Correcting Soybean Manganese Deficiencies on Coastal Plain Soils to Improve Yields and Balance Nutrients on the Delmarva Peninsula

Final Project Report

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Project Summary

Micronutrient deficiencies, particularly manganese (Mn), are often overlooked, but can significantly reduce soybean yields. Sandy soils with low buffering, like those on the Mid-Atlantic Coastal Plain capacity are especially susceptible to higher pH, which limits plant availability of Mn. The objective of this research was to evaluate the tissue and yield response to foliar Mn application when Mn deficiency is predicted by a pre-plant routine soil test.

In cooperation with local farmers, we established replicated in-field strip trials in 2019 and 2020 and small-plots at the University of Delaware Warrington Irrigation Farm in 2020 to evaluate foliar application of Mn to soybean at two rates (0 and 1.5 lb/ac Mn) on crop yield and tissue concentrations. Initial soil test reports collected from participating farmers included soil test Mn interpretations that suggested soils were within the low to sufficient ranges for Mehlich 3 Mn. However, Mn deficiency was unlikely based on the calculated Mn availability index (MnAI), which was above 35 for all sites.

Yield data was collected at harvest using a calibrated yield monitor. Plant tissue samples were collected at pod fill from the University of Delaware site only in 2020. We reported no significant yield or tissue Mn response to foliar Mn application. as the soil pH and Mn concentrations were conducive to soil Mn availability. As such, we do not recommend that farmers apply foliar Mn unless soil MnAI is below 25 or if Mn deficiency was observed and documented previously by a tissue test.

However, soybean is known to be a Mn sensitive crop and Mn deficiencies have been documented in poorly buffered sandy Delaware soils. Soil testing remains the best line of

defense against soybean Mn deficiency. Growers and consultants should use soil test Mn concentrations and soil pH values to calculate the MnAI based on the most recent soil test rather than relying on interpretation charts alone. For fields with soil MnAI between 25 and 35, we recommend scouting in-season for Mn deficiency symptoms, and confirming suspected deficiencies with a tissue test prior to application of foliar Mn.

Additional research is needed on soils with suspected Mn deficiency (MnAI <25) to determine the economic value of foliar Mn applications to soybean.

Rationale and Significance

Historical application of poultry litter at rates exceeding crop removal has led to build-up of soil test P to levels that exceed agronomic optimum across much of the Delmarva Peninsula. Scientists have linked agricultural P losses from “high P” soils to water quality degradation in the region (Sims et al., 2000). The widespread occurrence of “high P” soils on the Delmarva is related to a regional P imbalance resulting from intensive poultry production within the region (Beegle et al., 2002; Slaton et al., 2004). Annual consumption of grain crops (corn and soybean) by Delmarva grown broilers consistently exceeds the amount of grain produced in the region. As a result, poultry integrators are forced to import grain from outside the region, typically the Mid-western US. On average, 8.83 million bushels of soybean were imported annually to the Delmarva region over the last decade (2007 to 2016) to meet the feeding needs of the poultry industry (Delmarva Poultry Industry, 2017). Considering the concentration of P in soybean grain averages 0.31 lb/bu grain (Shober et al. 2012), the average annual amount of P imported into the region in soybean grain was 1,386 ton/year.

While some of the P in this imported grain is exported from the region in meat and other poultry by-products, a significant amount of P in the grain is excreted in manure and remains on the Peninsula after the birds are gone. Because P has no atmospheric pathway, it accumulates in poultry litter that must be land applied within or exported from the region at a cost. As such, it is important to explore options that can help achieve regional nutrient balance to ensure sustainable production of poultry on the Delmarva.

Increasing crop yields on Delmarva is one strategy to move the region closer to nutrient balance by reducing the need to import grain. Increasing yields can be challenging for agronomists and producers because the sandy, Coastal Plain soils of the region typically have low organic matter and low inherent fertility. For example, soils on the Coastal Plain of the Mid-Atlantic have variable properties, which make management of micronutrients difficult. Micronutrient deficiencies, particularly manganese (Mn), are often overlooked, but can significantly reduce soybean yields. Sandy soils with low buffering capacity are especially susceptible to higher pH, which limits plant availability of Mn (Camberato, 2000). Heavier soils, while better buffered, may still have low Mn concentrations due to their alluvial parent material (Miller, 2016).

Foliar application of Mn during the growing season can improve visual Mn deficiencies; however, limited data on yield response to foliar Mn is available. Recommendations for foliar Mn application can be improved by observing a range of soil textures, and comparing pH and response to additional Mn. The range of soil types in this region makes it more difficult to determine the best pH to maximize Mn availability. In addition, research on the accuracy of soil and tissue tests to predict Mn deficiency is also necessary. While routine soil tests indicate Mn surplus or deficiency, their accuracy for predicting a positive yield response to Mn application needs evaluation. Tissue tests are more accurate at identifying Mn deficiencies, but may not be taken until symptoms appear, at which time yield may already be negatively impacted.

Project Objectives

The objective of this research is to evaluate the tissue and yield response to foliar Mn application when Mn deficiency is predicted by a pre-plant routine soil test. The overall goal of our work is to determine if foliar Mn applications can increase yields across the region to help achieve nutrient balance, while maintaining or improving grower profitability (considering the cost of fertilizer and fuel across the field).

Methods

<u>Cooperator Identification and Soil Screening</u>
We had planned to survey Extension Educators and Agricultural Service Providers in Delaware and Maryland to identify fields with a history of visual or measured Mn deficiencies or based on known soil map units with Mn deficiencies. However, because funding for this project was established in late spring 2019, time constraints prevented us from completing a thorough soil testing survey to identify the possible extent of Mn deficiency in Delaware in 2019; COVID eliminated our ability to complete the surveys in 2020. Regardless, we were able to identify three farmers with suspected soybean Mn deficiency to participate in on-farm strip trials in 2019 and 2020. All farmers completed the field trials in 2019. Two of the three confirmed farmer-led field trials were planted in 2020, but Mn treatments were not applied by two farmers due to circumstances that were out of their control. The remaining farmer-led field trial was planted and Mn was applied to the crop in 2020; however, flooding in the trial field resulted in our inability to harvest two of the four replications. We also planted a small plot study at the University of Delaware Warrington Irrigation farm in 2020. Two of the three initial cooperators agreed to repeat the field trials in 2021, but again these cooperators were unable to apply Mn treatments due to circumstances that were out of their control.

Soil series information was collected using the University of California's Soil Web Earth file that overlays USDA-NCSS detailed soil survey data (SSURGO) in Google Earth. For all planted field trials, cooperating farmers provided soil test reports for the trial fields. These soil samples were collected by the participating farmer or their representative within three years of the field studies. Soils were analyzed for pH and Mehlich-3 Mn by a local soil testing laboratory. Manganese availability index (MnAI) values were calculated using the equation:

$$\text{MnAI} = 101.7 - (15.2 \times \text{soil pH}) + (2.11 \times \text{M3-Mn})$$

where MnAI is the Mn availability index, soil pH is measured in water (1:1 V:V), and M3-Mn is Mehlich 3 soil test Mn in lb/A (Shober et al., 2020). Field location, soil series information, and soil analysis for all planted trials is located in Table 1.

Table 1. Field locations, soil series, and initial soil properties for Delaware farmer-led strip trials testing foliar manganese applications to soybean.

Field Location	Year	Dominant Soil Series	Soil pH	Mehlich-3 Mn (lb/A)	Mn Availability Index
Greenwood, DE	2019	Hambrook sandy loam	6.4	32	72
Laurel, DE	2019	Pepperbox-Rosedale complex	6.0	18	48
Millsboro, DE	2019	Henlopen loamy sand	Not provided	Not provided	Not provided
Greenwood, DE	2020	Woodstown sandy loam	6.1	30	72
Harbeson, DE*	2020	Rosedale loamy sand	5.9	28	71

**The Harbeson site was located at the University of Delaware Warrington Irrigation Farm and was conducted as a small-plot study.*

<u>Field-Trial Design, Data Collection, and Analysis</u>

At each grower-managed location, cooperators established eight strips that were 90 ft wide by field length to accommodate use of farmer-owned equipment (sprayers, yield monitor). The cooperating farmers planted full-season or double-crop soybeans in the selected field, with variety, seeding rate, and other management parameters determined by the cooperator. Two Mn treatments (0 and 1.5 lb/ac) were applied in a randomized complete block design with four replications. Yield data was collected at harvest by the cooperating farmer using a calibrated yield monitor.

At the Harbeson, DE site, University of Delaware staff established soybeans in 90 ft × 90 ft small plots under center pivot irrigation. Manganese treatments (0 and 1.5 lb/ac) were applied on 27 Jul 2020 in a randomized complete block design with five replications. Trifoliate leaf tissue will be sampled from each plot after Mn application and were analyzed for total digestible nutrients. Yield data was collected from each plot at harvest using a calibrated yield monitor.

Data were analyzed using a mixed-model analysis of variance to evaluate the effects of Mn application on soybean yield and tissue Mn concentration (Harbeson only). Site location and Mn treatment were included in the model as fixed effects and replication was included as a random effect. Normality of data was determined by examining residual plots. Pairwise comparisons were compared using Tukey's Honestly Significant Difference test at an alpha level of 0.1.

Results

Initial Soil Screening

Initial soil test reports indicated that soil Mn concentrations were in the low (<30 lb/A) to sufficient range (>30 lb/A) for all farmer cooperator sites (Table 1). Based on the soil test information, the Laurel (2019) and Millsboro (2020) cooperators could infer that their soybean crops might potentially suffer from a moderate Mn deficiency or "hidden hunger". However, all sites were above the 3.4 lb/A soil Mn concentration that is listed in the University of Delaware soybean fertility recommendations as the concentration under which crops should be monitored for Mn deficiency (Shober et al. 2020). Manganese availability in soils is pH dependent, with availability decreasing as soil pH increases. As such, University of Delaware recommends using the soil Mn Availability Index (MnAI) rather than soil test Mn results alone to determine the susceptibility of soybean crops to Mn deficiency. Manganese deficiency is likely when the MnAI is less than 25, but unlikely when the MnAI is above 35. When MnAI is between 25 and 35, University of Delaware recommends that crops be monitored for Mn deficiencies, especially if liming was recommended. Based on University of Delaware MnAI interpretations, we would not expect a Mn deficiency for soybean at any of the field trial sites, as the calculated MnAI values all exceeded 35 (Table 1).

Soybean Yield

Soybean yields were analyzed across all sites for each trial year because we reported no significant site effect on yield. In 2019, soybean yields were not affected by Mn treatment (P = 0.7324), with yields averaging 42.9 ± 3.3 bu/A for crops receiving the foliar Mn application and 42.3 ± 2.6 bu/A for beans that received no Mn. Soybean yields in 2020 were higher than in 2019; however, we still saw no yield response to Mn application (P = 0.5993). In 2020, soybean yield following foliar Mn treatment averaged 62.8 ± 4.2 bu/A compared to 61.8 ± 6.7 bu/A for the untreated beans. The lack of yield response to foliar Mn applications was not surprising, considering the soil MnAI indicated that Mn deficiency was unlikely to occur (Table 1; Shober et al. 2020). As such, we conclude that Mn application was not in the economic interest of the growers at these field sites.

Soybean Tissue Mn Concentrations

Concentrations of Mn in soybean leaf tissue samples collected at pod fill from plots at the University of Delaware Warrington Irrigation Research Farm were also not affected by foliar Mn application. Average concentrations of Mn-treated tissue was 81.0 ± 14.3 mg/kg compared to 67.2 ± 18.0 mg/kg; these values were not statistically different (P = 0.1719). And while Mn concentration of the Mn-treated soybean tissue was numerically higher, concentrations for all tissue samples were well within the published Mn sufficiency ranges for soybean (17-100 mg/kg; Miller and Shober 2020). In fact, the untreated tissue samples had concentrations of Mn that were higher than tissue Mn concentrations from samples collected from the University of Delaware variety trials in Dagsboro, Georgetown, and Middletown in 2020, which averaged 52.4 mg/kg (Miller and Shober 2020).

Conclusions and Recommendations

Foliar applications of Mn to soybean crops did not result in significant increases in yield when the soil MnAI was above 35 because the soil pH and Mn concentrations were conducive to soil Mn availability. As such, we do not recommend that farmers apply foliar Mn unless soil MnAI is below 25 or if Mn deficiency was previously observed and documented by a tissue test.

However, soybean is known to be a Mn sensitive crop and Mn deficiencies have been documented in poorly buffered sandy Delaware soils. Soil testing remains the best line of defense against soybean Mn deficiency. Growers and consultants should use soil test Mn concentrations and soil pH values to calculate the MnAI based on the most recent soil test data rather than relying on interpretation charts alone. For fields with soil MnAI between 25 and 35, we recommend scouting in-season for Mn deficiency symptoms, and confirming suspected deficiencies with a tissue test prior to application of foliar Mn.

Additional research is needed on soils with suspected Mn deficiency (MnAI <25) to determine the economic value of foliar Mn applications to soybean.

References

Miller, J. and Shober, A. (2020) A Survey of Delaware Soybean Variety Tissue Nutrient Concentrations. Final Report to the Delaware Soybean Board. Available at: https://www.soybeanresearchdata.com/download.aspx?file=Progress5File&name=53769_2020_Delaware_Tissue_Survey_Final_Report.pdf

Shober, A.L., Gartley, K., and Miller, J. (2020) Nutrient Recommendations - Agronomic Crops. University of Delaware Cooperative Extension. Newark, DE. Available at: https://www.udel.edu/academics/colleges/canr/cooperative-extension/environmental-stewardship/soil-testing/nutrient-recommendations/