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Sulfur Fertilization for Soybeans (and Other Grain Legumes)

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Sulfur is one of the six macronutrients that plants need for growth in addition to nitrogen (N), potassium (K), phosphorus (P), sulfur (S), calcium (Ca), and magnesium (Mg). Sulfur is taken up in similar quantities to P, but has widely been ignored as a part of farmer's routine nutrient management for several reasons. Historically, S was applied routinely as part of organic amendments such as manure and compost and as an "impurity" in common fertilizers. Until the implementation of the amendments to the Clean Air Act in 1990, S was supplied in sufficient quantities through atmospheric deposition and mineralization of organic S in soils. However, with today's higher yield agriculture, decreased atmospheric deposition and purified synthetic fertilizers, soils in the mid-Atlantic are becoming widely deficient in S.

Sulfur works closely with nitrogen in grain legume (soybean, bean, pea, peanuts) production. It is essential for nitrogen fixation and protein and oil synthesis. Sulfur is a key component of sulfur containing amino acids (SCAA) cysteine and methionine which are necessary for all non-ruminant animals (people included) to utilize proteins. These amino acids often limit the feed and food value of grain legumes. Grain legumes are second only to grains as the most widely grown crop worldwide and serve as a main protein source for many of the world's populations as well as non- ruminant animals. Humans (and chickens) cannot synthesize methionine and cysteine and therefore must get it from dietary sources.

Responses in both yield and protein quality (amino acid composition) are most likely in sandy textured soils. However, finer textured soils will also likely become deficient in the coming decades. Sandy soils tend to be low in S because they have little anion exchange capacity (sulfate is held by iron coatings on soils), low organic matter (S is part of soil organic matter and is released during decay much like nitrogen is) and rate of leaching (S leaches away as sulfate anions).

A preliminary survey of MD soybeans by the Weil lab in the Department of Environmental Science and Technology found a wide range of S content and N/S ratios in the seed suggesting that many soils, especially the sandy soils on the eastern shore would be responsive to improved S management. A ratio of nitrogen to sulfur in the seeds greater than about 20 to 1 is often the best indication of sulfur deficiency. The range of seed

Do neonicotinoid seed treatments impact soil health and quality in grain crops?

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Background: As a protection against early season insect pests, seeds from various crops are treated with neonicotinoid insecticides. However, when neonicotinoids are used this way, only 1.6 to 20% of the active ingredients are taken up the by plant, with the rest remaining in the soil[1]. The persistence of neonicotinoids in the soil depends on a number of factors such as microbial activity, temperature, soil moisture and soil pH. Field studies performed in other regions indicate active ingredients from neonicotinoid seed treatments (NSTs) persist in the soil from 80 days up to multiple years[2], and how long the active ingredients from NSTs remain in the soil in Maryland is unknown.

In the soil, neonicotinoids could negatively impact various soil organisms including predatory arthropods like ground beetles and rove beetles[3,4,5]. Lab studies have shown that neonicotinoids are lethal to earthworms at high doses and can affect behavior and physiology at low doses[5]. Neonicotinoids can also alter the abundance, community structure and activity levels of soil microbes[6,7]. Earthworms and soil microbes play an important role in maintaining the physical and chemical properties of soil; therefore, neonicotinoid persistence in the soil could reduce soil health and fertility.

Another potential impact of neonicotinoids remaining in the soil is the uptake of active ingredients by non-crop plants. Neonicotinoid residues have been found in the flowers of plants growing around NST treated fields, which could be a source of exposure for pollinators[8].

To address these concerns, we conducted a three-year study to better understand the risks of using two neonicotinoid seed treatments, Cruiser® 5FS (thiamethoxam, Syngenta) and Gaucho® 600 Flowable (imidacloprid, Bayer) in a 3-year grain crop rotation of full-season soybean, winter wheat, double-cropped soybean and corn.

Objectives: To determine the effects of NSTs on 1) soil physical and chemical properties and 2) abundance and community structure of soil microbes. We also 3) test whether neonicotinoids remaining in the soil can be taken up by non-target plants, specifically flowering winter annual plants. By conducting the study over three years, we can determine whether there are any cumulative impacts of repeated NST use.

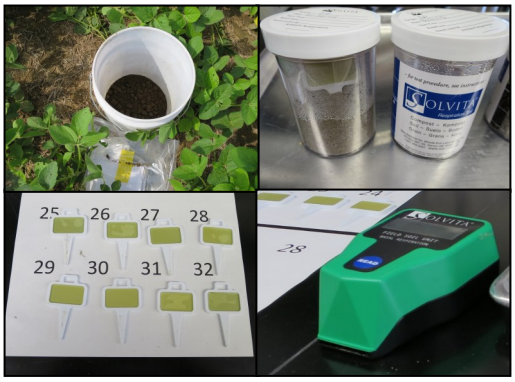

Fig. 1. *The process of collecting soil and setting up the Solvita test for measuring soil respiration.*

Experimental Design & Soil Collection: The study was conducted at two sites in Maryland (Beltsville and Queenstown). At each site, we planted four replicate plots of each of the following treatments using standard Mid-Atlantic production practices:

1. Control (bare seed)
2. Fungicide (fungicide seed treatment)
3. Cruiser + Fungicide (insecticide + fungicide seed treatment)
4. Gaucho + Fungicide (insecticide + fungicide seed treatment)

In all cases, soil was collected from each plot by taking 30 soil cores of roughly 5-inch depth. Cores were taken across the entire plot area both between rows and within them. The soil was mixed thoroughly and combined into a single sample per plot.

Physical & chemical soil properties: Before planting soybean in 2015, soil was collected and used to measure several important soil health parameters, namely: pH, soluble salt content, active carbon, percent carbon, hydrogen and nitrogen, available nitrogen

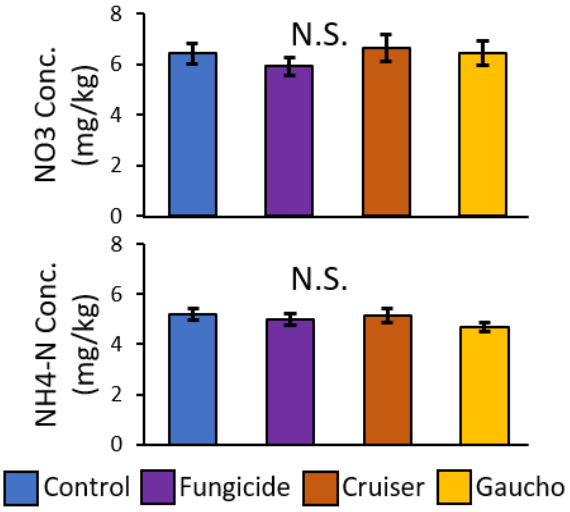

Fig. 2. *Concentration of nitrate ions (top) and ammonium ions (bottom) in soil collected in 2017. Error bars indicate standard error, N.S. = no significance.*

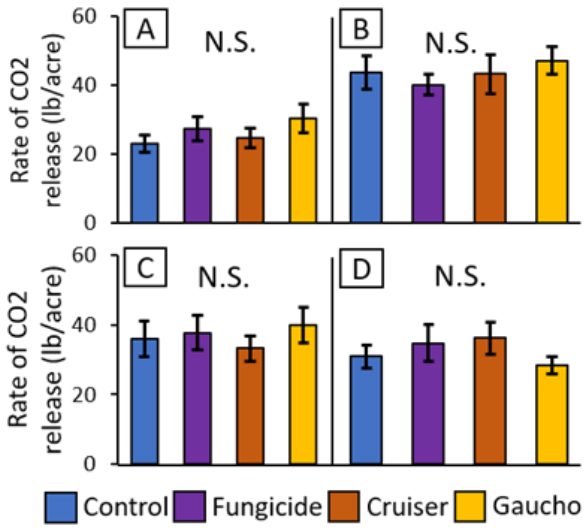

Fig. 3. *Impact of NSTs on the rate of CO_2 release from the soil, combined across study sites and sampling dates in A) full season soybean B) wheat c) double cropped soybean and D) corn. Error bars represent standard error, N.S.= no significance.*

(nitrate and ammonium ion concentration) and wet aggregate stability. These starting measurements were used to ensure plots were relatively similar at the start of the experiment. At the end of the experiment, after corn was harvested in 2017, these measurements were repeated to measure treatment effects. While we did not expect these values to be directly affected by NSTs, they could be altered indirectly by the impact of the insecticides on soil organisms like earthworms and microbe communities. Our analysis found that soil parameters were similar between plots at the beginning of the study. NSTs did not impact any of the soil quality parameters that we measured at the end of the study (Fig. 2).

Microbial analysis: During each crop cycle, we collected soil from each plot at several time points for microbial analysis. A portion of the sample was used for Solvita basal respiration tests (Fig. 1). This test measures the rate of CO2 release from the soil as an indicator of general biological activity in the soil. It is designed to be used by growers to test soil health in the field. Some of the soil was also frozen for future analysis of microbial abundance and community composition through quantitative PCR and Illumina sequencing of the 16S ribosomal RNA gene. The Solvita test kit did not detect differences in soil respiration between treatments in any of the crops (Fig. 3). Neonicotinoids may alter the soil microbial community composition without affecting overall microbial abundance. We will be able to ascertain this after completing the Illumina sequencing.

Fig. 4. *Buds from common henbit (top) and common chickweed (bottom) were collected for neonicotinoid residue analysis.*

Uptake by non-target plants: To determine whether neonicotinoids are taken up by non-crop plants, we collected flower buds from weedy winter annual plants (common chickweed and common henbit, Fig. 4) growing within our plots in the early spring. In 2016 (when wheat was in the ground), we were able to gather enough henbit at Beltsville and chickweed at Queenstown. In 2017 (after double cropped soybean was harvested), we collected both plants at Beltsville and chickweed at Queenstown. The buds were tested for the presence of imidacloprid, thiamethoxam and clothianidin, which is a break down product of

thiamethoxam. In 2016, neonicotinoid residues were not found in any of the samples. In 2017, no neonicotinoid residues were found in the chickweed samples from Queenstown or the henbit samples from Beltsville. Trace amounts of imidacloprid were found in four of the chickweed samples from Beltsville. As the chemical was present in plots of all four treatments in very low concentrations, its presence does not appear to be correlated to the experiment.

Conclusions: Our results so far indicate that NSTs do not impact soil physical/chemical properties or respiration when measured by Solvita basal respiration tests. As Maryland tends to have sandy soil and a lot of rainfall, it is possible that neonicotinoids, which are highly water soluble, get washed into water bodies instead of persisting in the soil. Our microbial analysis will determine whether neonicotinoids alter the soil microbial community. We also found that neonicotinoids from seed treatments were not taken up by winter annual flowers in our study; though trace residues indicate that these flowers may be capable of taking up active ingredient from the soil. Because our samples were taken prior to planting, residues likely did not come from planting dust or insecticide sprays. Measurable neonicotinoid residues have also previously been found in the pollen and nectar of wildflowers collected in the spring and summer following fall planting of neonicotinoid treated crops[8].

In this study we also found no pest suppression or yield benefits from NSTs, likely due to low early season insect pressure throughout the study (2017 Agronomy News, Issue 7). Producers can make the best use of NSTs where they regularly have high early season insect pest pressure and they should only be used where needed.

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Spotted Lanternfly Confirmed in Maryland

Maryland Department of Agriculture press release, abridged

The Maryland Department of Agriculture has confirmed that a single adult spotted lanternfly has been found on a trap in the northeast corner of Cecil County near the border of Pennsylvania and Delaware. This is the first confirmed sighting of the invasive species in Maryland, and the department does not believe there is an established population of the pest in the state.

The spotted lanternfly poses a major threat to the region's agricultural industries as they feed on over 70 different types of plants and crops – including grapes, hops, apples, peaches, oak, pine and many others. Originally from Asia, the spotted lanternfly is non-native to the U.S. and was first detected in Berks County, Pennsylvania in the fall of 2014. As a known plant-hopper and hitchhiker, the spotted lanternfly has spread to 13 counties within Pennsylvania and has confirmed populations in Delaware, Virginia, and New Jersey.

The department's Plant Protection and Weed Management Program continues to work with the University of Maryland Extension, the U.S. Department of Agriculture (USDA), the USDA Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), and others to monitor the insect in Maryland via trap surveys. The department has also launched outreach and education campaigns aimed at