United Soybean Board Domestic Programs

Report Form

Project # and Title: 2177 Increasing Soybean Productivity while Improving Soil Quality and Mitigating Climate Change

Reporting Period: Final report

Project Status: Ended

OVERALL GOAL

The growing worldwide demand for soybeans, together with the change in global climate, creates both great opportunities and great challenges for soybean producers in the United States. There will be increasing pressure to expand soybean production onto more marginal lands and to also grow soybeans continuously without rotations. Our overall goal is to provide: (1) science-based practical information that will lead to sustainable agronomic management systems; (2) economic analyses of their costs and benefits; and (3) education and outreach programs for their adoption. Outcomes of this research are innovative management systems based on holistic approaches that include no-tillage, multifunctional cover crops and gypsum soil amendment. These novel systems will increase soybean yields even when soybeans are grown on marginal lands or under intensified growing conditions while, maintaining sustainable environmental practices that reduce soil erosion and greenhouse gas emissions, improve soil and water quality, and enhance overall ecosystem services.

STRATEGY

Develop and field test the sustainability and productivity of no-tillage systems with the application of gypsum and cover crops for (1) soybean production with corn rotation on more fragile lands, and (2) continuous soybean production on higher quality soil.

The proposed strategy addresses the action plan "*Enhance farm efficiency and soy sustainability performance"* of Objective 3 of USB Long-Range Strategic Plan: *Promote U.S. sustainable soybean production through responsible stewardship while acknowledging global market needs*.

A. DELIVERABLES

Strategy 1

We have established field research plots at four sites: (1) Farmland, Indiana, (2) Auburn, Alabama, (3) Piketon, Ohio, and (4) Hoytville, Ohio. The field research was conducted for two years with two soybean varieties, a regular oil and a high oil content, grown in both a continuous soybean and a corn/soybean rotation. Cereal rye was used as a cover crop and FGD gypsum was applied to all plots at the rate of 0, 1000, or 2000 lbs/acre.

Soil quality analysis - Baseline soil quality was evaluated in Alabama, Indiana, Hoytville (OH), and Piketon (OH) on loamy sand, silt loam, and a silty clay loam soil in 2011 and 2012. Results showed that soil quality properties varied significantly among the sites and also between soil depths. Alabama had the poorest soil quality followed by Piketon, as compared with the higher quality soils at the Hoytville and Indiana sites. On average, surface soil had higher soil quality than the sub-surface soil. However, site x depth was significant only for pH, active carbon (AC), metabolic quotient (qR), total N (TN) and soil quality index (SQ_{index}). The Alabama site had lower soil pH compared to other sites. Soil cation exchange capacity (Ec) was highest at the Hoytville and Indiana sites and lowest at the Piketon site. The Hoytville and Indiana sites had the highest concentration of total organic carbon (TC), intermediate at the Piketon site, and lowest at the Alabama site. Likewise, a significantly higher AC concentration was measured at the Indiana and Hoytville sites as compared with the Piketon and Alabama sites. Soil microbial biomass, as a sensitive indicator of soil quality, was significantly higher at both the Piketon and Indiana sites compared with the Hoytville and Alabama sites. The metabolic quotient (qR), as a measure of the biologically labile C pool of total organic C, significantly varied among the sites. The Piketon site had the largest pool of biologically labile C and the Alabama site had the lowest biologically labile C pool in TC. Like TC, a similar variation was observed on the TN concentration among the sites. Highest aggregate stability (AS) was measured at the Hoytville site, intermediate AS was measured at the Indiana and Piketon sites, and lowest AS was measured at the Alabama site (Appendix 1).

These soil quality data and the assessments of soil quality at each site are to be considered baseline information. The original goal of this project was to measure soil quality at various sites, including several low quality sites, and then measure changes in these soil quality parameters as we implemented practices such as use of cover crops. This information is especially important where continuous soybeans are being grown because without some management intervention practices, such as cover crops, it will be difficult to recommend farmers grow continuous soybeans because of the difficulty of maintaining good soil quality with this practice. Unfortunately, the early end to this project, will not allow us to make any conclusions about how our management practices may impact soil quality and change a soil from a low quality soil to a higher quality soil, even when continuous soybeans are grown.

Infiltration - Infiltration is a process referring to the entry of water into soils. The rate of infiltration is an important soil hydrological parameter indicating how much water can enter a soil and the potential of runoff with a determined water supply rate. The average infiltration rate at the Indiana site was 22.6 mm per hour and at the Piketon site was 28 mm per hour. The infiltration rate at both sites was not affected by gypsum application or the cover crop treatments ($P < 0.5$).

Greenhouse gas emission - Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) were determined from gas samples collected from the control (no FGD gypsum) and the high FGD gypsum (2,000 lbs/acre) plots with cover crop and without cover crop during the 2012 and 2013 growing seasons. It appears that neither the addition of gypsum nor the growing of cover crop as part of a continuous soybean cropping system influence the emission of CO_2, CH_4, and N_2O gases. However, differences in climatic conditions and soil types at the different sites may influence the release of these gases to the atmosphere (Appendix 2).

Diseases and nematodes - We routinely monitored for symptoms of *Phytophthora* root and stem rot, sudden death syndrome and nematode infestation but found no evidence of disease and nematodes.

Heavy metal and mercury analyses - A meta-analysis that combined data from all four sites evaluated concentrations of 17 elements in soybean grain in 2013 (Appendix 3). All but five elements (Al, Co, Cd, Cr, Si) are essential nutrients for plant growth. Concentrations for seven trace elements that were always or primarily below the instrument detection limits (mg/kg) are not included in this table. These seven elements (with detection limits in mg/kg following in parentheses) included As (1.93), Be (0.069). Pb (0.863), Sb (1.50), Se (2.46), Tl (0.641), V (0.782). The statistically significant differences that are noted (Appendix 3) are small in magnitude and would not be important in managing a soybean crop. The Hg was also analyzed in soybean grain and none of the treatments significantly affected the concentrations that were measured. These data are consistent with other data that have been reported on how gypsum affects trace elements in soil and indicate that FGD gypsum use should not be a concern as related to any impacts associated with trace elements. For a suite of 10 papers on the sustainable use of FGD gypsum in agricultural systems that were published in the first issue of 2014 in the *Journal of Environmental Quality* see (https://www.agronomy.org/publications/jeq/tocs/43/1#h2-SPECIAL%20SECTION:%20SUSTAINABLE%20USE%20OF%20FGD%20GYPSUM%20IN%20AGRICULTURAL%20SYSTEMS).

There were significant effects of site on concentrations of all elements except Al and Fe. The site(s) with greatest concentrations varied with element. Indiana had highest concentrations of S, Zn, and Cr; Alabama had highest concentrations of Ca, Mn, and Co; and Hoytville had greatest concentrations of Cu, Mo, Ni, and Si. Potassium and B were greatest at Indiana and Hoytville, P was greatest at Indiana and Piketon, Mg was greatest at Indiana and Alabama, and Cd was greatest at Piketon and Alabama.

Concentrations of P, K, S, Cu, and Ni were affected significantly by cover crop treatment. These elements all had greater concentrations in plots without a cover crop than in plots with a cover crop. Only P and Mo were affected significantly by gypsum treatment. Both elements had greater concentrations in plots without gypsum (Appendix 3).

Nodule count and nitrogen fixation capacity - Nodule count was determined from plant samples of the control (no FGD gypsum) and the high FGD gypsum (2,000 lbs/acre) plots with cover crop and without cover crop. Nodule count/plant was different across the sites. When the data were pooled, nodule count was higher with the FGD gypsum application (43/plant) than without FGD gypsum application (36/plant). Nodule count was also higher with cover crop (43/plant) than without cover crop (36/plant). Nitrogen fixation capacity was not different among the three sites in Alabama, Indiana and Hoytville, but lower at the Piketon site. Nitrogen fixation capacity averaged 66.9% and did not differ between the FGD gypsum application and no FGD gypsum application. However, cover crop significantly increased the N fixation capacity compared to no cover crop.

These results indicate the positive effect of FGD gypsum and cover crop on the productivity potential of soybean plant. If continually practiced, they should result in an improvement in soil quality and crop yield when continuous soybean and soybean in rotation with corn are grown.

Carbon, Nitrogen and protein composition of soybean grain - The level of total C, N and protein in the grain differs among the sites and were highest at the Indiana site, following by the Alabama and Piketon sites. The C-to-N ratio (C/N), on the other hand, was highest at the Piketon site and there were no differences between the Indiana and Alabama sites. FGD gypsum application and cover crop produced grain with higher total C than the control (no FGD gypsum) and no cover crop treatment. Total N, protein and the C/N ratio in the grain were not affected by FGD gypsum and cover crop treatment.

Cover crop biomass **-** Biomass samples were collected from the control (no FGD gypsum applied) and the high rate FGD gypsum treatment areas at all four sites. Total biomass production was different across the sites as was expected because of soil and weather conditions. When the data were pooled across the sites, it was apparent that there was greater biomass production with FGD gypsum application (1,049 kg/ha) than without FGD gypsum application (734 kg/ha). The difference was highly significant ($P < 0.0028$). From a soil health and carbon sequestration point of view, greater production of cover crop biomass will be beneficial in sequestering more carbon in the soil. This will lead to increased soil organic matter content, improved soil health, and greater retention of N. Over the long haul, it should also improve grain production.

Grain yield - Grain yields were collected from all treatments in both 2012 and 2013. The results indicated that yields were different between years and locations. There were no yield differences or trends due to the FGD gypsum treatments or the cover crop treatments for the two years combined, although there were significant effects in individual years (Appendix 4). The early indicators are that grain yields should improve with time with these treatments, but the project was aborted before we could obtain the longer-term data that was planned for this project (Appendix 5).

Profitability analysis - To calculate expected profitability of the proposed sustainable agronomic system for a commercial scale farm, we utilized soybean performance data for all treatments including rotation, cover crop, gypsum application and high-oil soybean variety at the four sites. Multivariate regression analysis of the 2013 data indicated that FGD gypsum did not affect yield, while cover crops produced an average 3.63 additional bushels of soybean yield per acre. The high oil soybean variety yielded 4.58 bushels/acre more than the conventional oil variety. Soybean yields on continuous soybean plots averaged 5.46 bushels/acre less than for soybeans following corn.

These results represent the combined experiences of the four test sites in 2013, when rainfall was more normal than in the 2012 with extreme drought. It should be underscored that this represents only the second year experience with each of these treatments. One must be careful to draw conclusions from this short-term set of results. For instance, a survey of gypsum-using farmers conducted in 2013 by

Batte and Forster (Batte, Marvin T. and D. Lynn Forster. "Economic Impact of Gypsum: A Study of Midwestern Crop Growers". 2014) found that these farmers observed yield increases associated with gypsum use on a number of crops, and that the magnitude of the yield premium increased for farmers who had applied gypsum for four or more years. This may suggest that the gypsum use may display positive impacts in our own study as we continue the study over time. Likewise, we may see changes in magnitudes of other treatments (especially cover crops and continuous soybeans) as we track these over an extended study period (Appendix 5).

Strategy 2

Telling our story

The outreach efforts included demonstration plots at three major farm shows, writing two fact sheets, establishing a website and Facebook presence, speaking at conferences, and getting articles published in ag media.

<u>Demonstration plots -</u> Our first activity was to work with the four farm show sites to establish demonstration plots. At each site (except Nebraska's Husker Harvest Days), we have two sets of no-till plots that include a continuous soybean rotation and a corn/soybean rotation. For each crop, there are four plots as follows: 1) no treatment; 2) FGD gypsum; 3) FGD gypsum and cover crop; and 4) cover crop. Other than these two variables, normal agronomic practices were used for growing the crops.

The plots at the site of Penn State University's Ag Progress Days were prepared and managed by Greg Roth, Extension Agronomist. The Iowa site of Farm Progress Show was established and managed by Tom Kaspar, USDA-ARS. In Ohio, the Farm Science Review site has been managed by Matt Sullivan, Assistant Director of FSR, and Randall Reeder.

At the Husker Harvest Days in Nebraska, we had an exhibit at the Nebraska Soybean Association tent, but no plots. The circumstances are not conducive to setting up a demo area for this project. At the Illinois location of Farm Progress Show (alternate years), it was also not conducive to establish plots, so we (in 2013) had a display in the tent of the Illinois Soybean Association and talked with interested visitors. A commercial exhibitor (Gypsoil) also gave us space for a display of the two fact sheets.

The demo plots at three sites (Pennsylvania, Ohio and Iowa) provided excellent opportunities to educate farmers and others about improving soybean productivity while improving soil quality. At all four locations (including Illinois), we also had a display with fact sheets at the tent or building of the state Soybean organization.

Both years, Greg Roth and Randall Reeder presented six programs during the Pennsylvania Ag Progress Days. In Ohio both years, Randall Reeder was assisted by Rafiq Islam, Warren Dick and Norm Fausey in visiting one-on-one with Farm Science Review visitors in the plot area. At Farm Progress Show in Iowa (2012), Randall Reeder visited one-on-one with visitors, including many from other countries. At Farm Progress Show in Illinois (2013) he talked to visitors in the Illinois Soybean Association tent.

Fact sheets - We published two 4-page fact sheets. The first, in 2012, described the overall project and included key points about using cover crops and gypsum with no-till soybean production. The second, in 2013, was written specifically to provide tips for storing, loading and applying FGD gypsum. The fact sheets have been distributed at various educational events, including the annual Ohio No-Till Conference, Ohio No-till Field Days, Ohio's annual Conservation Tillage Conference, National No-Till Conferences (in St. Louis, MO, and Springfield, IL), and statewide soybean conferences in Nebraska, Pennsylvania, and Illinois.

Social media - The web site (**http://fabe.osu.edu/usb),** hosted by the OSU Food, Agricultural and Biological Engineering Dept., makes it convenient for frequent updates and additions. The two fact sheets written specifically for this project are available free on the web page. There are also links to an extensive library of research articles, presentations, factsheets that provide information about gypsum as an agricultural amendment. Our Facebook page, "Soybean Productivity," is updated in a timely manner (https://www.facebook.com/SoybeanProductivity).

Presentations - Randall Reeder presented results of the first two years at three conferences in late 2013 and early 2014. Economic analysis based on the 2013 crop year, prepared by Marv Batte, was a key part of the Powerpoint presentations. Information on heavy metals, high oleic soybeans, and soil infiltration tests was included. Warren Dick made presentations at the Ohio No-Till Conference (http://fabe.osu.edu/sites/fabe/files/imce/files/No-till/CTC/CTC.2013_3.pdf) and at the Midwest Soil Improvement Symposium (http://www.gypsoil.com/media-library/documents/36.pdf). Both of these presentations were made in Ada, OH during March 6-7, 2013.

Print media - Ohio's Country Journal has published information on this USB project, and details about the demonstration plots at Farm Science Review. With only two years of results, it has not been appropriate to publish in any national ag magazines or websites.

Plan for 2014 - The demonstration plots in Pennsylvania and Ohio are prepared for the 2014 crop year with cover crops planted and gypsum applied (or ready to apply in early spring).

B. ASSESSMENT OF PROGRESS

We have made a great deal of progress, during the two years of this project, toward our overall goal. As listed above and in the attached appendices, we have provided: (1) science-based practical information for the development of profitable and sustainable agronomic management systems for soybean production; (2) economic analyses of their costs and benefits for a typical, commercial scale farm; and (3) education and outreach programs for their adoption. We have accomplished the majority of the performance measures set forth in the proposal. Regarding the development of scientific publications, because of the severe drought in 2012, we only had one good year of field data in 2013. Publications of field research findings in scientific journals usually require two years of data. We are currently evaluating the data and may need to wait for an additional year before publication.

C. LEVERAGING ADDITIONAL NON-USB FUNDING

1. Randall Reeder has received a $21,500 grant from the Ohio Soybean Council to continue the Ohio field research and demo plots at Farm Science Review in 2014.

2. Greg Roth and Randall Reeder received a $2,500 grant from the Pennsylvania Soybean Council to continue the Penn State University demo plots and educational program in 2014.

3. Warren Dick (The Ohio State University) has received a $406,181 research award from the Ohio Coal Development Office in Columbus, OH (http://www.ohioairquality.org/ocdo/ocdo.asp). An additional $605,689 has been received as cost share from the Electrical Power Research Institute (EPRI, Palo Alto, CA), and $206,662 in support from other project participants, including The Ohio State University. This project has four specific objectives that will provide information related to appropriate use of gypsum for environmental and agricultural benefits. These objectives are (1) demonstrate at field scale that FGD gypsum applied to agricultural fields can reduce P loading to surface waters; (2) assess on-farm agricultural management practices that utilize FGD gypsum to enhance crop yields; (3) perform plot scale studies to provide answers to specific questions concerning application rates, yield increases, and soil and crop types; (4) develop best management practices for on-farm FGD gypsum use and perform

education/outreach to extend proper FGD gypsum use to agricultural communities in Ohio. The first objective related to reducing off-site movement of P to sensitive rivers and lakes is considered of most importance for this project. Although we will obtain data from soybean fields and plots treated with gypsum versus no gypsum, this is a rather small part of the overall project.

4. Rafiq Islam has received a $25,000 grant from the Ohio Soybean Council in 2014. The project goal is to develop a farmer-friendly spreadsheet-based soil organic matter (SOM) calculator that will allow producers to select management practices that conserve or build SOM and improve soil health to increase soybean productivity. The tool will be based on soil and crop data collected from farmer fields and long-term experiments at different locations in Ohio. The results will be developed into a software (calculator) and recommendations, which can be communicated to industry, policy makers and government agencies. The tool will serve as the basis for new programs that simultaneously support the soybean production and biofuel industry and protect Ohio agroecosystems from SOM losses and declining soil health.

Additionally, Rafiq Islam also received a $25,000 grant from the Battelle Foundation to evaluate (1) the performance of three organic materials/products (produced from soybean hulls) for their ability to bind and retain soluble reactive phosphorus from farmland runoff and leaching, and (2) the quality of phosphorus-enriched organic materials as fertilizer.

D. SUGGESTIONS (List any suggestions you feel would be beneficial for the United Soybean Board)
Interest in using gypsum as a soil amendment to improve soil and water quality is strong. Compared to the amount of research related to N, P and K for crop production, however, a very small effort has been devoted to the study of gypsum as a soil amendment. There are three important areas of focus that will need to be addressed to provide good quality data to growers, consultants and university extension agents. These include (1) expansion of our knowledge base related to best management practices that include gypsum as one of a suite of options for improving crop production and for increasing soil and water quality; (2) education to counteract much misinformation about gypsum—for example there are still many people who believe gypsum is a liming agent and this definitely is not true; and (3) providing data to gypsum producers/suppliers so that they will be more willing to make their gypsum available to growers—often a major reason growers do not use gypsum, even though they would like to try using it, is because there is not a readily available source of gypsum where they live.

Long-term studies are clearly needed when assessing gypsum effects on soybean production. Unlike a quick response to N fertilizer, for example, many of the benefits associated with gypsum use accumulate slowly over time. In this respect, gypsum use is analogous to no-till crop production practices where the benefits of no-tillage are often not fully realized until three or more years after it is initially practiced on a field.

E. LIST OF APPENDICES

Appendix 1. Initial soil quality properties

Appendix 2. Greenhouse gas emission

Appendix 3. Heavy metal elements in 2013 soybean grain

Appendix 4. Soybean grain yield

Appendix 5. Profitability analysis