Role of Soil Management in Control of Soil-Borne Diseases

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Summary
Soil-borne diseases are a significant cause of reduction in crop yield. Alternative management of soils can enhance the natural disease-controlling organisms in the soil. This study explores the impact of alternative production methods on a primary soybean disease, charcoal rot, caused by the fungus *Macrophomina phaseolina*. Treatments that could potentially enhance or reduce the disease pressure were implemented, and soil tests were conducted for nutrients, soil properties, and disease presence. Manure increased the nutrient levels in the soil, as expected, but did not impact the disease control. Solarization increased the temperature within the plots, and increased the number of colony forming units (CFUs) of *M. phaseolina*.

Introduction
Suppressive soils have been defined as soils that can inhibit the growth of naturally occurring soil-borne diseases. These soils are capable of suppressing or controlling disease-causing organisms, including fungi (e.g. *Fusarium virguliforme* (cause of sudden death syndrome, SDS), *Macrophomina phaseolina* (cause of charcoal rot), Phytophthora root rot (*Phytophthora sojae*), and nematodes (e.g., soybean cyst nematode, *Heterodera glycines*). How the native soil microbial communities reduce disease is not known. Knowledge of factors that contribute to and support these beneficial microbial communities is also unknown.

One example of this natural improvement in soil microbial community reducing disease was demonstrated in our previous research (Sassenrath et al., 2017, 2019) that demonstrated that a high-glucosinolate mustard (*Brassica juncea*) reduced fungal populations that caused charcoal rot in soil and in soybean plants. Here, we expand on those results by exploring the interaction between soil health and disease pressure. Management practices that increase, decrease, or maintain disease pressure were tested in field studies to determine the impact on soil health, fungal pathogen presence, and soybean growth and yield.

Impact of Soil Health on Soybean Disease
Crop plants that are disease hosts increase the number of disease-causing organisms in the soil. We have previously shown the increase in colony forming units (CFU) of *M. phaseolina* in the soil after soybean production (Sassenrath et al., 2019). Other factors that reduce soil-borne diseases include high-glucosinolate mustard as a cover crop (Sassenrath et al., 2017, 2019) and increasing the soil temperature (e.g., "solarization"). Use of animal manures greatly increases the diversity of the soil microbial community, and beneficial microorganisms in particular. In addition to improving the nutrient balance of the soil, manure may contribute to reduced disease pressure (Graham et al., 2014) and soybean cyst nematode populations (Bao et al., 2013).

Diseases are primary factors that reduce the yield and quality of soybeans in Kansas and throughout the world. Soil-borne diseases are prevalent in eastern Kansas crop fields. Certain plants have been shown to produce chemicals that act as biofumigants that control or reduce harmful soil fungi. Animal manures have also been used to alter the soil microbiome to improve control of disease organisms. Our working hypothesis is that improving the overall soil health by supporting healthy soil microbial communities can reduce disease pressure, i.e. creating suppressive soils by altering management practices will reduce disease pressure. This research explores the relationship between soil health and disease pressure. The research tests the ability of cover crops, animal manure, and solarization to control or reduce charcoal rot in soybean production through improved soil microbial communities.

Experimental Procedures

Replicated plots were established at the Southeast Research and Extension Center in Parsons in the spring, 2023. Plots included: fallow, mustard cover crop, soybean, corn stubble, cow manure, and plastic sheets. Temperature and moisture sensors (Hobo, Onset, Inc., Bourne, MA) were installed at 2-in. depth in the soil, and temperature and moisture were recorded continuously. Plastic sheets provide a "solarization" treatment, increasing soil temperature and potentially reducing soil microbes. Plastic sheets were placed on plots and held in place with concrete blocks. Corn stubble was spread to about a 2-in. layer; corn stubble provides more carbon for soil microbes, increasing their abundance, but is also a host for *M. phaseolina*, potentially increasing the disease prevalence. Animal manure provides an additional food source for the microbes and adds additional microbes to the soil; manure has been shown to reduce some pathogens in soil. Cow manure was spread to about a 2-in. layer on the plots. Mustard cover crop has been shown to reduce the number of CFUs of *M. phaseolina*, while soybeans are a host and increase the CFUs of *M. phaseolina*. The high-glucosinolate mustard, Might Mustard Pacific Gold (Johnny's Selected Seeds, Winslow, ME) was broadcast in plots in early April. The fallow treatment was left unplanted and served as a control. Five cultivars of soybeans, ranging from MG 3.2 to 5.2, were also planted to test for variation in charcoal rot sensitivity.

Soil samples to a depth of 6" were collected in spring prior to implemented treatments, mid-season, and after harvest. Soils were analyzed for nutrients and microbial activity, and for the number of CFUs of *M. phaseolina*. Soil microbial activity was measured with the CO_2-burst test (Solvita, Woods End, ME).

Results and Discussion

Nutrients changed in response to treatments (Table 1). As anticipated, the cow manure treatment had the highest levels of organic matter (OM), potassium (K), and phosphorus (P). Surprisingly, the solarization treatment (plastic film) had the highest total nitrogen (N) and microbiologically active carbon.

Interesting differences were observed in the environment within the soil in the different treatments (Figure 1). The soil with animal manure retained the most moisture (Figure 1), most likely due to the coverage of the soil reduce evaporation from the soil surface. Similarly, corn stalks and plastic reduced evaporative losses and retained soil moisture. Mustard seed and soybeans removed soil moisture, resulting in soil moisture levels that were below the fallow treatment. The solarization treatment (plastic) increased soil temperature an average of 15 degrees above that of bare soil (fallow) (Figure 2). Cow manure and corn stubble kept the soil an average 8 degrees cooler. Plants (soybeans and mustard seed cover crop) also kept the soil cooler, but not as cool as for corn stubble and manure.

The soil microbial activity, as measured by the Solvita CO_2-burst test, was very high in the corn stubble and manure, as would be expected from the high carbon content of those materials (Fig. 3). The soil that had been treated with cow manure also had much higher microbial activity, but the activity under the corn stubble was less than that planted to soybeans. Microbial activity with the mustard seed cover crop was also low. The fallow and solarization treatments had the lowest microbial activity at mid-season.

Conclusions

The soil microbiome controls many of the functions of the soil. It is possible, through alternative management practices, to alter the soil microbiome to support helpful organisms, such as arbuscular mycorrhizae, while controlling disease-causing organisms. Preliminary evidence from this study showed a minor change in microbial composition and activity with treatments. However, the unusually hot and dry weather may have compromised the results, as soybean yields were greatly reduced.

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Table 1. Changes in soil nutrients with treatment

Mid-season	Organic matter, %	Potassium, ppm	Mehlich P, ppm	Total N, ppm
Corn stubble	1.9	74.5	23.0	13.4
Cow manure	2.4	150.5	47.3	16.1
Fallow	2.0	66.8	18.5	13.2
Mustard seed	2.1	78.5	23.0	15.6
Plastic film	2.0	62.3	19.5	21.2
Soybeans	2.0	73.8	20.3	12.9

At harvest	Organic matter, %	Potassium, ppm	Mehlich P, ppm	Total N, ppm
Corn stubble	2.0	80.3	27.3	19.6
Cow manure	2.2	160.3	53.0	27.8
Fallow	2.0	60.8	25.8	20.1
Mustard seed	2.0	74.5	29.0	21.8
Plastic film	2.0	60.3	29.0	33.3
Soybeans	2.0	71.8	25.5	19.2

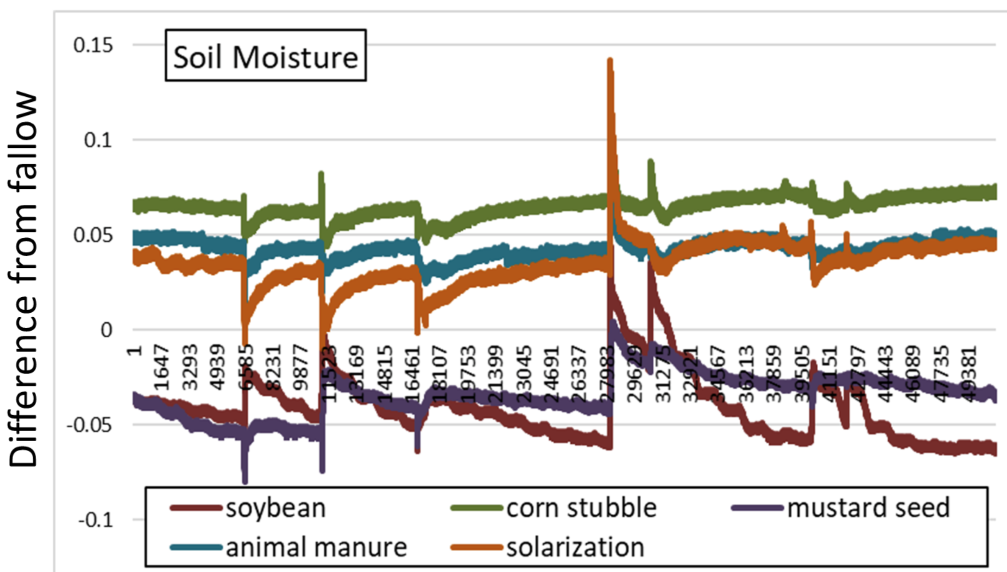

Figure 1. Difference in soil moisture at 2-in. soil depth between fallow and different treatments.

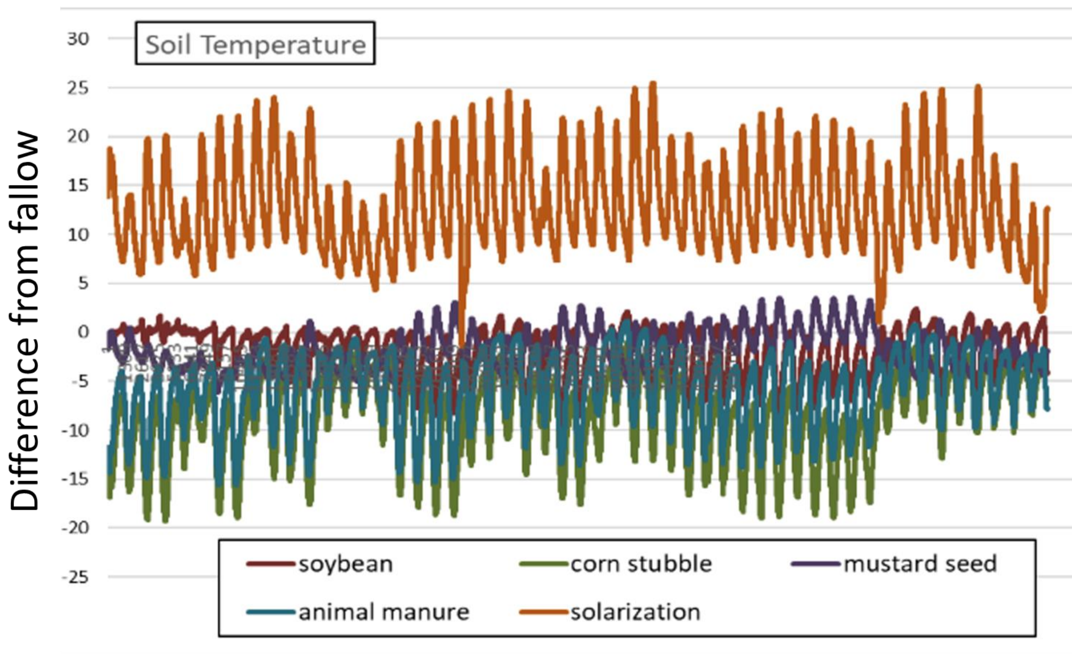

Figure 2. Difference in soil temperature (°F) at 2-in.” soil depth between fallow and treatments.

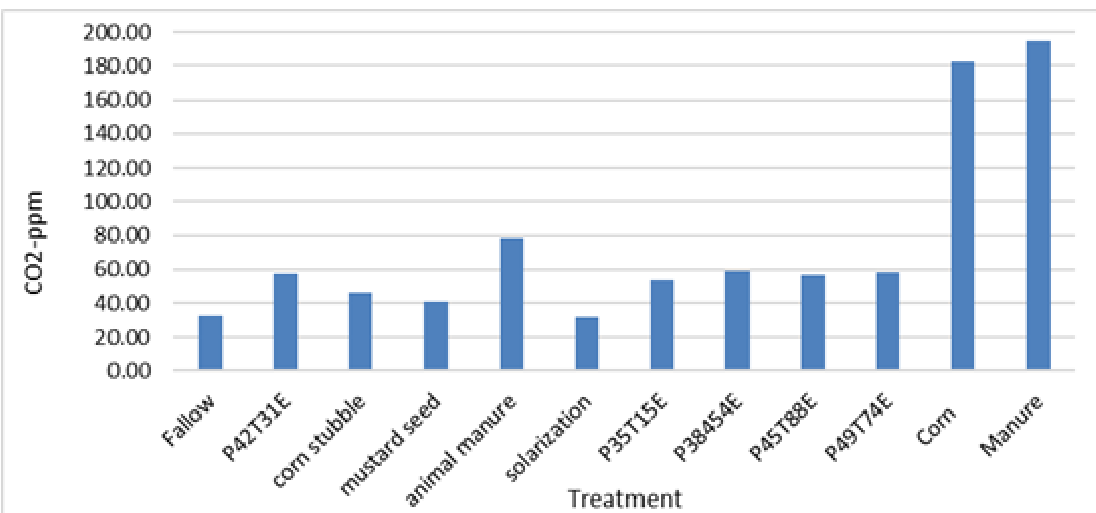

Figure 3. CO_2 burst test for different treatments.