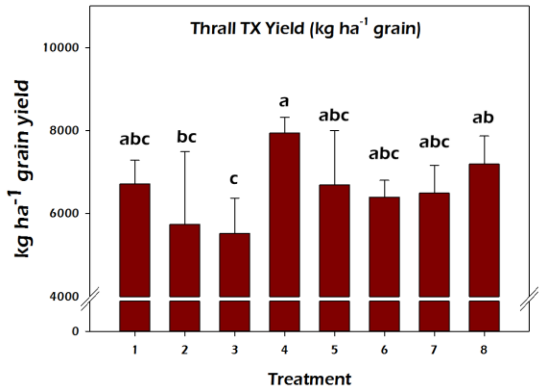


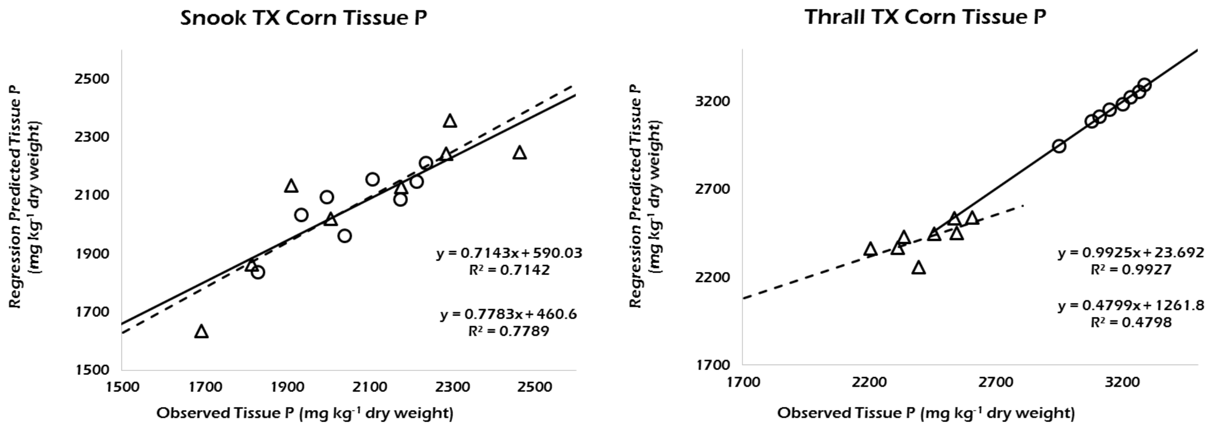
Figure 7a & 7b: Corn grain yield in kg/ha for both study sites.

Leaf Tissue:

Regression Analysis of Leaf Tissue Concentration revealed significant relationships between P uptake in corn at both sites as a function of both rate and depth of placement of liquid P fertilizer (Figures 8a & 8b). In equation 1:

$$P_{conc} = a*rate + b*depth + c \qquad \text{Eq 1.}$$

Where a, b, & c are constant parameters fit to the observed data resulted in 'fit' parameters that were significant at the $\alpha = 0.10$ level except for the case of the late tissue sampling at the Thrall TX study site. Parameters for the early tissue sampling event at the same site were significant at the $\alpha = 0.05$, however. The Thrall TX site is on a poorly drained soil and experienced several severe rainfall events between early and late sampling events that left the soil ponded and/or saturated for prolonged periods of time. This condition resulted in increased variability within treatments across blocks that can explain the poor relationship in the late tissue sampling regression results as well as the mixed results in grain yield from the same site (Figure 7b).



Figures 3a & 3b: ***Figure 3a.*** Early and late tissue P contents in corn taken from the Snook TX study site. Both sampling times significantly ($\alpha <= 0.1$) and positively correlated with both rate and depth of P fertilizer placement. ***Figure 3b***. Early and late tissue P contents in corn taken from the Snook TX study site. Only the early sampling significantly ($\alpha <= 0.05$) and positively correlated with both rate and depth of P fertilizer placement

Conclusions & Recommendations

Open source software such as ImageJ can be used effectively to evaluate differences in root growth patterns. Lower root densities observed near the concentrated zone of banded P fertilizer can be explained as a 'rhizo-economic' reaction, where less energy is necessary to extract localized nutrients. Other explanations might be considered, including an adverse effect on root growth as a result of high concentrations of P-fertilizer in a localized zone in the soil. However, an inhibition of root growth due to the salt effect can be rejected due to the significant and positive effects of both rate and placement on corn P uptake, as indicated by both early and late season tissue analysis

More work can be done to investigate the use of 3-dimensional imaging to compare root growth patterns in the future. Additional studies in the following year are recommended to ensure that results are repeatable under different growing season conditions.