DOUBLE CROPPING WHEAT SYSTEM EFFECTS ON SOIL EXTRACELLULAR ENZYME ACTIVITY RELATED TO NITROGEN AND PHOSPHOROUS CYCLING ACROSS TEXAS

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ABSTRACT

Conventional management of agricultural systems can threaten soil health by contributing to soil erosion, soil carbon loss, and inefficient water use in crop production. Cover crops and conservation tillage have been reported to improve soil health, but the additional planting and maintenance comes at an additional cost. Double-cropping systems have the potential to mitigate that cost by providing producers with a secondary crop and an additional income source while supporting soil health benefits. One key metric for evaluating the effects of management on soil health is through extracellular enzyme activity, which plays a vital role in nutrient cycling of a system. This project evaluated double-cropping wheat systems and tillage practices across three study locations in Texas: Texas A&M AgriLife Research Lubbock, Stiles Farm Foundation in Thrall, and Texas A&M AgriLife Research Beeville. Tillage treatments included: 1) conventional tillage (disk plow), 2) strip-till, and 3) no-till. Cropping treatments included: 1) wheat-sorghum, 2) wheat-sesame, 3) wheat-cowpea, 4) wheat-cover crop mix, and 5) wheat-summer fallow. Activities of β-glucosaminidase, phosphatase (acid and alkaline), related to nitrogen and phosphorus cycling, respectively, will be measured on samples collected from 0-5 and 5-15 cm depths in the summer of 2021. Expect to see greater β-glucosaminidase and phosphatase activity in study plots that incorporated year-long cover with a grain crop or a cover crop and no-till compared to a wheat-fallow and conventional tillage system. Results will help to identify conservation management practices, specifically double cropping, that can help provide additional economic value to producers while providing data on maintaining or improving the health of soil systems.

INTRODUCTION

Evaluating soil enzyme activities can provide information about the nutrient cycling potential of a system and soil organic matter dynamics (Udawatta et al., 2008). Although many enzymes exist within the soil environment, two of the more common enzymes evaluated in agricultural systems include β-glucosaminidase and phosphatase (acid/alkaline) due to the release of associated nutrients, as they are involved in the final hydrolysis step, required by soil microorganisms and plants (Tabatabai, 1994). These enzyme assays are common indicators of nitrogen and phosphorus cycling, respectively.

Management practices that can affect enzyme activity levels found in soil include cropping system management such as diversity, rotations, and residue management

(Deng and Tabatabai, 1997; Zak et al., 2003; Karlen et al., 2006), tillage practices (Sharma et al., 2013; Chu et al., 2016; Veum at al., 2015), and soil amendments including fertilizers, manure, and compost (Miller and Dick, 1995; Klose et al., 1999, Deng et al., 2000). These variations in management practices affect the microbial communities by increasing the diversity and amount of organic material inputs, disturbing soil aggregates, exposing and relocating sequestered and bound organic residues, and adding variable nutrient loads into the system.

Improving the health of soil can be done by introducing conservation management practices that include cover cropping, reduction in tillage, or a combination of both (Veum et al., 2015; Dairon et al., 2017; Nunes et al., 2018). Although cover cropping can provide soil health benefits, the planting and maintenance that comes along with this practice can be a deterrent for adoption by many producers. Double cropping, defined as a secondary crop grown within the same growing season, can replace a cover crop. This type of cropping system has the potential to provide soil health benefits and can be used as a secondary income source, offsetting planting and maintenance costs. Conservation tillage, including no-till and strip-till, can improve soil health by reducing the amount of physical disturbance to the soil environment. This reduction in disturbance can positively increase soil aggregation, water infiltration and holding capacity, nutrient retention, and soil carbon sequestration (Tebrugge and During, 1999). Currently, in the Southern Great Plains, only 2.1% of agricultural lands are double-cropped (Boechers et al., 2014) and Texas alone has one of the lowest implementation rates of no-till (15%) in the United States (Myers and LaRose, 2019). With reductions in croplands in the South-Central United States (USDA-NASS, 2017) and long fallow periods following the harvest of winter wheat (*Triticum aestivum* L.), the identification and implementation of double cropping systems suited to the area needs to be researched.

This study examined the effects of conservation management practices on β-glucosaminidase and phosphatase activity in short-term (~5 years) plots located at three sites across Texas. The objective of this study was to quantify the impact of conservation management practices (double cropping and reduced tillage) on nutrient cycling potential related to nitrogen and phosphorous cycling compared to conventional management practices (summer fallow and conventional tillage) in a wheat production system.

MATERIALS AND METHODS

Three study sites across Texas were used for the purpose of this research: Texas A&M AgriLife Research and Extension Center at Lubbock, TX, USA (33°4’27” N 101°49’31” W, elevation 1,003 m), Texas A&M AgriLife Research - Beeville Station, TX, USA (28°27’16” N 97°42’22” W, elevation 77 m), and the Stiles Farm Foundation located in Thrall, TX, USA (30°35’53” N 97°17’58” W, elevation 172 m). This study began in the winter of 2016 with the planting of winter wheat to be used as the primary crop in the double cropping system. Field layout is presented by Bekewe et al. (2022) and consisted of a randomized complete block split-plot design with tillage as main-plot and cropping system as split-plot, with three replications. Tillage treatments included: (1) conventional tillage (disk plow; 15 cm depth), (2) strip-tillage, or (3) no-tillage.

Secondary summer cropping treatments included: (1) cowpea (*Vigna unguiculata* L. Walp.), (2) sesame (*Sesamum indicum* L.), (3) grain sorghum (*Sorghum bicolor* L. Moench.*),* (4) a cover crop mix [Sunn hemp (*Crotalaria juncea* L.), Lablab (*Lablab purpureus* L. Sweet), Buckwheat (*Fagopyrum esculentum* Moench.*),* Cowpea, Pearl millet (*Pennisetum glaucum* [L.] R. Br.), Foxtail millet (*Setaria italica* [L.] P. Beauv.), Sunflower (*Helianthus annus* L.), Guar (*Cyamopsis tetragonoloba* [L.] Taubert), and Peanut (*Archis hypogaea* L.)], with a (5) fallow treatment as a control. Composite soil samples, using three cores, were collected at depths of 0-5 and 5-15 cm during the summer of 2021 (Beeville: June 23rd; Thrall: June 24th; Lubbock: July 15th) using a Giddings hydraulic soil probe following winter wheat harvest.

Potential soil enzyme activity of β-glucosidase, β-glucosaminidase, acid phosphatase, and arylsulfatase were assayed following protocols described in Tabatabai (1994), Parham and Deng (2000), and Dick (2011). The amount of soil and volume of solutions was reduced by half maintaining the soil:solution ratio used in the original assays (Acosta-Martinez and Cotton, 2017) without the addition of toluene to reduce environmental concerns associated with generated waste (Acosta-Martinez and Tabatabai, 2011). In brief, 0.5 g of air-dried soil was weighed out in duplicate and one control into 50 mL conical centrifuge tubes. For each assay 2 mL of appropriate buffer and 0.5 mL of substrate at optimal pH was added to samples and incubated at 37 °C for 1 h. After incubation 0.5 mL of 0.5 M $CaCl_2$ and 2 mL of appropriate stop solution was added to develop color of solution and stop reaction. Controls received 0.5 mL of substrate after reaction was stopped. Table 2.1 outlines buffers, substrates and stop solution for each individual enzyme. Samples were centrifuged at 1750 rpm for 5 minutes and a 250 µL aliquot of solution was pipetted into a 96-well assay plate. Enzyme activity was determined colorimetrically using a microplate spectrophotometer (BioTek Epoch) to measure amount of p-nitrophenol (PNP), expressed as mg PNP kg^{-1} soil h^{-1}, released at 400 nm. Measured control values were subtracted from the average of the two duplicates.

RESULTS AND DISCUSSION

β-glucosaminidase

Significant differences in β-glucosaminidase activity were present in Beeville and varied between cropping systems, tillage, and depth treatments (Figure 1). No significant differences were found in Lubbock and Thrall amongst cropping systems or tillage treatments. This enzyme activity had significant differences in cropping system at 0-5 and 5-15 cm, and in tillage treatments at 5-15 cm in the Beeville location. The greatest β-glucosaminidase activity measured at 0-5 cm in cropping systems was in sorghum (19 mg PNP kg^{-1} soil h^{-1}) compared to cowpea, fallow, and sesame (15, 13, and 15 mg PNP kg^{-1} soil h^{-1}, respectively). At 5-15 cm the greatest activity was measured in sorghum (9 mg PNP kg^{-1} soil h^{-1}) compared to cowpea and fallow (7 and 6 mg PNP kg^{-1} soil h^{-1}, respectively).

Generally, systems that implemented a secondary crop compared to fallow had greater activity at 0-5 cm and 5-15 cm depths. This increase in nutrient cycling potential is likely due to the benefits associated with double cropping systems. These benefits

included maximizing soil cover, extending the amount of living plants in terms of biomass production and below ground root systems, increased soil organic matter through increased plant production and root exudates, and an increase in microbial population growth and associated byproducts.

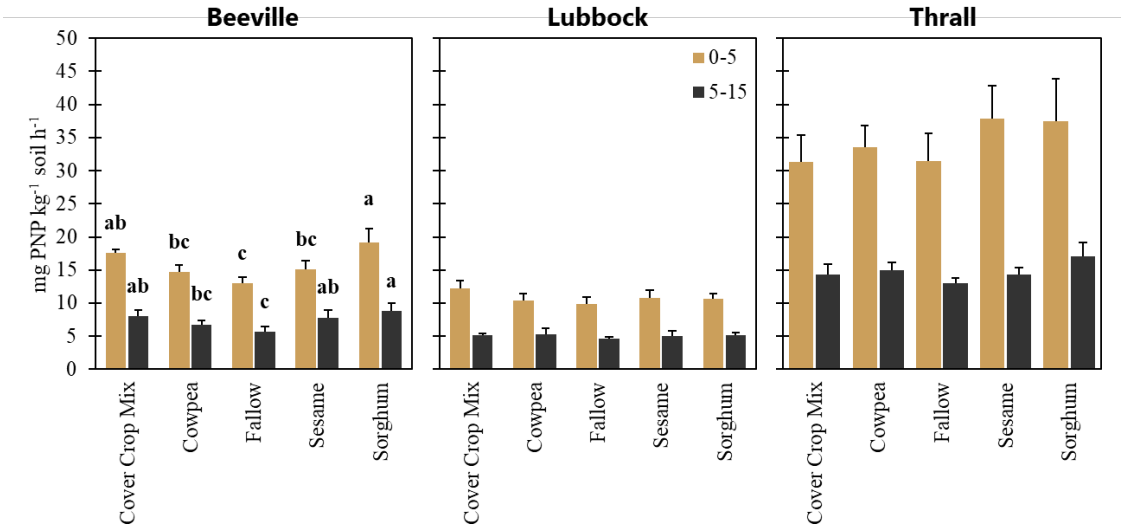

Figure 1. Enzyme activity potential as affected by cropping systems at 0-5 and 5-15 cm β-glucosaminidase in Beeville, Lubbock, and Thrall, TX. Means within location, cropping treatment, and depth with differing LSD letters represent significant differences at $p < 0.05$. If letters are not included, differences were not determined. Error bars represent standard error of the sample mean.

Acid Phosphatase

Significant differences in acid phosphatase activity were not determined at any location amongst cropping system treatments (Figure 2). Generally, systems that implemented a secondary crop compared to fallow had greater activity at 0-5 cm and 5-15 cm depths.

Acid phosphatase has been reported to be associated with soil pH and recommended to assay on soils with a pH below 7 (Acosta-Martinez and Tabatabai, 2000). Therefore, this assay is limited, and not recommended, in discerning management effects in soils with a soil pH greater than 7 at which the recommendation of enzyme assay to evaluate becomes alkaline phosphatase. Soil pH values determined at the 0-5 and 5-15 cm depths in Beeville, Lubbock, and Thrall ranged from 6.98 to 8.47, 7.77 to 8.49, and 5.44 to 7.83, respectively, and was likely affecting the difference in activity between locations. Thrall acid phosphatase activity ranged from 105 to 575 mg PNP kg^{-1} soil h^{-1}, with Beeville and Lubbock ranging from 33 to 209 mg PNP kg^{-1} soil h^{-1}, and 9 to 79 mg PNP kg^{-1} soil h^{-1}, respectively.

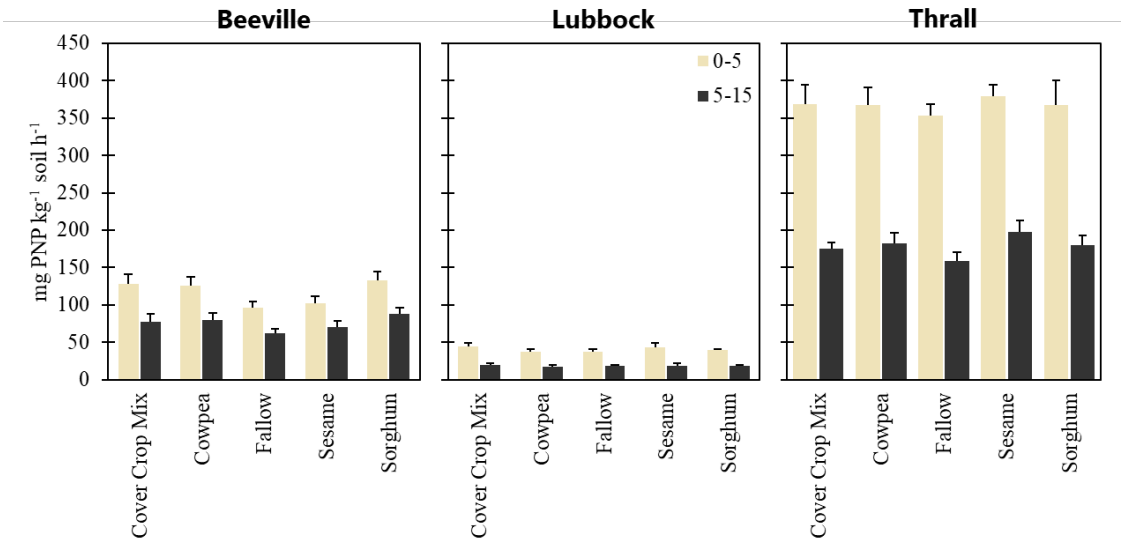

Figure 2. Enzyme activity potential as affected by cropping systems at 0-5 and 5-15 cm for acid phosphatase in Beeville, Lubbock, and Thrall, TX. Significant differences were not determined at a $p < 0.05$. Error bars represent standard error of the sample mean.

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