2021 Final Report Summary Sheet

Grantee Information

Project Title: Evaluating slow-release P fertilizers to increase crop production and environmental quality

Institution: University of Illinois Urbana-Champaign

Primary Investigator: Andrew Margenot

NREC Project # 2018-4-360731-385

Is your project on target from an IMPLEMENTATION standpoint? ☒ Yes ☐ No

If you answered "no" please explain:

Is your project on target from a BUDGET standpoint? ☒ Yes ☐ No

If you answered "no" please explain:

Based on what you know today, will you meet the objectives of your project on-time and on-budget? ☒ Yes ☐ No

If you answered "no" please explain:

Have you encountered any issues related to this project? ☐ Yes ☒ No

If you answered "yes" please explain:

Have you reached any conclusions related to this project that you would like to highlight? ☒ Yes ☐ No

If you answered "yes" please explain:

- Though often proposed as a P fertilizer, struvite has not been sufficiently evaluated in the peer-reviewed scientific literature to enable its use by farmers. Current research on struvite as a P fertilizer is (1) is largely greenhouse-based (78% of observations), (2) does not record yield at the field-scale (<1%), (3) utilizes unrealistically high P application rates that bias findings in favor of struvite, (4) does not evaluate granule size, timing, or placement on crop response, and (5) does not evaluate blends of struvite with ammonium phosphates or super phosphates. Additionally, (6) no studies to-date comprehensively determine dual agricultural and environmental (P loss risk) outcomes of struvite. Each and every one of these deficits are being addressed in our ongoing NREC-supported research.
- In soils with deficient STP (<18 mg/kg Mehlich III colorimetric), 50-50% struvite-MAP blends appear optimum for maximizing vegetative corn and soybean growth while minimizing residual STP by up to -18%. This indicates lower DRP loss risk from surface soils via run-off without compromised crop growth.
- In soils with optimum to high STP, corn yields are unaffected by up to 75% struvite substitution and yields of double-cropped wheat and soybean are unaffected by up to 100% struvite substitution for MAP. This likely reflects 'banked' P from previous applications, but on the other hand is representative of STP in IL production agriculture (according to IPNI 2014 data). Future research should evaluate mechanisms and kinetics of crop uptake of struvite-derived vs native STP.
- Timing (fall vs spring) and placement (broadcast vs banding) did not influence corn yield response to struvite-MAP blends of up to 75% of total P in 2019 and 2020 for corn at three sites (Urbana, IL; Effingham, IL: Streator, IL), nor soybean at

two sites in 2019 and 2020 (Urbana, IL), nor wheat in 2019 (Urbana, IL) if soil test P levels were adequate. Thus, at maintenance rates (Illinois Agronomy Handbook), struvite can be a near-complete substitute for MAP or DAP.

- Residual struvite granules remaining in soils at the time of sampling may inflate apparent STP values, but these increases are sufficiently high (+600%) from a single granule being present in the relatively low soil mass being used for testing (2 g soil) that this potential artifact is easily identifiable. Over two growing seasons, we have found that approximately 45-55% of struvite can remain undissolved.
- However, residual granules of struvite present at the end of the growing season are chemically and physically weathered, as revealed by state-of-the-art scanning electron microscopy and electron dispersion spectroscopy (SEM-EDS), suggesting that residual granules are more likely to dissolve than freshly applied struvite in the subsequent season
- Arbuscular mycorrhizal associations can increase solubilization of struvite by up to 40%, indicating that greater soil health and conservation practices like reduced tillage can promote biological solubilization of struvite.
- Adding struvite on the same P basis as highly water-soluble P fertilizers can decrease soil test P levels and water-soluble soil P, indicating it can be used to maintain yields but decrease residual soil test P values.
- The majority of P absorbed by corn by V7 is soil-derived, meaning that initial lags in struvite dissolution may not necessarily impair corn growth in 'typical' Illinois soils that are well-managed to have adequate soil test P levels.

Have you completed any outreach activities related this project? Or do you have any activities planned? ☒ **Yes** ☐ **No**

Since the last annual report, the following additional activities have been completed on communication and outreach of this work.

(**Bold names** indicate undergraduate students, graduate students, or post-doctoral scholars supported by NREC, as well as PI.)

Completed Presentations (oral unless otherwise indicated)

1. Margenot, A.J. Phosphorus Management and Water Quality Implications. Advanced Soil Health Training, SW Indiana Focus Area. July 21, 2021. Vincennes, IN.
2. Margenot, A.J. Managing phosphorus to reduce nitrogen losses? The curious case of ammonium phosphates. Ewing RDC Field Day. July 22, 2021. Ewing, IL.
3. Margenot, A.J. Phosphorus Research in Illinois. 2021 Nutrient Stewardship Field Day: Warren/Henderson Co. Kirkwood, IL. Aug 26, 2021.

Publications *(since the last annual report)*

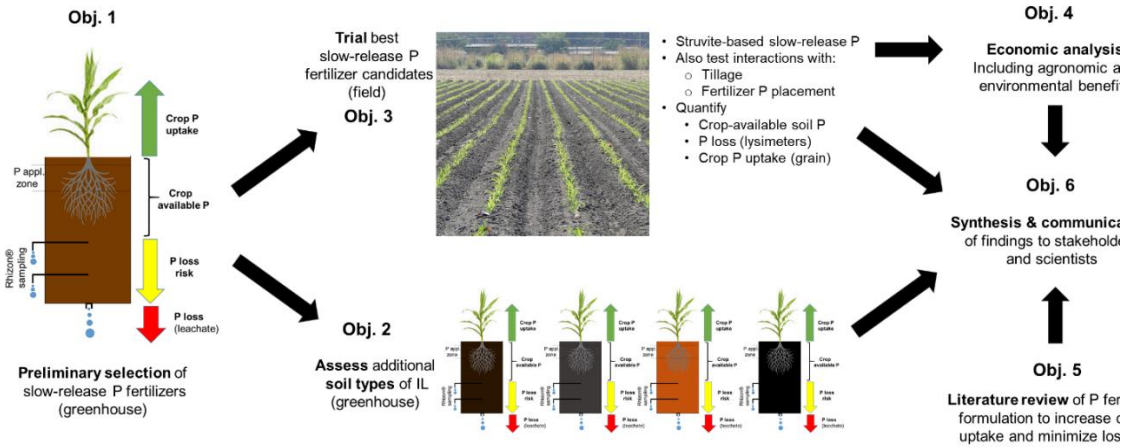
1. **Di Tomassi, I., Chatterjee, N.,** Barrios Masias, F., Zhou, Q., **Gu, C.**, **Margenot, A.J.** 2021. Arbuscular mycorrhizae increase biomass and nutrient uptake of tomato fertilized with struvite compared to monoammonium phosphate. *Plant and Soil*. 464: 321–333 https://doi.org/10.1007/s11104-021-04957-2
2. **Gu, C.,** Zhou, Q., Cusick, R.S., **Margenot, A.J.** 2021. Evaluating agronomic soil phosphorus tests for soils amended with struvite. *Geoderma*. 399: 115093. https://doi.org/10.1016/j.geoderma.2021.115093

In review:

1. Ruffatto, K., Emaminejad, A., Juneja, A., Kurambhatti, C., **Margenot, A.J.**, Singh, V., **Cusick, R.D.** Mapping the national P recovery potential from wastewater treatment plants and corn biorefineries. *Environmental Science & Technology*. Submitted Nov 25, 2021.

Please write a detailed summary report that includes: Details of each objective and the progress made towards its competition, planned research activities for 2020, major accomplishments, any preliminary findings or data relevant to the project, relevant budgeting, and any publications or outreach accomplished from the research. Also this year please include a one page summary with relevant data tables or graphs and pictures related to the project that you would like included in the NREC end of the year report.

In the fourth and final year of this NREC project, we have completed the outstanding objectives #2, 3 and 4, as well as contributing to outreach and dissemination of objective #6 (objectives #1 and #5 were fully completed in previous project years).



Thus, as will be detailed in the Final Project Report (forthcoming), we have successfully completed all project objectives. Additionally, we expanded on the depth objective #3 via an extra on-farm trial, added a soil testing component in response to private sector (FS) feedback, and added a novel approach using world-class radioisotopic techniques to solve a question that arose from field trials. We have leveraged part of this work to pursue two additional federal grants, an NSF ECO-CBET (currently in review), and the US-Israel BARD (currently in review). Specifically:

- An on-farm site was added in central-south Illinois in Effingham Co., in collaboration with a farmer who approached the research team at the 2020 NREC Research Investment Insight Live event.
- Finalizing a follow-up study in response to the suggestion by an FS researcher that residual struvite granules could throw off soil test P values – now published as Gu et al. 2021 (please see Publications).
- Adding an evaluation of how soil heath (mycorrhizal fungi) can influence struvite utilization by the crop plant – now published as Di Tomassi et al. 2021 (please see Publications)
- Utilizing radiolabeling of struvite and MAP, one of the few labs in the United States that employs this cutting-edge technique, to quantify soil vs fertilizer contribution to early stage (up to V7) corn uptake. This will help test the hypothesis generated from field trial evaluations that in adequate soil test P fields (>40-50 lbs/ac), struvite does not impair yields as has been observed in P-deficient soils because current soil P concentrations contribute to plant uptake to cover the lag in struvite dissolution.

A key part of this year has been the analysis. This work will be the basis of a PhD student's dissertation (Neha Chatterjee), currently in progress. This will entail three additional publications, all of which are in varying stages of preparation for submission. Three are anticipated to be submitted in 2022, and the fourth in early 2023.

1. Chatterjee, N., Margenot, A.J. 33-P labeling reveals maize uptake of phosphorus from MAP and struvite in adequate soil test P soils in Illinois. To be submitted to *Soil Biology and Biochemistry*.

2. Chatterjee, N., Isermann, D., Isermann, J., Bohnhoff, K., Hertzberger, A.J., Margenot, A.J. Struvite substitution for MAP or DAP maintains maize and soybean yields while decreasing water-extractable P in surface soils. To be submitted to *Plant and Soil*.
3. Chatterjee, N., Margenot, A.J. Struvite substitution, placement and timing effects on yield soil phosphate loss risk in double cropped wheat-soybean in central Illinois. To be submitted to *Agronomy Journal*.