

# BIOAg Project Report

Report Type: PROGRESS

Title: Building Soil Health Resiliency Through Vermicompost Tea Application

## Principal Investigator(s) and Cooperator(s):

PI: Courtney Gardner, Co-PI: Jan Boll, Cooperators: Russ Davis (Organix) and Brian Andersen (Andersen Organics)

## Abstract:

Agricultural intensification to meet the food needs of an increasing global population has placed tremendous pressure on our ability to maintain the health and quality of our soils. More holistic agricultural systems that encourage sustainable waste management and reuse are urgently needed to protect soil health and its roles in food production and security. Vermicompost tea produced by worm-based agricultural waste treatment systems has the potential to simultaneously improve soil and crop health and promote sustainable waste management. We hypothesize that vermicompost tea will improve soil health and onion production by increasing the abundance of beneficial microbes and nutrients in soils following tea application. This research will test this hypothesis by evaluating the distribution of nutrient cycling and plant growth promoting bacteria (Objective 1), onion production (Objective 1), and subsurface nutrient transport (Objective 2) in soils before and after vermicompost tea application.

## Project Description:

The world's population is expected to increase to 10 billion people by 2050, indicating that the burden placed on our natural resources and existing agricultural systems will continue to grow. This situation presents both a wicked problem and equally significant opportunities to reimagine our food production systems, enhance nutrient cycling and efficiency and to increase the positive role agriculture can play in mitigating climate change. The health and quality of our soil resources is a key driver of food production and the ecosystem services that maintain our local, regional, and global environments. Soil health, the physical, chemical, and biological properties that sustain plant and animal productivity, is primarily controlled by land management practices<sup>1-4</sup>. Agricultural intensification to meet the food needs of the global population has placed tremendous pressure on our ability to maintain the health and quality of our soils. Additionally, the traditional nutrient cycle whereby manure and other agricultural waste products are applied to agricultural lands for crop production has become disconnected. There is a critical need to maintain and enhance the quality of our soil resources for future generations. To achieve this goal, more holistic agricultural systems, particularly those that promote healthy nutrient cycling and leverage the natural metabolisms of soil microbiomes, are urgently needed to protect existing soil resources and optimize crop yields.

Vermiculture-based water filtration is a worm-based wastewater treatment systems and is an emerging technology of great interest to diverse agricultural industries including dairies, vineyards, and onion and potato production (Figure 1). The system is capable of simultaneously producing nutrient filtered irrigation water from agricultural waste (e.g., dairy waste, viticulture waste) and producing high-quality byproducts that can be used to enhance soil health and fertility, offering an innovative and potentially

transformative solution to this challenge. Vermiculture-based filtration leverages the metabolic power of worms and microbes during vermifiltration of wastewater. The compost tea (“vermicompost tea”) produced from this process contains macronutrients, micronutrients, and microbes<sup>5-7</sup> taken directly from worm compost and, as a result, has tremendous potential to elevate soil health and support the growth of a wide variety of crops<sup>8,9</sup>. Vermi-processing is likely to be more cost effective and efficient than conventional waste management strategies for dairy manure and other agriculture wastes, which are not easily scalable. Despite its potential, we have an almost complete lack of understanding regarding the positive effects vermicompost tea can have on soil health, which is needed to truly optimize these systems and increase agricultural sustainability<sup>10-13</sup>. Agricultural soils remain black boxes with few insights into the biological and physico-chemical drivers of soil health before, during, and after vermicompost tea applications or how vermicompost tea can increase the land profitability. This lack of knowledge has limited our ability to optimize these systems, improve soil health, and increase agricultural sustainability. Additional research is needed to determine the cause-and-effect relationships among vermicompost tea, soil microbiomes, soil health, and nutrient availability to verify potential benefits to producers and sustainable agriculture.

## Objectives

The goal of our project is to evaluate the ability of vermicompost tea to improve long-term soil health and crop productivity while reducing impacts on water quality. Our guiding hypothesis is that vermicompost tea produced during dairy waste treatment contains nutrients and microbes that directly stimulate soil microbes to enhance nutrient bioavailability and crop development. Our research objectives are:

Objective 1: Examine soil microbiomes as a driver of soil health and onion production following vermicompost tea application

Objective 2: Evaluate nutrient transport in soils and shallow groundwater and the potential risks of nutrient pollution in subsurface water

## Outputs

### Activities:

1. Over the first several months of the BioAg award period, research activities have focused on student mentoring and training, methods optimization, and experimental design for the remaining BioAg award period and beyond. To begin, we have conducted several field sites to Royal Dairy in Royal City, WA to introduce the graduate to collaborators and collect preliminary samples from the vermiculture waste treatment system. To date, we have collected several influent, effluent, and worm beds samples to analyze for microbial community structure and health. Understanding the microbiomes associated with the vermitea production system is critical for understanding and predicting the microbiomes of vermitea itself. We are currently isolating DNA from each sample to characterize microbial community densities using qPCR. We will also assess the abundance of key nutrient cycling bacteria such as nitrifiers and denitrifiers. Future experiments include construction of lab-scale microcosms to assess soil and crop health following vermitea application.

Critically, construction of an on-site vermitea production facility has not yet been completed and as a result, we have been unable to collect vermitea samples for analysis or conducting lab experiments. This has delayed project progress. Based on our communication with Russ Davis, we expect to be able to collect vermitea in early 2023. To overcome this hurdle, we have continued to optimize our experimental methods and experimental plans. This includes optimizing our molecular methods for sample analysis (e.g., DNA isolation, qPCR assay design), which has been completed.

To maintain project progress, we have also expanded the scope of original proposal to include analysis of soil microbial community development and transport following vermitea application. These experiments will be conducted as column studies using three native agricultural soils collected from multiple locations across the Pacific Northwest. To this end, we have performed several experiments to evaluate transport in soils sampled from local agricultural properties and completed pre-modeling analyses for column studies. These activities involved collaboration among all collaborators and student researchers. To begin, soil physical properties were characterized (e.g., analysis for cations, pH, and textural classification). We have concluded preliminary experiments using our collected soils to determine approximate boundary head difference required for replicating realistic flow rates in our soil samples. Using our Yakima silt loam and a dry packing technique we were able to obtain column near-saturation and flows on the order of several ml/min with easily achievable head difference on the order of 1 foot. We have also tested several passive tracers for downstream hydrologic flow characterization, concluding that KBr was the most optimal tracer for these studies. Using results from these preliminary experiments we have designed the specifications for our flow control equipment and are in the process of obtaining same. Once mature vermitea can be collected from Royal City Dairy in 2023, we will begin full scale column experiments. Briefly, these will involve packing the columns with native soils, applying field-relevant volumes of vermitea to 'topsoils', allowing vermitea to incubate and flushing flow-through columns with water to simulate realistic rain and irrigation events. Soil microbial communities will be analyzed pre- and post-vermitea application. Flow through water quality will also be analyzed to evaluate nutrient transport potential.

2. The PI began mentoring one MS student in Fall 2022 who is the primary graduate student currently assigned to this project. The student is pursuing a PhD in Civil Engineering while receiving interdisciplinary training in environmental engineering, biostatistics, molecular biology, and microbiology. The graduate students involved in this project are female and thus belong to a group historically underrepresented in engineering fields, thereby serving as role models to other students in their communities. The PD has also advised one undergraduate researcher that has assisted graduate students in methods development and analysis.

3. The PD is developing a "Environmental Microbes and Sustainable Agriculture" unit into her graduate course in Environmental Microbiology (course number CE584) for Spring 2023. In this course unit, the PD discusses topics covered in the original proposal

such as the role of soil microbes in supporting crop health, environment-microbe dynamics that impact agriculture, sustainable on-site agricultural waste management strategies, vermicompost and vermicompost tea, and a discussion of how soil microbiome assembly and activity remain poorly understood. The unit will be amended throughout the semester, and in subsequent years, to include developing project findings.

## Impacts

- Short-Term: This project will provide immediate insights into the microbiology and nutrient loading of a model on-site vermifiltration system located in Royal City, WA. Insights will include influents, effluents, and worm bed solids collected from the vermifiltration system.
- Intermediate-Term: Future experiments will expand these insights to include vermitea, soils with and without vermitea amendments, and onions without vermitea amendments.
- Long-Term: Long term insights include improved guidance for vermitea application rates and timing. Annotation of vermifiltration and vermitea microbiomes will also provide lasting insights into the biostimulation potential of vermitea (e.g., nutrient cycling activities) and other valorized waste products produced from vermifiltration (e.g., compost). These data may also provide a foundation for predicting vermitea microbiomes based on influent characteristics and vermifiltration system conditions.

## Additional funding applied for/secured:

The PI has applied for and received funding for a project that expand the scope of the current project. This includes funding from the Washington State Applied Bioenergy Appendix A program (Co-PI: Gardner). The PI has also applied for funding under the USDA SBIR program and this proposal is still in review. The PI will also apply for FFAR funding, using results from the current BioAg project as preliminary data.

## Graduate students funded:

This project supports one M.S. student in the department of Civil and Environmental Engineering. This student joined WSU in August 2022 and has an anticipated graduation date of May 2024. This student is female, and thus, belongs an underrepresented ground in engineering.

## Recommendations for future research:

Additional research will focus on continuing analysis of vermifiltration influent, effluent, and worm bed samples. Once vermitea can be collected and transported to WSU, the PI's research team will also conduct future experiments that 1) Use lab-scale microcosms to assess soil and crop health following vermitea application and 2) evaluate microbiome transport and nutrient transport in flow-through columns.