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Compost Amendments on Urban Soils vs. Water Retention

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Abstract

This study was undertaken to investigate the impact of compost on urban soils' ability to retain water. Data from past studies led to the development of the hypothesis that compost will increase soil's water-holding capacity up to a certain point, but, if too much compost is present, the soil will become hydrophobic. To test this hypothesis, four treatments were chosen in the form of compost layers of increasing thicknesses (0-inch compost layer, 1-inch compost layer, 2-inch compost layer, 3-inch compost layer), and three repetitions of each treatment were randomly assigned to twelve planting plots of equal size. Kale seeds were planted evenly in each plot and were tended as needed and watered consistently for the duration of two thirty-day trials. Soil moisture, temperature, and conductivity were measured with a soil probe twice weekly throughout the trials. The data showed an inverse relationship between compost and soil moisture: Soil moisture decreased as compost thickness increased. The same trend was seen between conductivity and compost. Temperature was not impacted by compost. This data led to a rejection of the hypothesis that compost increases soil's water-holding capacity up to a certain limit. These unexpected results could be attributed to the shallow soil measurements achieved by the probe. In future research, a different method should be used to measure soil moisture in order to determine the characteristics of the soil below the compost layer. This study revealed implications for plants of different rooting lengths and provided insight for future designs of urban soil research projects.

Acknowledgements

Dr. Ryan McEwan provided figures generated by R Software as well as guidance and expertise throughout the extent of this investigation. Stephen Mackell, farm manager of Mission of Mary Cooperative, provided insight, resources, and assistance for the duration of this project. University of Dayton Honors Program provided funding for this project.

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Introduction

The U.S. food system profoundly impacts economics, social structures, and environmental functions, and, due to its size, consequences of this system can be global in scale. Due to its capitalist framework, the U.S. food system operates with the primary objective of earning a profit. The idea of "feeding people" is of secondary concern to making money. This arrangement results in the food system catering to the wealthy sector of the population because of the opportunity for a larger profit. The benefits of the food system are concentrated for those with high economic status, and the members of the population with lower economic standing are left out of the process (Holt-Gimenéz 2017).

Currently, thirty-three percent of the world's population is hungry. Simultaneously, forty percent of food produced globally each year is wasted. Concerns about producing a sufficient quantity to sustain the planet's climbing population are misguided; enough food was produced last year to feed ten to eleven billion people. The real issues resulting in hunger are poverty and lack of access, not quantity (Holt-Gimenéz 2017). Because there is a severely unequal distribution of wealth, there is an unequal distribution of food, and this imbalance leads to the birth of "food deserts," which are defined by the U.S. Department of Agriculture as "low-income census tracts where a substantial number or share of residents have low access to fresh, nutritious foods." Food desert communities exist because a profit is not available; food is not taken to these places because the people are too poor to buy it. In a capitalist system, if there is not a market to make money, there is no purpose, so these communities go without.

The environment and industrial agriculture, the dominant method of food production in the U.S., are in direct opposition. Industrial agriculture results in severe losses in terrestrial and aquatic biodiversity every year due to the repeated usage of pesticides, herbicides, and fertilizers. A loss in biodiversity equates to a loss in resiliency. As ecosystems surrounding agriculture fields are continually weakened by chemical use, they will be less stable and less equipped to recover from a shock.

Additionally, the agricultural sector is the second highest global carbon emitter every year, according the EPA. Heavy machine tillage of the land releases stored carbon as soil is disturbed and turned over in preparation for planting. Fossil fuels are used in production to manufacture pesticides, fertilizers, and GMO seeds; they are also used in industrial harvesting equipment, as well as processing and shipment. Every step of the industrial agriculture process is dependent upon fossil fuels.

The pace and methodology of industrial agriculture repeatedly degrades soil ecology and is counter to soil's natural processes. All ecosystems grow, develop, and gain richness with time and lack of disturbance, and the same is true for soil ecosystems. A thriving soil ecosystem is comprised of biotic and abiotic factors along with a multitude of microorganisms. Due to the heavily disturbing nature of industrial agriculture, these ecosystems are destroyed year after year, and the rapid pace of modern agriculture does not allow time for rebuilding (Fortier 2014). Farmers are advised to counteract this degradation with fertilizers, but fertilizers only replace one component of a vastly intricate soil ecosystem, so they are not sustainable for long term growing.

The proposed solution to the current food system's inherent social and environmental issues is to regionalize and demassify the food system. This can be achieved through the implementation of community gardens, CSA programs, and farmer's markets. Small-scale, regenerative, bio-intensive farming that utilizes the power of soil and people can bring communities one step closer to regaining their food sovereignty and restoring soil ecosystems.

Mission of Mary Cooperative, a sustainable urban farming operation in Dayton, Ohio exemplifies the potential of this new model of farming. The cooperative was founded in 2010 and began with a single garden located in a food desert neighborhood. For a decade now, Mission of Mary has confronted the issues of vacant urban lots and the East Dayton community's limited access to fresh, nutritious produce. The cooperative has converted over four acres of unused urban spaces into agricultural plots. A two-tiered CSA program is offered in order to make fresh produce available to families of all socioeconomic standings. Mission of Mary's produce is sold at local markets throughout the growing season, and a variety of education and community engagement programs are open to the public. In 2019, Mission of Mary produced over fifty thousand pounds of seventy varieties of produce using environmentally conscious farming methods. Mission of Mary, along with many other community farms, has proven the positive social and environmental impacts a small, sustainable farm can offer to a community.

The nature of urban soils is a relatively unexplored topic in research. The limited literature available pertaining to soil-water relations, along with collaboration with Mission of Mary Cooperative, led to the development of this project. In a paper addressing the need for urban soil science research, Dr. Sloan of Texas A&M expressed the importance of research for urban municipalities to utilize in order to improve water use efficiency (Sloan 2012). Dr. Biernbaum of Michigan State University found that commercially made soil is manufactured to have a limited water-holding capacity. Commercially made soil is used in the setting of urban agriculture for potting or raised beds, and this research shows that extra effort must be made to ensure these soils are saturated enough to support crops. Dr. Biernbaum reported that ninety to ninety-five percent of the time soils, and consequently the crops, do not receive sufficient water (Biernbaum 2020). These commercially made soils are manufactured to prepare for the exception, making watering more difficult for farmers.

Dr. Curtis and Dr. Claassen of the University of California conducted a study investigating the viability of composting as a revegetation technique for disturbed soils. In the study, the soils of interest were highly disturbed soils at construction sites. The researchers hypothesized that water stress was the main cause of limited revegetation. Compost incorporation into the soils resulted in a twofold increase in available water and four times more biomass production than the control. This study proved composting to be a successful technique for improving the water-holding capacity of highly disturbed urban soils (Curtis and Claassen 2005).

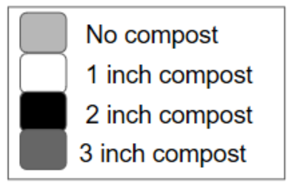
Dr. Bartoli and Dr. Dousset of the French National Centre for Scientific Research studied the effects of compost and organic inputs on the topsoil of a vineyard. This study showed bark, clover, and fescue soil amendments resulting in the development of hydrophobicity in soil. The hydrophobic properties were attributed to the conversion of organic residues during the composting process (Bartoli and Dousset 2011).

Past literature and the interests of Mission of Mary lead to the question of compost's impact on soil's water-holding capacity and, subsequently, the following hypothesis: Soil's water-holding capacity will increase with compost amendments until a maximum limit is reached; then, any compost incorporated above the soil's particular limit will lead it to become hydrophobic, causing its water-holding capacity to drop.

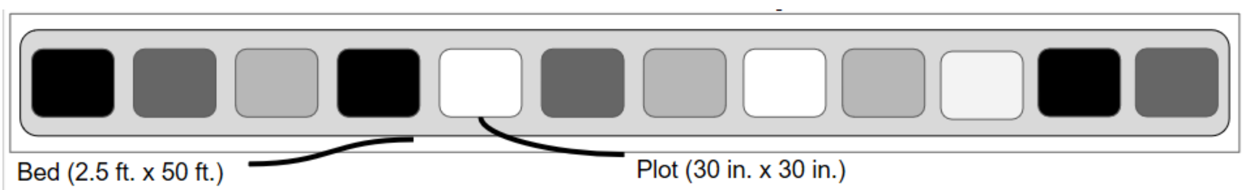
Materials and Methods

To test the hypothesis, two thirty-day trials were run. The first took place in spring of 2019 and the second in the fall of the same year. Each trial occurred in a greenhouse at Mission of Mary Cooperative, a sustainable, urban agriculture operation located in Dayton, Ohio. Twelve planting plots were designated within a single fifty-foot long garden bed. Each planting plot was thirty inches long and thirty inches wide and was randomly assigned to one of four treatments:

1.) No compost
2.) One-inch compost layer
3.) Two-inch compost layer
4.) Three-inch compost layer



There were three repetitions of each treatment, and an eighteen-inch buffer separated each planting plot.



Before the appropriate compost layers were administered, it was ensured that there was soil uniformity across all the plots in the garden bed. They received consistent care for several seasons, so the variance should have been minimal, but the topsoil across the bed was redistributed and mixed using a tilther which disturbs and mixes the top few inches of soil. Following this process, the appropriate compost treatments were added to the plots, and a tilther was used again to incorporate the compost into the top several inches of soil. The compost, obtained from a local mulch company, was comprised of shredded, aged leaves.

A seeder was used to plant kale seeds evenly across each plot. The kale in all plots was watered consistently and weeded as needed for each thirty-day cycle. For the duration of each trial, soil moisture (m^3/m^3), temperature (degrees Celsius), and conductivity (dS/M) were measured twice weekly using a moisture probe. Five measurements of each parameter were recorded per plot.

Following the collection of data, R software was used to run statistical analyses.

Results

In the spring trial, it was found that compost strongly impacted the soil parameters; however, the direction of the effects was unexpected. Soil moisture was highest in the treatments without compost and the lowest in the treatments with three inches of compost (Figure 1). This data does not support the original hypothesis. The soil moisture was expected to increase with compost depth and then decrease after a certain depth was reached, but the data shows a clear decrease in moisture as compost increases. Soil temperature in the spring trial showed no apparent relationship with compost depth (Figure 2). Spring conductivity displays the same trend seen with moisture. As compost depth increases, conductivity decreases (Figure 3). It is not surprising that conductivity follows the same trend as moisture because these two variables are closely related. Conductivity typically correlates with particle size and soil type.

The results of the fall trial closely resembled the findings of the spring trial. As compost depth increases, soil moisture decreases (Figure 4). The fall data shows soil temperature as also unaffected by compost. The temperature remains constant across the changing layers of compost (Figure 5). Fall conductivity decreases as the thickness of the applied compost layer increases (Figure 6).

Discussion

Urban agriculture practices often utilize non-traditional soil treatments such as compost application, and little scientific research has focused on the effectiveness of such practices. In the study, it was found that soil moisture decreases with compost application, temperature is unaffected by compost, and conductivity decreases as the thickness of a compost layer increases.

Perhaps the data displays this unexpected trend because there is more moisture in deeper soil than there is in the compost in the thin, top layer of soil. After it was applied to the plots, the compost was incorporated into the top few inches of the soil, and perhaps the compost dried out quicker than the soil itself, leaving the soil beneath the compost moister. Additionally, the soil probe only measures as far as the sensors extend, which is about three inches. It is probable that the probe only measured the moisture contained in the soil-compost mixture concentrated at the top of the soil, so the moisture of the soil lying beneath is unknown.

Due to the relationship between conductivity and moisture, these two parameters follow the same trend. Conductivity correlates with particle size and soil type, and particle size and soil type determine water-holding capacity. Because of this relationship, conductivity is often used to estimate yield potential in agricultural research (Barbosa 2011). By determining the water-holding capacity of an area of land, a prediction can be made as to how well the land will produce and support healthy crops.

The data gathered in this project could have implications for plants with various root lengths. Kale was planted in the bed used for this investigation, and the growth was minimal. This could be attributed to kale's shallow roots. Because its roots do not extend into deep soil, the top layer of soil is critical. The top layer of soil in this bed did not hold moisture as the compost depth increased, and this is likely the explanation as to why the kale did not grow. For plants whose roots extend into deep soil, the moisture in shallow soil is not as vital as it is for shallow rooters.

The watering method could also provide an explanation for the data. A sprinkler was used to water the beds in the greenhouse where this experiment occurred. Perhaps this style of watering does not lend itself to the ideal saturation for some crops. Driplines that lie along the bed itself and release water directly into the soil could potentially serve as a better watering style for some crops.

In future research pertaining to soil-water relations, a different method should be used to measure soil moisture deeper beneath the surface of the soil. Then data could be collected about the nature of the soil lying beneath various surface compost layers. Also, for future projects, a study should be undertaken to compare different irrigation methods, such as sprinkler versus driplines, to determine the potentially differing results in soil moisture. Composts comprised of different materials should also be investigated, as this study only utilized leaf compost. Perhaps other materials could hold moisture more efficiently. A study on the long-term effects of compost on soil-water relations in beds not previously cultivated would also be prudent.

Conclusion

Analysis of the collected data led to a rejection of the original hypothesis. Compost did not increase soil's water-holding capacity up to a certain limit. The data leads to the conclusion that compost decreases soil's water-holding capacity at the surface of the soil. This study holds implications for the design of future urban soil-water relations research that could investigate different irrigation methods and utilize other moisture measurement techniques to determine deeper soil moisture.

Figures

Figure 1 Spring moisture vs. compost

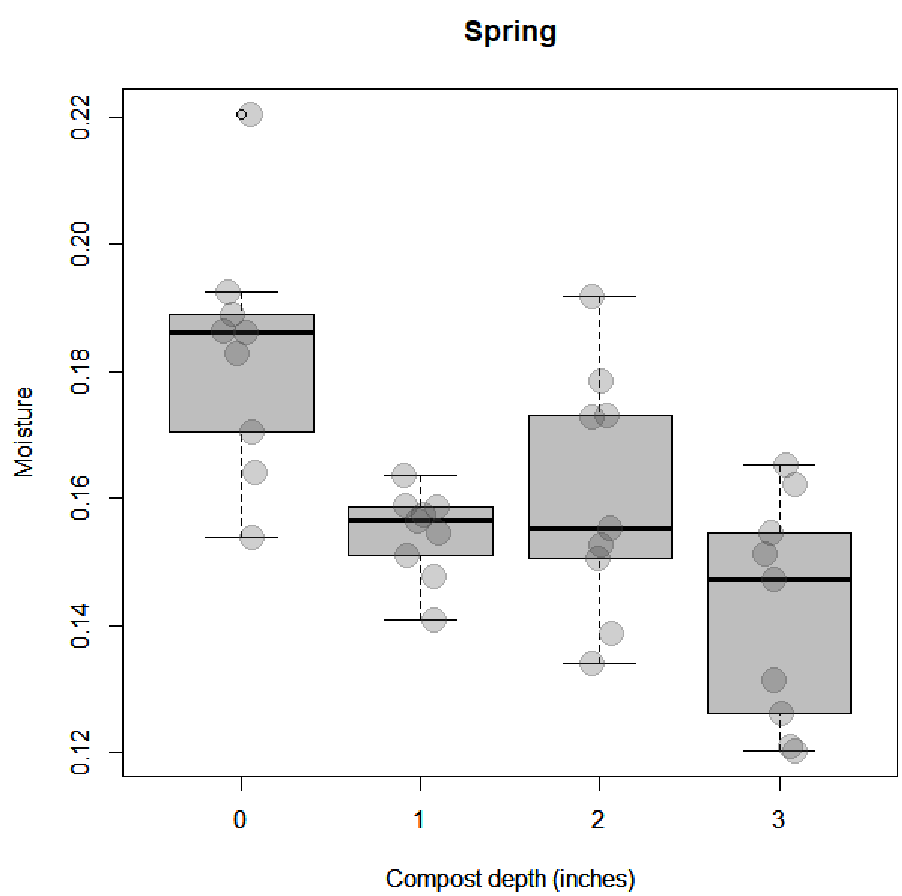


Figure 2. Spring temperature vs. Compost

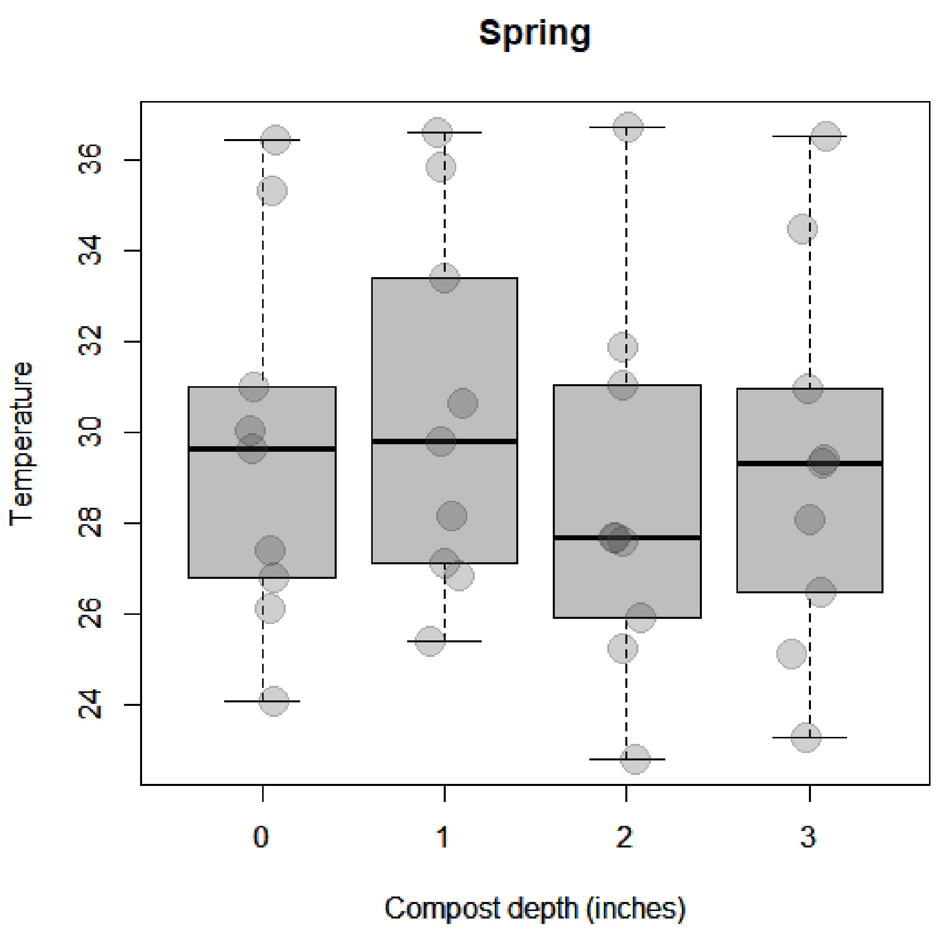


Figure 3. Spring conductivity vs. Compost

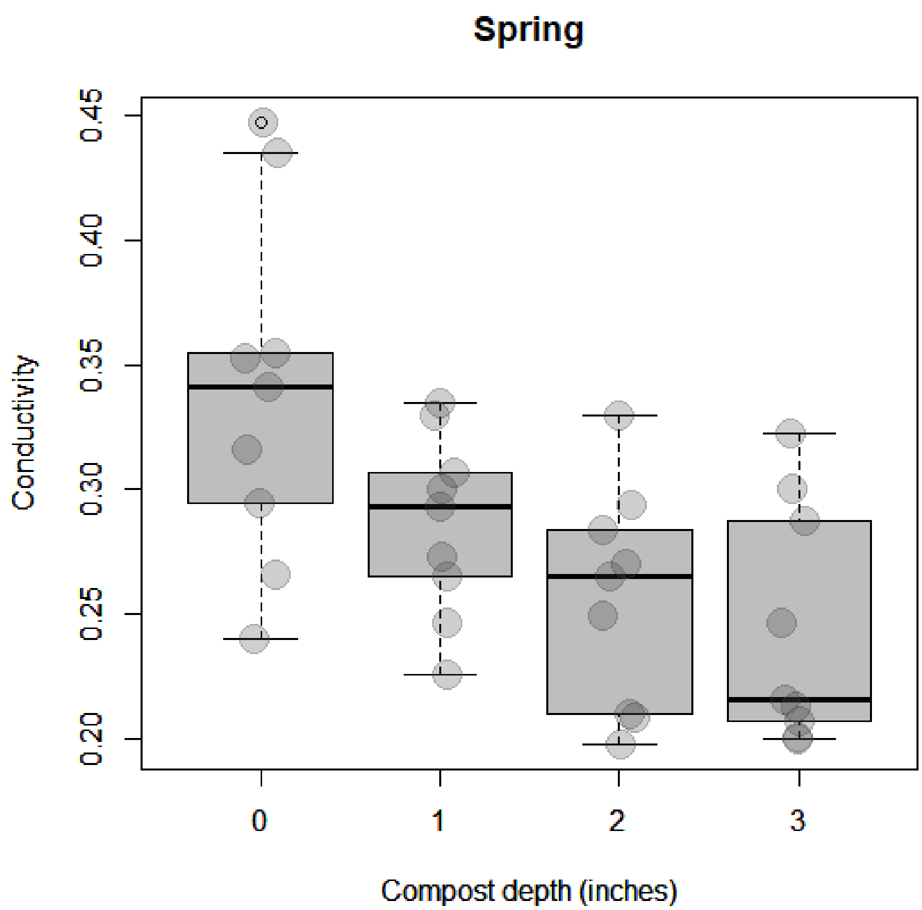


Figure 4. Fall moisture vs. Compost

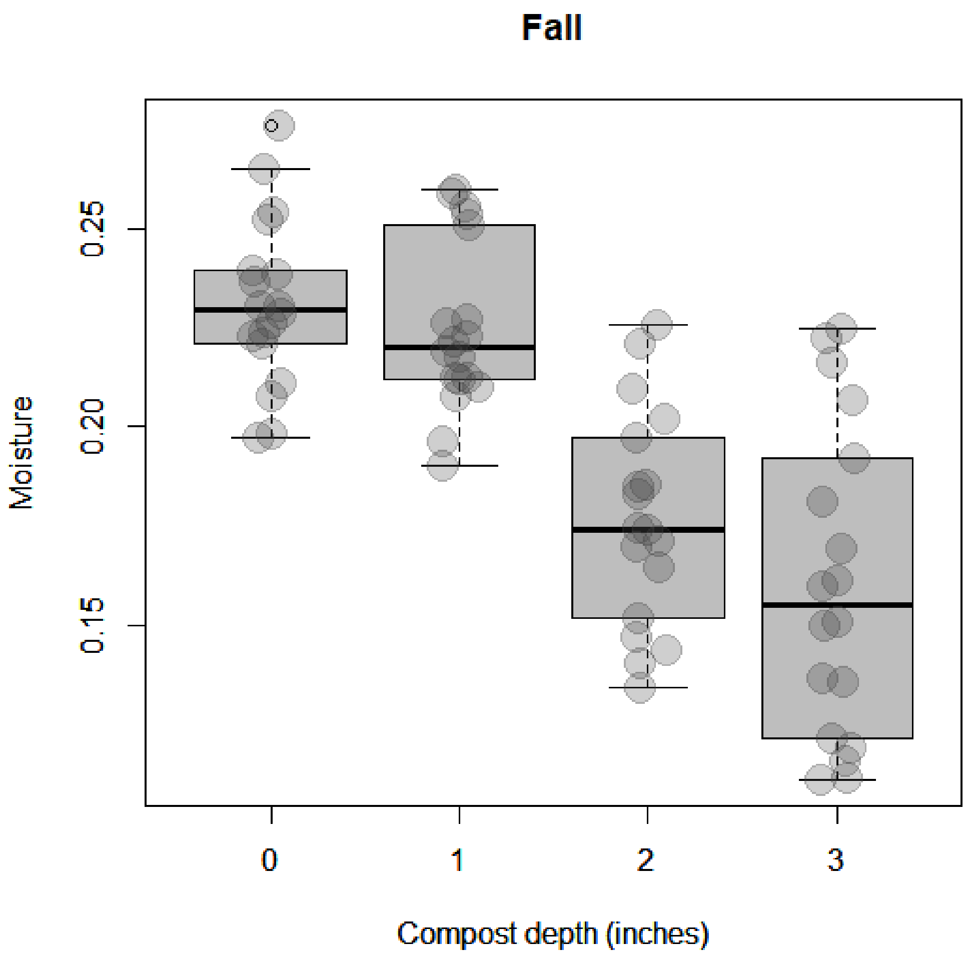


Figure 5. Fall temperature vs. Compost

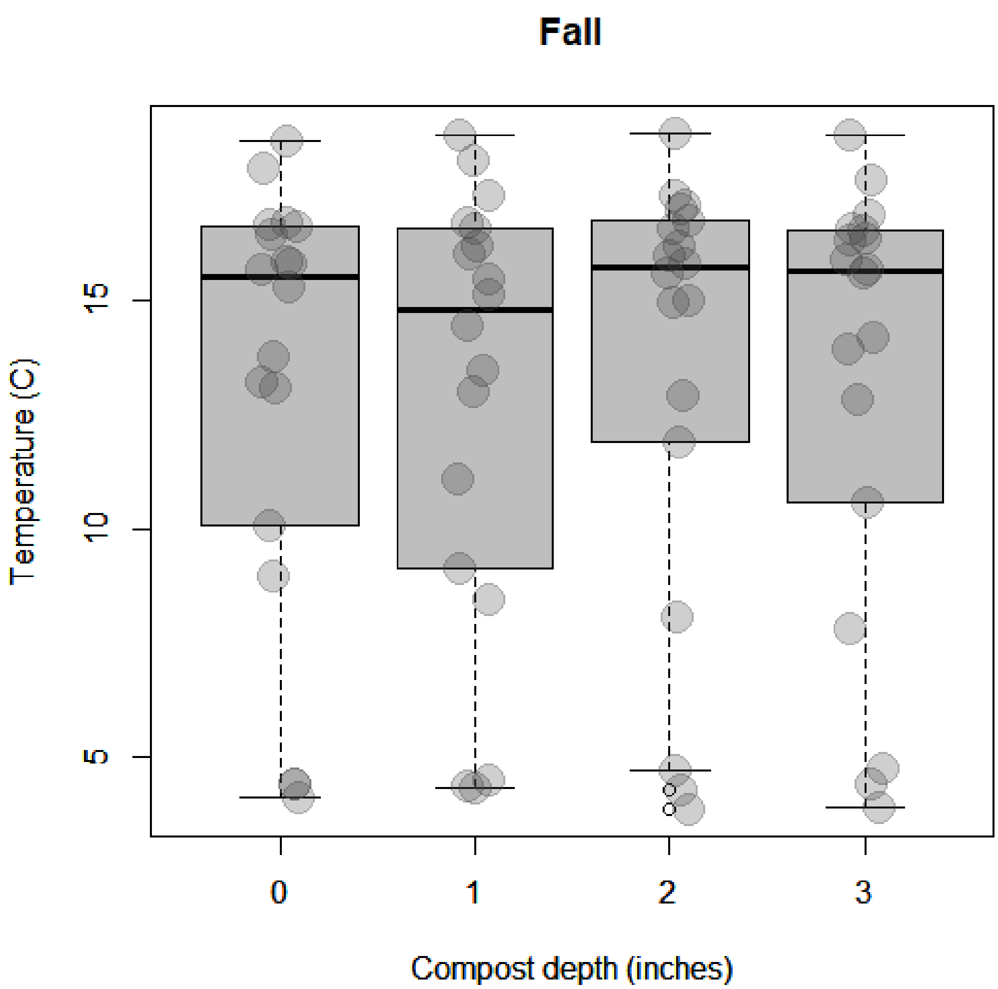
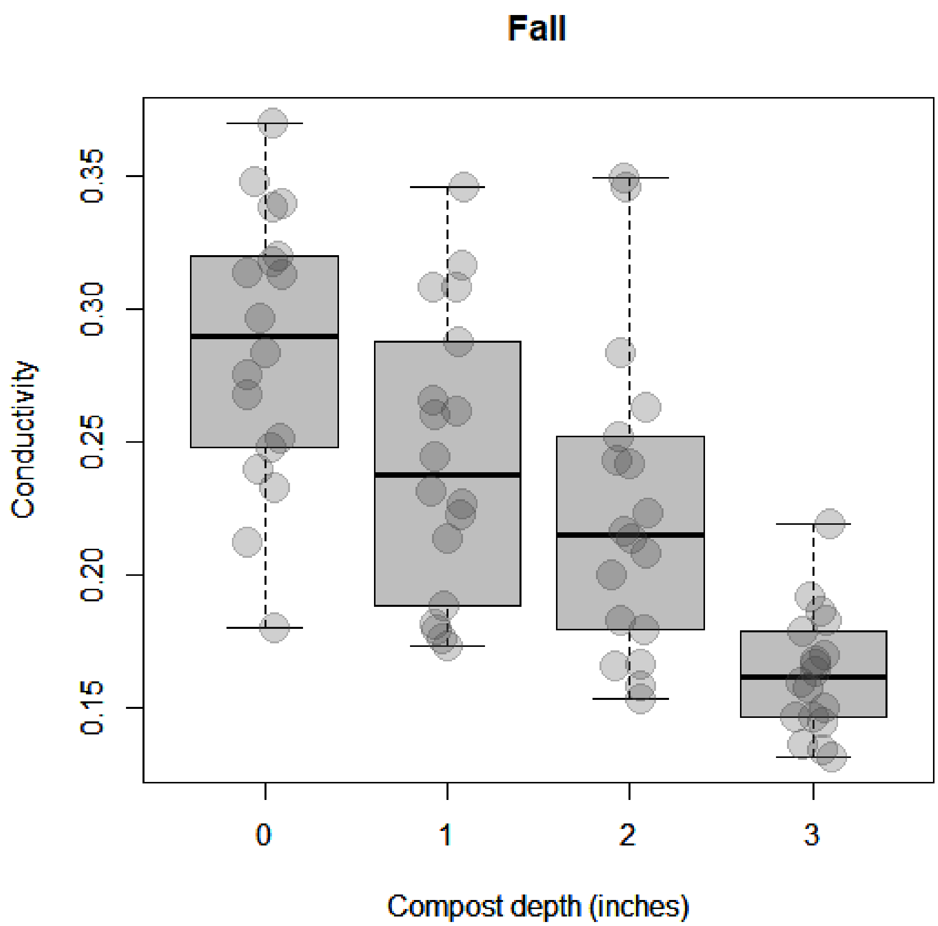


Figure 6. Fall conductivity vs. Compost



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