BIOAg Project Report

Report Type: Progress

Title: Quantifying Synergies Among Soil-Based Carbon-Drawdown Approaches

Principal Investigator(s) and Cooperator(s):

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Cooperators: Qualterra (né NuPhY né Ag Energy Solutions, Spokane, WA), Black Farmers Collective (Seattle, WA)

Abstract: Very large quantities of carbon dioxide (CO_2) will need to be removed from the atmosphere over the course of the next century or two to stabilize Earth's climate at a safe temperature. A handful of C-drawdown approaches are available to perform this task, three of which involve soils: increasing stocks of soil organic matter (SOM), making biochar (BC) and storing it in soil, and enhanced weathering (EW) of silicate rocks such as basalt that are rich in calcium, magnesium, iron and other trace nutrients. Current evidence suggests that BC can promote SOM formation over the long term, and that BC and crushed-basalt amendments improve soil fertility. However, no work has addressed the combined impacts of BC and SOM on EW rates in soils, of BC and crushed basalt on the rates of EW and compost maturation during the composting process, of soil amendments with co-composted BC and crushed basalt on crop yield and quality, and of hot CO_2-saturated water, prepared during BC production using waste heat and CO2, on rates of EW of crushed basalt. We hypothesize that these combined impacts will yield significant synergies in terms of crop yield and quality, compost-maturation rate, and total C drawdown by EW. The primary aim of this project is to quantify these synergies.

Project Description: The project is organized into four tasks.

Task 1: In cooperation with Qualterra/NuPhY/Ag Energy Solutions, measure EW rates during BC production using CO2-saturated water warmed by BC-process heat.

Task 2: Measure composting efficiency and EW rates during ambient-temperature co-composting experiments with BC, crushed basalt, and their combination.

Task 3: Measure crop yield and quality, and EW rates, in small greenhouse/field trials involving BC, crushed basalt, compost, and the co-composted products. Determine EW rates by the amount of inorganic C (soluble bicarbonate, solid carbonate) formed during the experiment.

Task 4: Estimate total C drawdown of various scenarios by a life cycle analysis.

Undergraduates and urban interns from under-represented minorities will perform much of the work. Results will be summarized in a formal report and submitted for publication.

Outputs:

- *Overview of Work Completed and in Progress*:
  Tasks 1 and 2 are mostly complete, Task 3 is 70% complete, and Task 4 has not yet started. A summary of each task follows.

- Task 1—We completed the experimental basalt weathering runs using bottled CO_2 and the apparatus described in last year's progress report. Unfortunately, because we were unable to gain access to the equipment needed for basalt comminution and pre-heating, experiments to test the impact of these parameters on weathering rates were not conducted. The final basalt weathering runs were completed in late March and early April 2022 to generate sufficient weathered basalt for use in Tasks 2 and 3. Samples of the basalt suspensions were gathered at various stages of the experiments and archived for determination of total alkalinity and total carbonate solids. These determinations are the last portion of the work in Task 1 that needs completion.
- Task 2—We prepared 12 1.5-cubic yard compost reactors designed to allow collection of leachates for alkalinity testing. The experiments involved four treatments (regular compost, and this treatment amended with 10% of biochar, weathered basalt, or a combination of biochar and weathered basalt) each replicated three times. Feedstock for the compost was chipped yard waste from a municipal source. We started the experiments during the first week of April, turned the compost once three weeks later, and terminated the experiments at the end of May. Temperature data, bulk compost, and leachate samples were collected from all 3 reps during the experiment. Because the Doug Collins was scheduled to be on sabbatical starting at the end of June, logistics dictated that only 1 rep for each treatment be screened at the end of the experiment to provide material for Task 3. Bulk compost samples were archived and together with the leachate samples await analysis.
- Task 3—This task involved two plant-growth experiments, one performed by the Black Farmers Collective (BFC) in Seattle using 5-gallon pots outdoors, and the other performed by the Horticulture Department (WSU-Hort) using 3-gallon pots in greenhouse facilities located on the Pullman campus. Both trials were with tomatoes but started late in the season. The BFC experiment was completed in the Fall, and fresh matter yield data were collected. Tomato starts for the WSU-Hort experiment were transplanted the 2nd and 4th weeks of September and the nominal 16-week experiment will continue into January 2023. Pot leachate samples were (and continue to be) collected, their pH and electrical conductivity measured, and then archived pending analysis for alkalinity by the University of Idaho Analytical Sciences Laboratory after the plant growth study is complete.
- Task 4—The LCA algorithm has been developed. Completion of the task awaits collection of all the total carbonate and alkalinity data from the 3 tasks.

- *Methods and Results*:

  Task 1—In the final production runs, we weathered as-received basalt for 48 h in deionized water at 25°C using ~15% (by volume) beverage-grade (99.9% purity by volume) CO2 diluted in air. A total of 120 kg of basalt was weathered in 6 separate runs. Each run was conducted using 2 reactors, each containing 10 kg of basalt and receiving about 77 cubic feet per hour of the 15% CO2 mixture (Fig. 1). Levels of CO2 were constantly monitored using a Model CM-0019 non-dispersive infrared sensor (0-30% range, 0.3 vol% nominal accuracy) and datalogger (https://www.CO2meter.com). Two 20-mL representative samples of the basalt suspension were collected at the start and end of each run for subsequent determination of solid carbonate content and aqueous alkalinity.

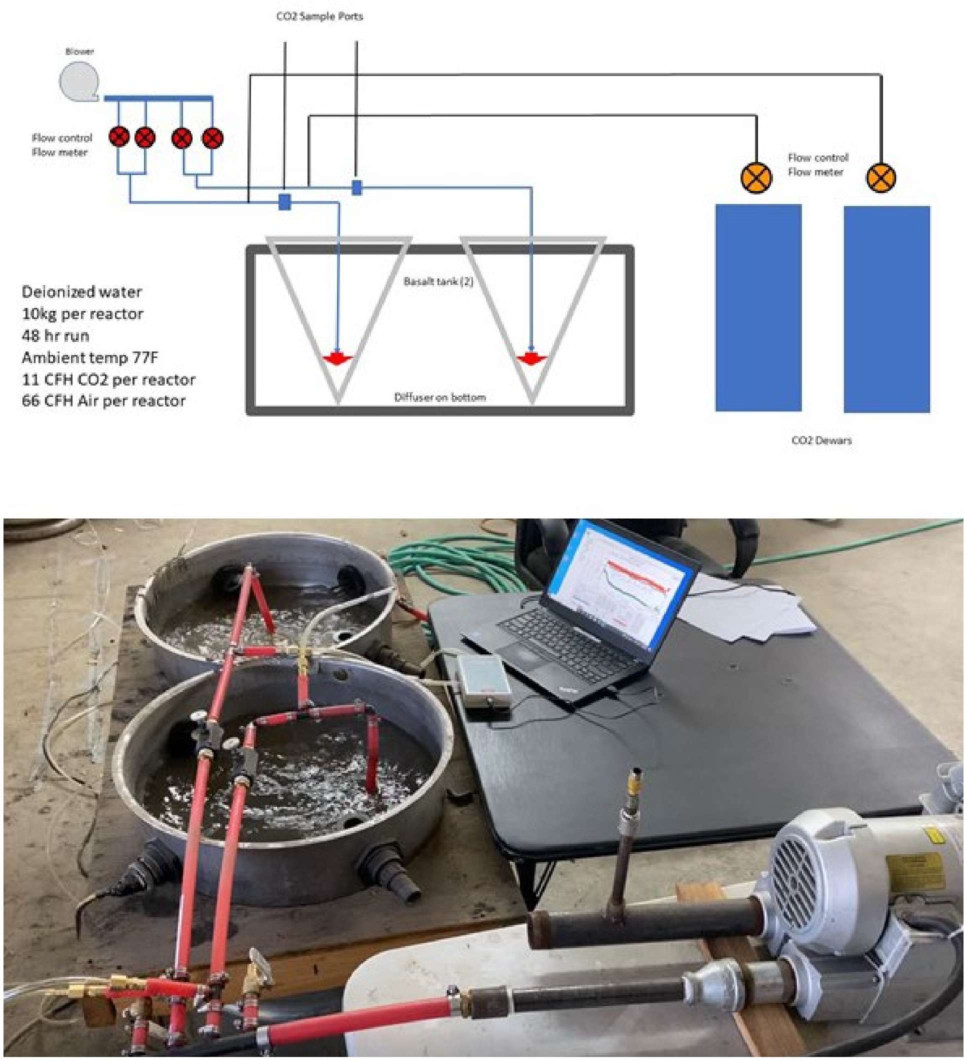

Figure 1. (top) Schematic of experimental set-up for weathering of basalt to be used in Tasks 2 and 3; (bottom) The weathering system in operation (schematic and photograph by David Drinkard)

Task 2—The compost experiments were started on 5-7 April 2021 (one replicate set of treatments on each day), turned on 25-27 April, and terminated on 23-25 May. Sensors inside each reactor recorded temperature continuously during the experiment. The compost reactors were a modified version of the reactors used by Bramwell et al. (2020 WSU Extension Tech Bulletin 71E https://pubs.extension.wsu.edu/utilizing-buckwheat-and-sudangrass-cover-crops-as-feedstock-in-aerated-static-compost-piles) and had a sloping floor design to allow collection of leachates (Fig. 2). Leachate samples were collected twice before the compost was turned. Due to the sloping ground on which the reactors were placed, the orientation of the reactors made a difference in the amount of leachate collected. Because low amounts of leachate were obtained for several reactors during the first collection (12 April) we re-oriented the reactors and added 5 gallons of tap water to each reactor on 18 April before collecting a second set of leachates on 20-21 April. Leachate samples were stored at 4°C pending pH/alkalinity analysis. We also collected bulk compost samples at the start, at turning, and at the end of the experiment. The initial and final compost samples were frozen, whereas the samples collected during turning were stored at 4°C pending analysis for C:N ratio, etc.

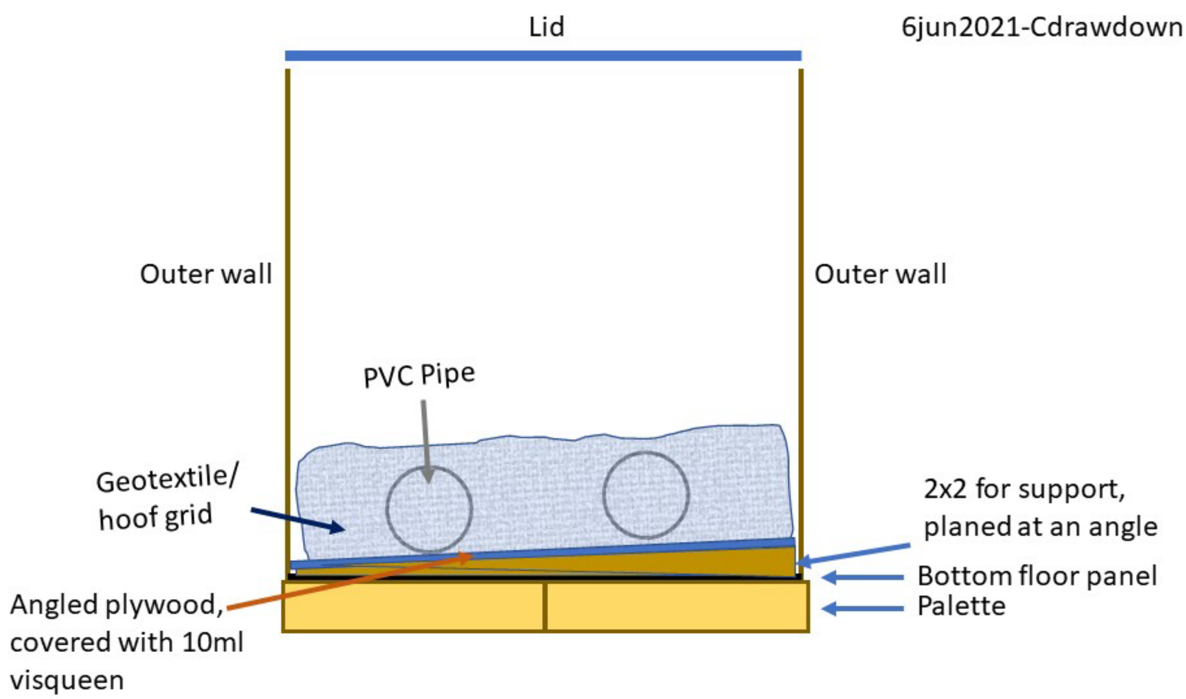

Figure 2. Schematic of compost reactor design with leachate collection capability.

Task 3—The treatments in the plant-response trials consisted of 6 soil amendment combinations and an unamended control. The amendments include compost, biochar, weathered basalt, co-composted biochar, co-composted weathered basalt, and co-composted biochar+weathered basalt. These amendments were made at ~10% by volume into potting soil. Both trials used determinate tomato varieties (*FL-17* at the BFC, *Oregon Spring* at WSU-Hort).

Each treatment in the BFC field trial was replicated 5 times. The sole data set generated contained the final fresh weights of the above-ground biomass (i.e., tomato plants including fruit) at harvest. The results (Fig.3) show a response of the tomato plants to all soil amendments, but no significant difference (P = 0.11) among the treatments.

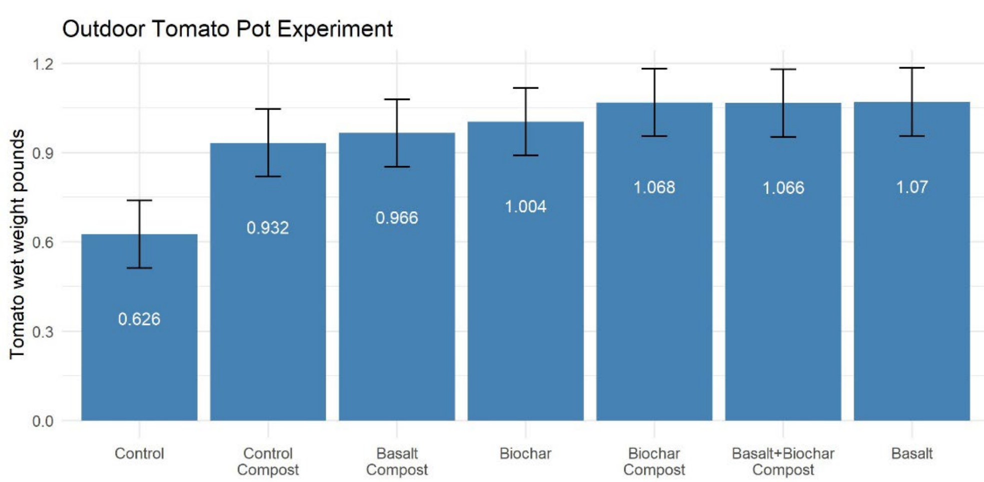

Figure 3. Total fresh weight of tomato plant biomass (including tomatoes) at harvest for the BFC field trial. Error bars are standard error of the mean (SEM) calculated from pooled error variance

In the WSU-Hort greenhouse study, two potting soils were used, Soil 1 for the composted amendments and Soil 2 for the un-composted biochar and weathered basalt, requiring two unamended soil controls. Tomato seedlings (Oregon Spring) were transplanted into 5-gallon pots containing the soil/amendment. Each treatment was replicated in 10 pots, for a total of 80 experimental units. Tomato seedlings were transplanted into the 50 pots with Soil A on 9 September 2022; the 30 pots with Soil B received seedlings on 23 September 2022. Pots were randomly located in the greenhouse (Fig. 2, left).

Figure 4. (left) Placement of tomato plants in the WSU-Hort greenhouse experiment; (center and right) collecting leachate samples and consolidating them in 250-mL bottles for each treatment

The WSU-Hort greenhouse study was designed to measure the differences in plant response (tomato yield and quality) as well as C-drawdown potential (as measured by alkalinity of water leached from the pots) associated with the soil amendments. Thus, watering levels were generally higher than normal to ensure the generation of sufficient leachate volumes for measurements of alkalinity, pH, and specific conductance. Once a week, exactly 1.5 L of greenhouse tap water was added to each pot and the leachate collected in a plastic tray beneath the pot (Fig. 3). The total volume of leachate from each pot was measured and 20 mL of the leachate was pipetted into a 250-mL glass bottle designated for that pot's treatment (Fig. 2, center and right). After all leachate samples had been collected, the 8 leachate bottles (one for each treatment and containing a maximum of 200 mL each) were then taken to the WSU-Hort wet laboratory. In the laboratory, a 50-mL aliquot was transferred to a 50-mL polypropylene centrifuge tube, which was tightly sealed and stored at 4°C for later determination of alkalinity by the University of Idaho Analytical Services Laboratory. Portions of the remaining leachate were analyzed immediately for specific conductivity and pH.

Figure 5. (top) Plastic trays used to collect pot leachate samples; (bottom) close-up view of leachate tray under pot

Midway through the WSU-Hort greenhouse study, some of the tomato plants in the Soil 1 group developed blossom rot. To try and counter this problem, the 09 November 2022 sampling used water that was 10 mM in $CaCl_2$ as the leaching solution. On 08 December 2022, harvesting of the tomato plants in the Soil 1 group was initiated.

Preliminary results of the WSU-Hort greenhouse study, which is still in progress, show high variability week-to-week in the average leachate volume collected (Fig. 4, left). This variability most likely reflects conditions inside the greenhouse rather than differences in the age of the tomato plants, as trends are similar for the two Soil groups even though they were separated by 2 weeks in age (data in Figures 4 and 5 are plotted in terms of the Soil 1 group age). Although the trends are similar, the leachate volumes for the Soil 2 group are consistently larger than for the Soil 1 group indicating a difference between the two soils. Initially, the leachate pHs were low (~ 6), but they increased during the experiment to approach the pH of the tap water used for leaching after ~75 days (Fig. 4, right). Notably, the pH of the co-composted basalt treatment is consistently higher than the other treatments during the first two months of the study. The specific conductivity of the leachates starts high (near 2000 umho cm^{-1}) and decreases steadily during the first 60 days to approach that of the tap water used for leaching (Fig. 5). Measured conductivity for Soil 2 treatment group is generally lower than for the Soil 1 treatment group, again indicating a difference between the two soils. The initial harvest data for the Soil 1 treatment group suggest that all compost-related treatments yield comparable or higher production than the unamended soil. Among the amended soils, the co-composted biochar treatment seems to yield the lowest number of tomatoes per plant and total tomato weight per plant but the highest Brix sugar measurements. Statistical analysis of the final numbers will be performed to ascertain whether these differences are significant.

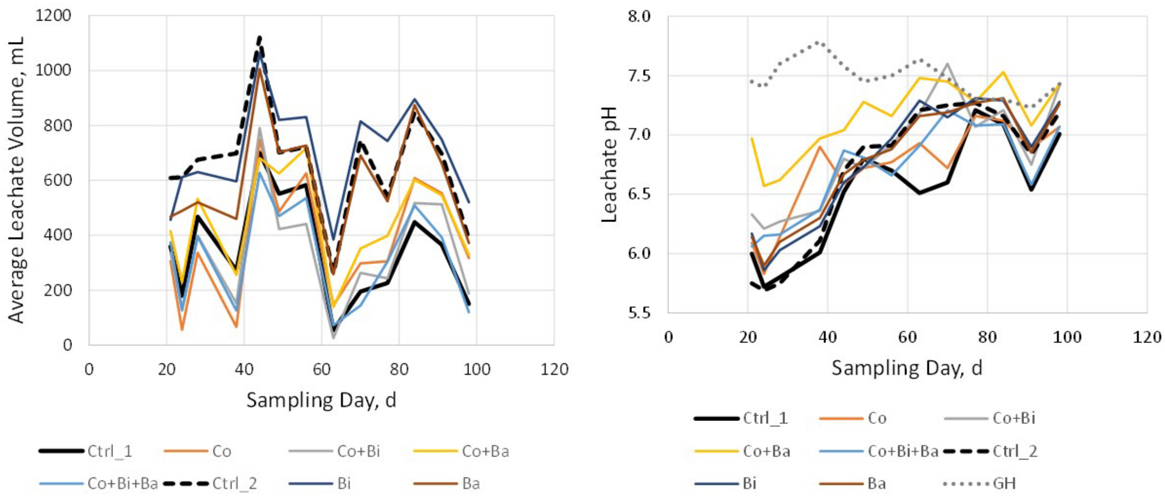

Figure 6. (left) Preliminary mean volumes of leachate collected per pot for each treatment; (right) mean leachate pH values measured per treatment. Sampling days are days after tomato seedlings were transplanted in the Soil 1 group.

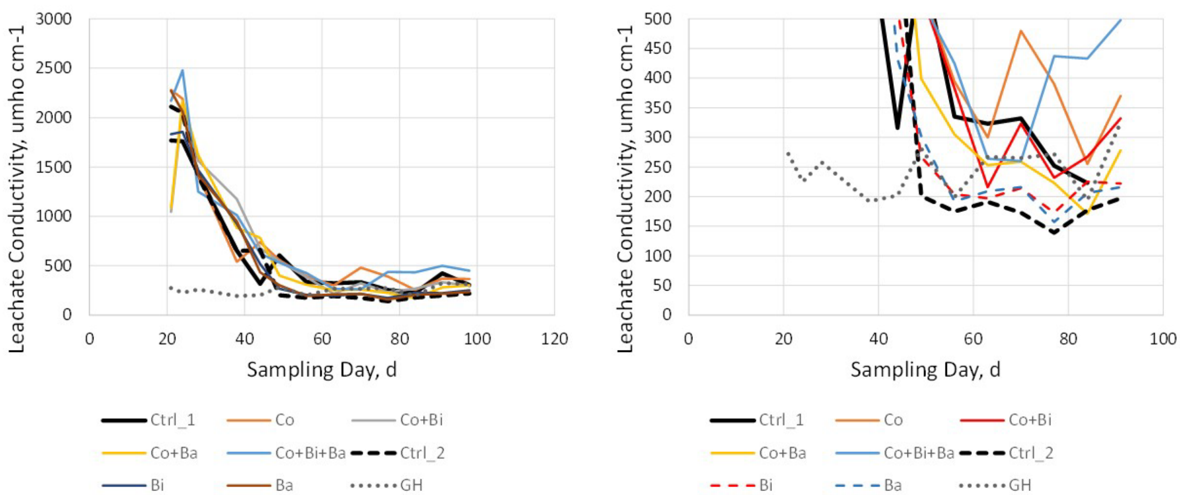

Figure 7. (left) Preliminary mean leachate specific conductivity data for each treatment and for greenhouse tap water used to leach pots (GH); (right) same data with expanded y-axis to show details. Sampling days are days after tomato seedlings were transplanted in the Soil 1 group.

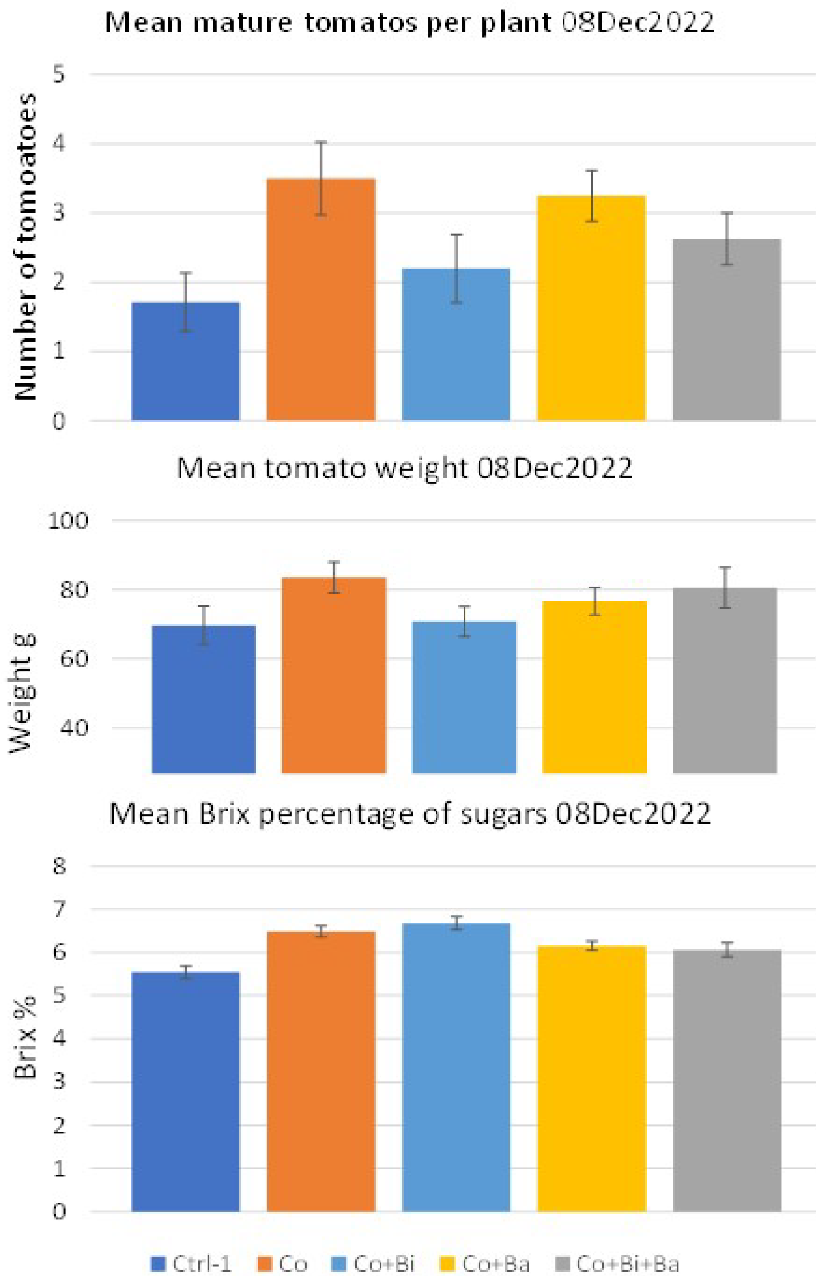

Figure 8. Preliminary harvest results for Soil 1 group of treatments. Data collected 90 d after tomato seedlings were transplanted.

- *Publications, Handouts, Other Text & Web Products*: None.
- *Outreach & Education Activities*: None.

Impacts

- Short-Term: None.
- Intermediate-Term: None.
- Long-Term: None.

Additional funding applied for/secured:

The USDOE_STTR grant application by Ag Energy Solutions submitted in November 2021 and entitled "Carbon Capture by Biochar using Enhanced Carbonate Formation" was not selected for funding. However, a second grant application to the Washington State Department of Commerce in June 2022 led by Myno Carbon Corp in partnership with WSU-CSANR and PNNL was selected for funding. This project, which is entitled "Feasibility Assessment for Utilizing Biomass Energy and Biochar Waste Heat and CO2 for Carbon Capture, Utilization, and Storage via Crushed Basalt Mineralization and Other Pathways", is a direct offshoot of the work funded by BIOAg in Task 1 of the current BIOAg project. The WA-Commerce project started in July of 2022 and runs through June 2023. The WSU-CSANR portion of the project is funded at $50K.

Graduate students funded: None.

Recommendations for future research: None currently, but we expect the final report will highlight several recommendations based on the full set of results.