Effects of Wood-based Compost on Soil Health Indicators in an Organic Loam

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ABSTRACT

The contribution of organic matter to soil health has been identified in soils around the world and widely researched in terms of its effects on soil physical, chemical and biological characteristics. However, there is still much to learn when it comes to cultivating favourable environments in which a diversity of microbial populations thrive. Wood compost sources natural to the West Coast may hold the potential to boost soil microbial populations and enhance soil health. First Nation's ingenuity has fuelled their knowledge of naturally available materials since time immemorial and has allowed the selective cultivation of foods, fibres and medicines without a reliance on synthetic or imported inputs (Deur & Turner 2005). We follow their lead in mimicking the natural systems operating in our environment and aim to replicate the fertile ecosystems provided by nurse logs in our mighty coastal forests. We used a completely randomized design to compare a commercially available compost with a wood-based compost to determine their potential for enhancing soil microbial populations and soil health. Our methods included a metabolic measure of soil respiration, a determination of active carbon, a comparison of dry-weight shoot biomass of lettuce transplants and a count of fungal colony forming units in an organic loam soil. Our results indicated that despite significantly boosting active carbon in the soil and subsequently supporting larger microbial populations, and a higher fungal colony frequency, the wood based compost inhibited plant growth. This was likely due to nitrogen tie-up as a result of an excessively high C:N ratio. Further research is needed to reveal if wood based composts may be beneficial when used in combination additional N inputs. However, by establishing a locally available alternative to conventional compost, farmers may be compelled to adapt sustainable woodland management as a means of providing essential nutrient inputs while also improving the condition of the soil for supporting microbial life. This study aimed to connect the wisdom found in nature's systems with our potential to enhance soil health in managed agricultural landscapes with practices that go beyond simply organic methods.

Keywords: wood compost, soil health, fungal colony forming units, soil respiration, active carbon

PROJECT PROPOSAL

INTRODUCTION

Ecosystem Services

Living soils serve as a fundamental provider of ecosystems services. Their health and biodiversity directly allow for our well-being, long-term economic viability and the entirety of our environmental capital (Wall et al. 2012). Several international agreements have strived to protect this vital part of our biosphere including the United Nations Convention to Combat Desertification, the Convention on Biodiversity, and the Intergovernmental Panel on Climate Change. Yet, despite the multiple solutions and reliable scientific evidence our soils face degradation at an alarming rate (Wall et al. 2012). As time passes we further erode the earths ability to regulate carbon storage and greenhouse gas fluctuations, form new soils and maintain soil fertility, balance pest and disease populations, provide decontamination and bioremediation capabilities and serve as habitat and food for ourselves and the rest of the wild earth (Wall et. al. 2012). Addressing these environmental challenges reaches a true sense of urgency when realized in the context of increasing human populations, climate change and the increasing threats of insufficient water supply and fertile land. By increasing our understanding of the complexity of the soil ecosystem and how our management actions affect it, we reveal an opportunity to reverse the damages and perhaps revive resilient local agricultural networks, better integrated with the natural world.

Defining Soil Health

Soil quality has been defined as “the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health”(Doran and Parkin 1994). Soil quality is often used interchangeably with soil health, with the latter portraying more accurately the dynamic system of living organisms requiring both careful conservation and appropriate management (Bonilla et al. 2012). Consequently, evaluating soil health involves understanding a multifaceted set of processes and properties that work together to indicate a combination of physical, chemical and biological characteristics. Several indicators are often measured including the structural stability of aggregates, the water retention capacity, the capability of nutrient cycling, the ability to store organic carbon and the ability to naturally suppress soil-borne pathogens (Bonanomi et al. 2010). There is some disagreement over which combination of soil indicators best reflects the true health of the soil and perhaps it depends on the intended focus of attention (Meobius-Clune et al. 2016, Wall et al. 2012). However there is agreement on the key elements contributing to healthy soils, the most important of which relates the quality and quantity of organic material added. Organic matter plays a fundamental role in aggregate formation and is essential to creating the complex porous structure that supports a vast diversity of soil biota. It includes animal, plant and microbial residues in varying stages of decomposition along with deceased root hairs, fungal hyphae and animal corpses (Whalen and Sampedro 2010). The application of organic amendments has been directly related to an increase in biomass in multiple groups of soil organisms and changes in the community composition (Bonilla et al. 2012, Treonis 2010). In many cases organic soil amendments have increased measures of soil respiration, an indicator of total microbial activity (Bonilla et al. 2012). Furthermore organic amendments have proven beneficial in suppressing soil-borne plant diseases by reducing pathogen density and increasing populations of antagonistic micro-organisms (Garbeva et al. 2004). The development of suppressive soils, defined as those in which “the pathogen does not establish or persist, establishes but causes little or no damage, or establishes and causes disease for a while but thereafter [becomes] less important” (Baker and Cook 1974) indicates the effectiveness of pathogen inhibition as result of competition for resources commonly known as the general suppression mechanism (Bonilla et al, 2012). Although not all the mechanisms of disease suppression have been worked out, there is undoubtedly a link to changes in soil microbial community structure and thus an importance in furthering our understanding of these interactions (Garbeva et al. 2004, Wall et. al, 2012).

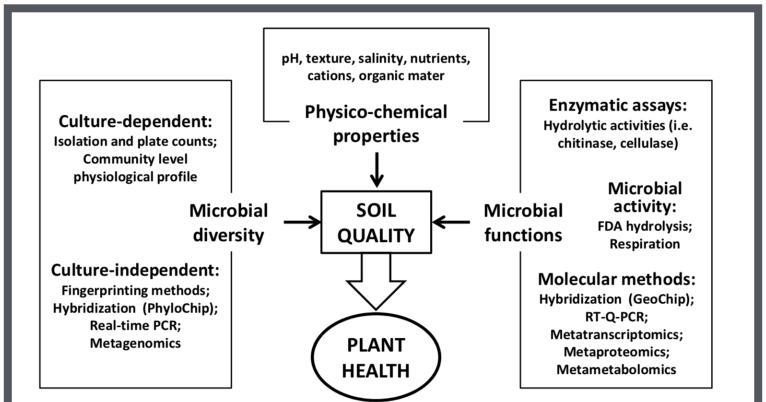

Figure 1. Parameters affecting soil quality and associated methodologies for their assessment (Bonilla et al. 2012)

The Focus on Soil Organisms

In recent years more attention has been given to the microbial community which has proven particularly responsive to changes in the environment while playing a major role in organic matter decomposition, maintenance of soil structure and pathogen suppression (Bonanomi et al. 2010). *Trichoderma* has been of special interest as an indicator of soil health because of its complex symbiotic relationship with plant roots, worldwide distribution and promising characteristics as an antagonistic fungi (Adnan et al. 2019). The benefits associated with *Trichoderma* include increased shoots and foliar growth, increased plant biomass, improved fruit production and exploration capacity of the root system and improved tolerance to water deficit (Donoso et al. 2007). Its presence has become an indicator of suppressive soils and has increasingly been the focus of a multitude of bio-control applications (Bonilla et al. 2012). Individual strains may also produce antibiotics (Harman 2011), create competition for nutrients and niches, activate plant defences, exhibit parasitism, predation and hydrolytic activities. However the contribution of each mechanism varies by disease (Bonilla et al. 2012). Although the enhancement of soil suppressiveness through the application of soil amendments has been widely described, especially for plant diseases, there is great variability in the effectiveness of suppression depending on the amendment, crop, pathogen and environmental conditions (Bonilla et al. 2012). Further research is needed to truly understand how increasing the abundance of beneficial organisms can be achieved through on farm practices and practical applications of available resources.

C:N Ratio and Feeding Soil Organisms

Ultimately the creation of soil organic matter and the suppressive mechanisms described above rely on an abundant microbial community which are fed in part by the organic inputs we provide. However, microbes require a specific diet which must be considered when evaluating the quality of the inputs we select. The ratio of the mass of carbon in a substance to the ratio of nitrogen is known as the Carbon to Nitrogen ratio (C:N)("C:N ratio USDA", 2011). This ratio impacts residue decomposition and the subsequent availability of nutrients for crop growth (see Figure 3). It is particularly important when thinking of our organic inputs as sources of feed for the microbial community because they must acquire enough carbon and nitrogen from the environment to maintain a ratio of near 8:1 in their bodies. The carbon is not only an energy source for the microorganisms but a product of their respiration lost as CO_2("C:N ratio USDA", 2011). In order to stay alive, enough carbon must be available for body maintenance and energy which typically translates to diet with a C:N ratio of 24:1 (16 parts for maintenance and 8 for energy). When food stuffs are added to the soil with a particularly high C:N ratio (lignin-rich, woody plant material), the microbes utilize nitrogen from the soil to balance their diet. This nitrogen tie up is called immobilization and creates a nitrogen deficit in the soil until their bodies decompose and release the nitrogen again through the mineralization process("C:N ratio USDA", 2011). This slowed decomposition may however be beneficial as decomposition must be slower than organic matter inputs in order to produce soil organic matter over the long term (Paul, 2016) .

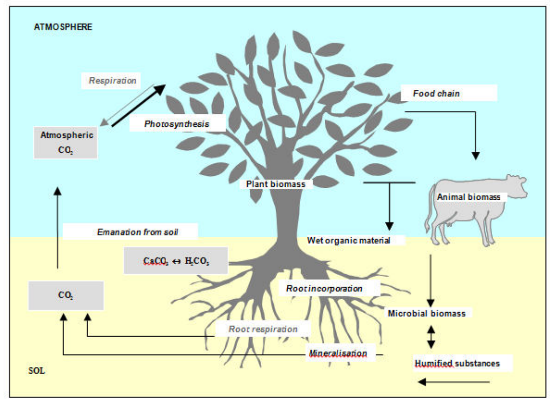

Figure 3. Carbon Cycle in soil-plant-animal systems ("Carbon-14 and the Environment", 2012)

OBJECTIVES

We hypothesized the application of wood-based compost would increase fungal colony frequency, measures of active carbon and microbial soil respiration while maintaining biomass production when compared with a commercially available organic compost and control. Shoot dry-weights were used to determine whether plant biomass was affected, soil respiration was used as an indicator of the total microbial life in the soil, while active carbon was used to quantify the energy source readily available to the microbial community. Enumeration of colony forming units (CFU) with a *Trichoderma* specific agar were used to determine whether compost choice impacted the frequency of *Trichoderma* colonies. However, no *Trichoderma* spp. were identified and a comparison of fungal colony forming units was evaluated instead. Our objective was to determine wether the application of wood compost enhanced soil microbial life (specifically *Trichoderma* spp.*),* while promoting healthy plant growth.

METHODS

Experimental Design and Study Locations

The experiment followed a completely randomized design with 3 treatments and ten replicates. The randomization scheme was generated using statistical software R (Figure 4). The lettuce transplants were selected for comparable size from a 128 tray. Lettuce was used because it is genetically homogenous, fast growing and visibly responsive to variable conditions. The trail took place in the passive solar dome located on KPU's Research & Teaching Farm at Garden City Lands in Richmond, BC. Lab analysis was completed in the Soils Lab at KPU Richmond Campus and the Institute for Sustainable Horticulture (ISH) in Langley, BC.

O1	W1	O2
C1	C2	O3
W2	C3	W3
O4	W4	C4
O5	C5	W5

O6	W6	C6
O7	C7	W7
O8	W8	O9
C8	C9	O10
W9	C10	W10

Figure 4. The randomization scheme and experimental set up

Experimental Treatments

Each experimental unit was composed of a 4" pot of soil and a lettuce transplant (cv. 'Hampton'). The compost treatment was amended with 25% (volume basis) commercial yard waste compost (Class A Boost Class A, Net Zero Waste, Abbotsford, BC), the wood treatment was amended with 25%(volume basis) wood-based compost (made from 5-10mm red alder shavings combined 50:50 with grass clippings and aged underground for 45 days) and the control had no amendment.

Data Collection Methods

The bulk soil was collected from a single bed on an organic vegetable farm (Friesen Farms, Langley, BC). A sub-sample was analyzed to determine fungal CFU counts, soil respiration and active carbon at ISH at the start of the trial. After two weeks, 'Hampton' green leaf lettuce transplants of uniform size were transplanted from sterile potting mix in a 128 tray to the 30 experimental units. During the 7 week growing period the replicates were evenly watered and the lettuce transplants were photographed and monitored for signs of stress. Observational notes and photographic records were kept weekly. At the end of the trial period the lettuce transplants were removed from each sample and oven dried for 24-48hrs to determine dry-weight shoot biomass in the Soils Lab. Soil samples from the rhizosphere were collected, air-dried in the Soils Lab and then analyzed at ISH for soil respiration, active carbon, and fungal CFU counts.

Enumeration of colony forming units is an important quality parameter. Colony forming units or CFUs refers to the estimated measure of cells that were able to grow colonies under the conditions of the test (temperature, time, media, available oxygen ect.). A Trichoderma-selective agar medium (Elad et al. 1981) was intended to quantify the frequency of *Trichoderma* spp. in the soil. However, no *Trichoderma* spp. could be identified and fungal units were quantified instead following protocol 2.21 Soil Dilution Plating (Tabert, 2019). The day 4, [1:100] plates were most suitable for manual eye-counting and were used for the analysis of fungal colony forming units.

Active carbon served as an indicator of the readily available food and energy sources of the microbial population in the soil. It has been directly correlated with particulate organic matter (POM) but without the complex procedure for measurement. Furthermore active carbon has been correlated with percentage organic matter, aggregate stability and respiration (Moebius-Clune et al. 2016). The protocol was adapted from the Cornell University Comprehensive Assessment of Soil Health Laboratory Standard Operating Procedures ((Moebius-Clune et al. 2016).

Respiration measures the metabolic activity of the soil microbial community by capturing and quantifying carbon dioxide (CO_2) produced from a re-wetted sample of air dried soil sealed in an airtight container for 4 days. The greater the evolved CO_2 release, the larger the microbial community. Soil respiration is a rapid, low-cost measure of the microbial activity in the soil. It lends insight to the ability of the microbial community to breakdown organic residues, storing, buffering and mineralizing nutrients so they become available to plants and other organisms (Moebius-Clune et al. 2016, Zilbilske 1994). The protocol was adapted from the Cornell University Comprehensive Assessment of Soil Health Laboratory Standard Operating Procedures ((Moebius-Clune et al. 2016).

Dry weight was used to avoid the pitfalls of fresh weight variability caused by environmental conditions. The protocol was adapted from University of Idaho's Principles of Vegetation Measurement & Assessment and Ecological Monitoring & Analysis guide (Launchbaugh 2009). The lettuce transplants were removed from the soil and cut to separate the root and shoot portions, then placed in paper bags. All samples were dried simultaneously in a forced-air oven set to low heat (70° F) for 48 hours until their weights stabilized. Each sample was then weighed on a milligrams scale and recorded.

Statistical Analysis

Data were tested for normality using the Shapiro-Wilk test. ANOVA was used to test for treatment effects. Means were separated by Tukey's Honest Significant Difference Test. All analysis employed the jamovi interface (The jamovi Project, 2019) for the R statistical computing environment (R Core Team, 2018), with alpha = 0.05 maintained throughout.

RESULTS & DISCUSSION

Active Carbon

More active carbon was found in the two treatments amended with compost than in the unamended soil or the bulk soil sample (Figure 6, Table 1). Because active carbon was not higher in the control treatment than in the bulk soil sample, the increase in active carbon was attributed to the compost amendment rather than the exudates and root interactions from the lettuce.

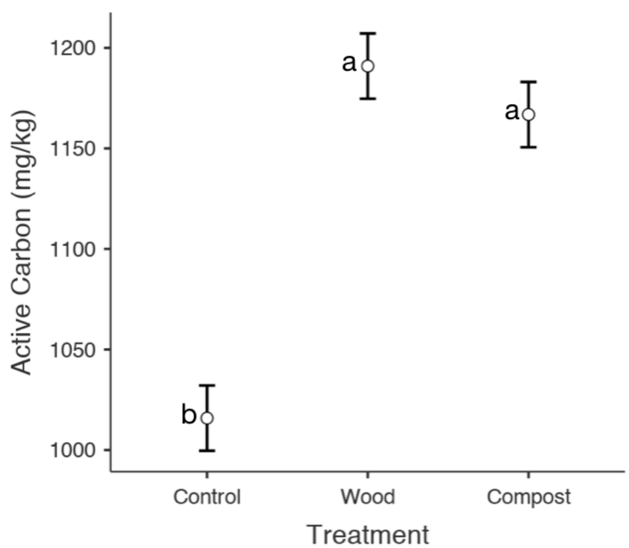

Figure 6. Active Carbon in soil teated with different soil amendments (control, wood-based and commercial organic compost). Error bars denote standard error of the mean (n=10) Means labelled with the same letter do not vary significantly (α = 0.05).

Estimated Marginal Means - Treatment

			95% Confidence Interval	
Treatment	Mean	SE	Lower	Upper
Control	1016	16.2	983	1049
Wood	1191	16.2	1158	1224
Compost	1167	16.2	1133	1200

Table 1. Estimated marginal means for active carbon showing standard error in soil teated with different soil amendments (control, wood-based and commercial organic compost).

Soil Respiration

Soil respiration was higher in the compost treatments than in the untreated control or bulk soil sample, and higher in the wood compost treatment than in the organic compost treatment (Figure 7, Table 2). Soil respiration has been positively correlated with active carbon. It indicates soil microbial activity associated with organic matter decomposition, an essential part of soil nutrient cycling that supports plant growth. Differences in soil respiration could be attributed to the compost inputs rather than the lettuce transplants (Figure 7, Table 2). The wood compost likely had a higher C:N ratio than the organic compost, resulting in slower initial decomposition. Short-term impacts could include nitrogen demobilization, while long-term benefits might include higher water holding capacity and reduced susceptibility to erosion. In the long term, inputs of carbon-rich materials improve soil fertility and quality. The organic compost likely had a more balanced C:N ratio, resulting in an earlier increase in fertility with longer-term benefits to soil structure ("Soil Respiration NRCS, n.d.).

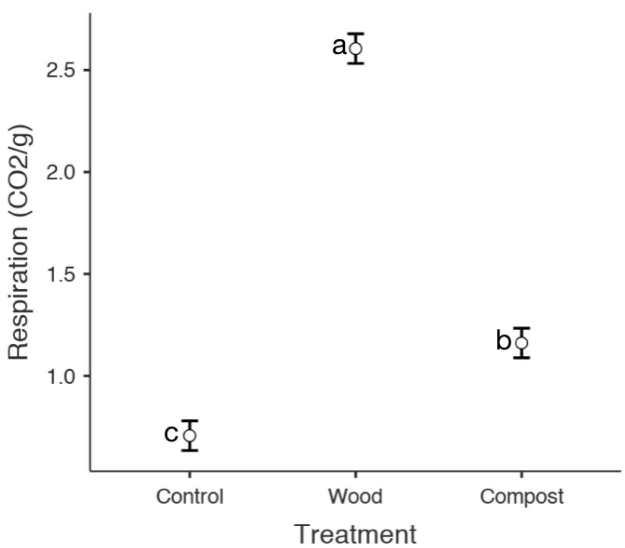

Figure 7. Soil Microbial Respiration in soil teated with different soil amendments (control, wood-based and commercial organic compost). Error bars denote standard error of the mean (n=10) Means labelled with the same letter do not vary significantly (α = 0.05).

Estimated Marginal Means - Treatment

			95% Confidence Interval	
Treatment	Mean	SE	Lower	Upper
Control	0.707	0.0726	0.558	0.856
Wood	2.605	0.0726	2.456	2.754
Compost	1.161	0.0726	1.012	1.310

Table 2. Soil microbial respiration showing standard error in soil teated with different soil amendments (control, wood-based and commercial organic compost).

Fungal CFU Counts

We relied on the day 4, 1:100 concentration plates to minimize human-caused experimental error during manual counting. The wood-based compost had more soil fungi than other treatments (Figure 8, Table 3). No *Trichoderma* spp. were identified among the fungi. Our results indicate that wood based compost may in fact boost fungal populations in the soil but did not provide evidence for practices that could enhance populations of *Trichoderma*. However, we were able to see connections between increased active carbon, increased soil respiration and increased fungal CFUs when the wood based compost was compared with the control.

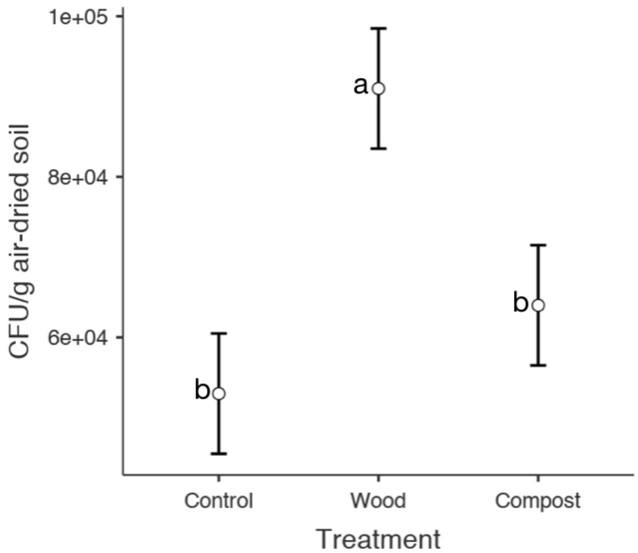

Figure 8. Fungal CFU counts (CFU/g air-dried soil) in soil teated with different soil amendments (control, wood-based and commercial organic compost). Error bars denote standard error of the mean (n=10) Means labelled with the same letter do not vary significantly (α = 0.05).

Estimated Marginal Means - Treatment

			95% Confidence Interval	
Treatment	Mean	SE	Lower	Upper
Control	53000	7488	37635	68365
Wood	91000	7488	75635	106365
Compost	64000	7488	48635	79365

Table 3. Estimated marginal means for fungal CFU counts (CFU/g air dried soil) in soil teated with different soil amendments (control, wood-based and commercial organic compost).

Shoot Dry-weight Biomass

Dry weight of lettuce shoots was higher in the commercial compost treatment and lower in the wood compost treatment than in the control (Figure 9, Table 4). Despite its potential benefits to the soil microbial populations, the wood-based compost inhibited plant growth in the short term, perhaps due to N-immobilization. Plants in the wood compost and control treatments exhibited chlorosis on their outer leaves during the first four weeks after transplanting, suggesting N deficiency. In the final three weeks of the trial, plants in wood compost treatment recovered from chlorosis but the larger plants in the commercial compost treatment exhibited stress symptoms (bolting and necrosis) suggesting they were becoming pot-bound.

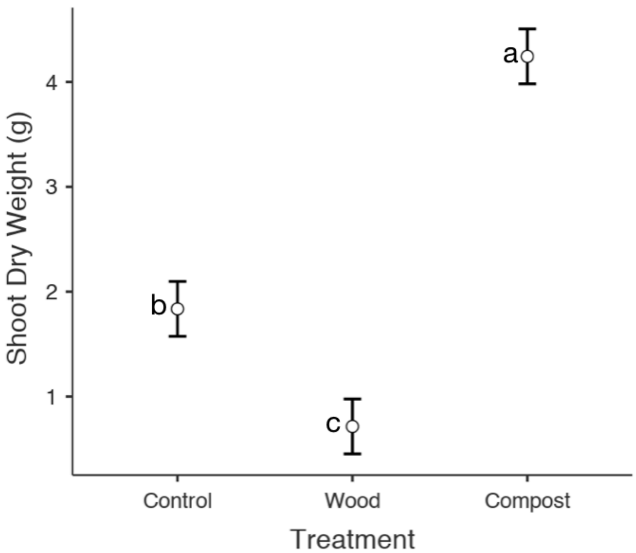

Figure 9. Shoot dry-weight biomass in soil teated with different soil amendments (control, wood-based and commercial organic compost). Error bars denote standard error of the mean (n=10) Means labelled with the same letter do not vary significantly (α = 0.05).

Estimated Marginal Means - Treatment

			95% Confidence Interval	
Treatment	Mean	SE	Lower	Upper
Control	1.836	0.262	1.299	2.37
Wood	0.715	0.262	0.178	1.25
Compost	4.244	0.262	3.707	4.78

Table 4. Estimated marginal means for shoot dry-weight in soil teated with different soil amendments (control, wood-based and commercial organic compost).

Figure 10. The image above captures the striking visual differences observed 2 weeks into the trail, where evidence of chlorosis in the outer leaves of the wood-compost and control treatments contrast will the larger, rich-green organic compost treated samples.

My results showed significant differences between group means indicating that plant growth, active carbon as well as the microbial community were impacted by the different composts applied. I discovered significant differences between the wood treatment in fungal CFU counts, active carbon, soil respiration and shoot dry-weight biomass compared to the control, indicating the application of compost applied can rapidly impact soil characteristics and microbial community responses even during a short 7 week growing period. However, plant growth was negatively affected which implies more caution must be taken to maintain a balanced C:N ratio in the amendment to avoid nitrogen tie-up and subsequent disruptions to plant growth (Figure 10).

CONCLUSIONS

Through this study I aimed to increase interest in the applications of wood compost as a tool for enhancing soil health, specifically through its effect on *Trichoderma* spp. populations. I also aimed to contribute to the understanding of factors affecting soil biology with a focus on their relationship to the type of amendment applied. I was able to conclude that wood based composts hold the potential to increase active carbon in the soil, supporting larger microbial populations and the presence of more fungal colonies. I was not able to conclude whether it influenced the presence of T*richoderma* spp. and thus contributed to the development of suppressive soils. I caution, the slow decomposition of high-lignin, wood-based composts may result in short-term immobilization thus inhibiting biomass production in a fast growing lettuce crop. The commercial compost increased active soil carbon and supported faster lettuce growth than the wood-based compost. Further research is needed to determine if the high C:N ratio of the wood compost could be overcome by applying it in combination with other practices that contribute nitrogen to the soil, such as green manures and nitrogen fixing cover crops or when used in the context of a perennial agriculture system where it could decompose in the soil over an extended period of time.

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