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Growth Variation of Lettuce (*Lactuca sativa)* and Cilantro (*Coriandrum sativum*) Seedlings with Different Types of Compost

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ABSTRACT

Compost is decomposed organic material from households, farms, and restaurants. Compost is used in organic agriculture to replenish the soil with nutrients such as carbon, nitrogen, phosphorus, and potassium. There are different methods of composting, such as bokashi fermentation, aerobic decomposition, and vermicomposting. Each method of composting as well as the composition of compost, provide plants with a different proportion of nutrients. The purpose of this study was to compare the growth of cilantro and lettuce seedlings in five types of compost, manure compost, coffee vermicompost, food waste vermicompost, food waste compost, fish feces, and a control of just soil. I grew 66 cilantro and 66 lettuce seedlings in small plastic bags with each of the compost treatments at a farm in San Luis, Costa Rica. I measured the number of leaves on each seedling and the height of each seedling before and after treatment. The seedlings grown in food waste vermicompost had the greatest height growth, 6.4±1.4 cm for lettuce and 3.4±0.54 cm for cilantro. Food waste compost also had high plant growth, 5.6±1.04 cm for lettuce and 2.5±0.69 cm for cilantro. The seedlings grown in coffee vermicompost, fish feces, and the control had the lowest growth. The manure compost yielded greater growth than the fish feces and soil control, but still had less growth than the food waste compost and food waste vermicompost. These results suggest that using compost for gardening yields greater growth than not using any compost. This study concludes that vermicompost from food waste provides the best nutritional requirements for seedlings.

Variación en crecimiento de plántulas de lechuga(*Lactuca sativa*) y culantro (*Coriandrum sativum*) en diferentes tipos de compost

RESUMEN

El compost es material orgánico descompuesto de hogares, fincas y restaurantes. El compost se usa en la agricultura orgánica para dar al suelo nutrientes como carbono, nitrógeno, fósforo y potasio. Existen diferentes métodos de compostaje, como la fermentación de bokashi, la descomposición aeróbica y el vermicompostaje. Cada método de compostaje, así como los constituyentes del compost, brinda a las plantas una proporción diferente de nutrientes. El propósito de este estudio fue comparar el crecimiento de plántulas de culantro y lechuga en cinco tipos de compost, compost de estiércol, vermicompost de café, vermicompost de desperdicio de comida, compost de desperdicios de comida, heces de peces y un control de solamente suelo. Sembré 66 plántulas de culantro y 66 de lechuga en pequeñas bolsas de plástico con cada uno de los tratamientos de compost en una finca en San Luis de Monteverde, Costa Rica. Durante diez días, medí el número de hojas en cada plántula y la altura de cada plántula antes y después del tratamiento. Las plántulas cultivadas en vermicompost de desperdicios de comida obtuvieron el mayor crecimiento en altura, 6.4±1.4 cm para la lechuga y 3.4±0.54 cm para el cilantro. El compost de desperdicios de alimentos también obtuvo un alto crecimiento de la planta, 5.6±1.04 cm para la lechuga y 2.5±0.69 cm para el cilantro. Las plántulas cultivadas en vermicompost de café, en heces de peces y el control tuvieron el crecimiento más bajo. El compost de estiércol produjo un mayor crecimiento que las heces de los peces y el control, pero aún así tuvo menos crecimiento que el compost de los desperdicios de comida y el vermicompost de desperdicio de comida. Estos resultados sugieren que usar compost para jardinería produce un mayor crecimiento que no usar nada en el suelo. El presente estudio concluye que el vermicompost de los residuos alimenticios proporciona los mejores requisitos nutricionales para las plántulas.

Compost is used as fertilizer in organic farming as an alternative to synthetic fertilizers used in conventional farming. Synthetic fertilizers are increasingly being used to raise crop growth as the demand for food also increases. Synthetic fertilizers have negative impacts on the environment, including pollution of water and releasing of nitrous oxides, which have a very high ability to trap heat in the atmosphere (Environment News South Africa). Compost utilizes food waste, leaves, manure, and other organic waste that otherwise go to the landfill, and converts it into nutritious fertilizer for plants. Compost consists of organic material such a food scraps, leaves, grass, and manure. The microorganisms that digest the organic material to produce compost need a carbon to nitrogen ratio of about 30 to 1. If there is too much nitrogen, then the microorganisms will not be able to use it all and the compost will smell. If there is not enough nitrogen, then the organic material will not completely decompose (McDowell, 2008). Brown matter provides carbon, and includes twigs, leaves, and grass. Green matter provides nitrogen, and includes food scraps and coffee grinds (Compost Guide). This organic waste is exposed to the air and is left to decompose by microorganisms and bacteria for a few months. Under natural conditions, elements that are taken up by the plant from the soil, are returned back to the soil when the plant dies and decomposes in the soil. However, when farming, a majority of the plant is removed at each harvest. The nutrients are not being returned to the soil, so many commercial farmers rely on synthetic fertilizers to produce adequate yields. Nitrogen, phosphorus, and potassium are the first elements to be depleted from the soil. Compost is rich in all three of these elements making it useful in organic farming (Kohnke, 1995).

Animal manure is often used for composting as a way of reusing waste from livestock agriculture systems. Different types of animals contain varying contents of nutrients in their feces. Chicken and fish manure are higher in nitrogen than cow manure. Livestock manure has a high urea content, which is acidic and can kill the plants (Pratt, 1961). Tilapia are often used in aquaculture systems to provide crops with nutrients. Unlike manure from livestock, which takes months to break down, the nutrients from fish feces can be used immediately. Fresh fish manure has similar levels of N, P, Ca, and Mg, compared to manure from cows and chickens. Fish manure tends to have a greater content of Mn, Cd, Cr, Pb, Fe, and Zn than other livestock manures, but has lower levels of K, Se, As, Co, and Ni (Naylor, 1999). Livestock and fish manure have varying levels of nutrients, so it is not known which would provide the optimal content of nutrients for seedlings.

In vermicomposting, red worms (*Eisenia foetida)* eat food scraps or previously composted material. It takes about three weeks for the worms to eat all of the organic material. The remaining earthworm excrements is then used as compost for plants. Worm excrements do not have as high urea content as livestock manure. Earthworm excrements store and provide 90-95 percent of soil nitrogen, 50 percent of phosphorous, and 80 percent of sulfur (Faniran, 1980).

In addition to vermicomposting, other methods of composting organic waste include bokashi fermentation and aerobic decomposition. In bokashi fermentation, food scraps, coffee chaff, and microbes, are placed in a sealed bucket, which create anaerobic conditions. Microbes obtain energy from molasses. This process allows non-plant material such as meat and dairy to be decomposed, whereas they are omitted from aerobic composting (Planet Natural).

In aerobic decomposition, microbes use oxygen and obtain energy from carbon. There must be about a three to one ratio of carbon to nitrogen in order for microbes to have enough carbon. The compost reaches the microbes' ideal temperatures of 115°F to 160°F. Aerobic compost must be continuously turned in order to distribute oxygen throughout the compost pile (*Aggie-Horticulture.tamu.edu*).

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The organic coffee farm, Life Monteverde, in Monteverde, Costa Rica uses two kilograms of each of their types of compost, (manure compost and coffee vermicompost) on their coffee trees, but they do not know which of the two is most effective. The environmental consultant and compost producer, Justin Welch, created a compost facility to test bokashi fermentation, aerobic decomposition, and vermicomposting. He collects food waste from restaurants, coffee waste from coffee farms, and cow manure from farms. Welch recently started using earthworms for the compost. He requires further research to understand how each compost compares in growing plants. It is therefore helpful to understand what type of compost yields the highest plant growth in order to increase efficiency with resources and labor. I tested different types of compost on cilantro and lettuce seedlings to determine which yields the greatest growth.

MATERIALS AND METHODS

This study took place in San Luis, Costa Rica from 14 May, 2018 to 25 May, 2018. I placed all of the seedlings along a wall of the house of Liliam Arce and Rafael Leiton in rows of five seedlings. They were sheltered under part of a nearby roof, so they were protected from the rain. I filled 132 small plastic bags with drainage holes, with 450 mL of soil, which was about half-full of the bag. I collected soil by digging a hole in a clearing in the ground at the study site in San Luis. I removed plants, rocks, and large roots from the 450 mL of soil. I then added 150 mL of the specified compost to each bag. According to Living Green (2014), there should be a mixture of 5 to 50 percent compost to soil. There is not an exact ideal percent, because different plants require different compost to soil ratios. I chose a ratio of three to one of soil to compost, because it is near the middle of the recommended ratio. I mixed the compost and the soil together by hand. I placed one hand into the bag and used all of my fingers to squish and mix the compost and soil together to about halfway down the bag. Some of the compost was clumped together, so I separated all of the clumps.

I made soil and compost mixtures of each of the Life Monteverde coffee farm's compost and both of Justin Welch's composts. The manure compost from the Life coffee farm consisted of 620 kg of the outer peel of the coffee fruit, 600 kg goat manure and 280 kg chicken manure from the Life farm, 3 liters "mountain microorganisms", 2 kg coffee parchment (the inner layer of the coffee bean), 240 kg inoculating material (additional microorganisms), 7.57 liters earthworm excrement tea, and 20 liters molasses. The molasses provides the microbes with a food source. I will refer to this compost as manure compost in the study. The vermicompost from the Life farm consisted mostly of the outer peel of coffee, earthworms, water, and penergetic (which lowers the acidity of the compost creating a favorable environment for the earthworms). I will refer to this compost as coffee vermicompost through the rest of the study.

Welch's compost consists of food waste, leaf litter, cow manure, coffee pulp, coffee chaff, and "mountain microorganisms". I will refer to this compost as food waste compost through the rest of the study. Welch's vermicompost consisted of food waste, leaf litter, and small amounts of coffee pulp and bokashi, which is coffee pulp inoculated with microorganisms. I will refer to this compost as food waste vermicompost through the rest of the study.

I made a liquid mixture of tilapia feces and a control using only soil. I obtained the tilapia feces from Marco Marin and Lorena Leiton's farm using a bucket to scoop out fecal water from the bottom of a man-made tilapia pond. This feces-water also contained algae that was growing on the bottom of the pond and leaf litter. I waited about five minutes for the solid particles to settle to the bottom of the bucket and poured out the upper-most water to make the feces-water more concentrated. I also removed any leaves and twigs from the water. I mixed the feces-water in the bucket and poured 150 mL of the water into each bag of the tilapia-feces treatments. For the soil control, I used the same soil as in the rest of the treatments.

I used cilantro (*Coriandrum sativum*) and lettuce (*Lactuca sativa)* seedlings grown in uniform plastic trays from Orlando Trejos' farm. I chose to grow cilantro and lettuce because they have a relatively high growth rate and start out uniform in size. I used 66 cilantro and 66 lettuce seedlings. This includes a total of 11 seedlings of both plant species for each treatment. I placed one lettuce seedling in each of the 66 lettuce labeled plastic bags. I placed one bunch of cilantro seedlings from one compartment of the plastic container into the plastic bags designated for cilantro. I labeled each bag with the compost treatment and numbers 1 through 11. The plants were placed on the ground together in close proximity along a building wall.

I measured the number of leaves and height with a ruler before treatment, on alternating days for a total of 14 days. I measured lettuce on the 16, 17, 19, 21, 23, and 25th of May, 2018. I measured the cilantro on 18, 20, 22, and 25th of March, 2018. I measured the height of the cilantro from the base of the stem to the tip of the tallest leaf in each bunch. For lettuce, I measured height from the base of the leaves to the tip of the tallest leaf.

To analyze my data, I calculated the difference between the final and initial heights for each seedling. I created box graphs for each of the cilantro and lettuce height differences and number of leaves before and after the experiment. I used letters 'a' through 'c' to indicate which treatments had significant difference between each other on the final day o measurement. I took the averages of all of the height differences and numbers of leaves. I reported these averages with the standard deviation. I performed one-way ANOVA tests to determine differences between treatments. I performed the Turkey-Kramer statistical test to determine whether there are significant differences between averages of each of the treatments.

RESULTS

Each cilantro seedling started with three leaves. Seven days later, all of the cilantro seedlings had four leaves, except for three seedlings of the fish feces treatment that only had three leaves, and three seedlings of the control that only had three leaves (Figure 1, $F_{(5,60)}=3.88$, $p<0.0041$). The control grew a significantly lower number of leaves than the manure, coffee vermicompost, food waste compost, and food waste vermicompost . The fish feces and control did not have a significant difference in leaf number.

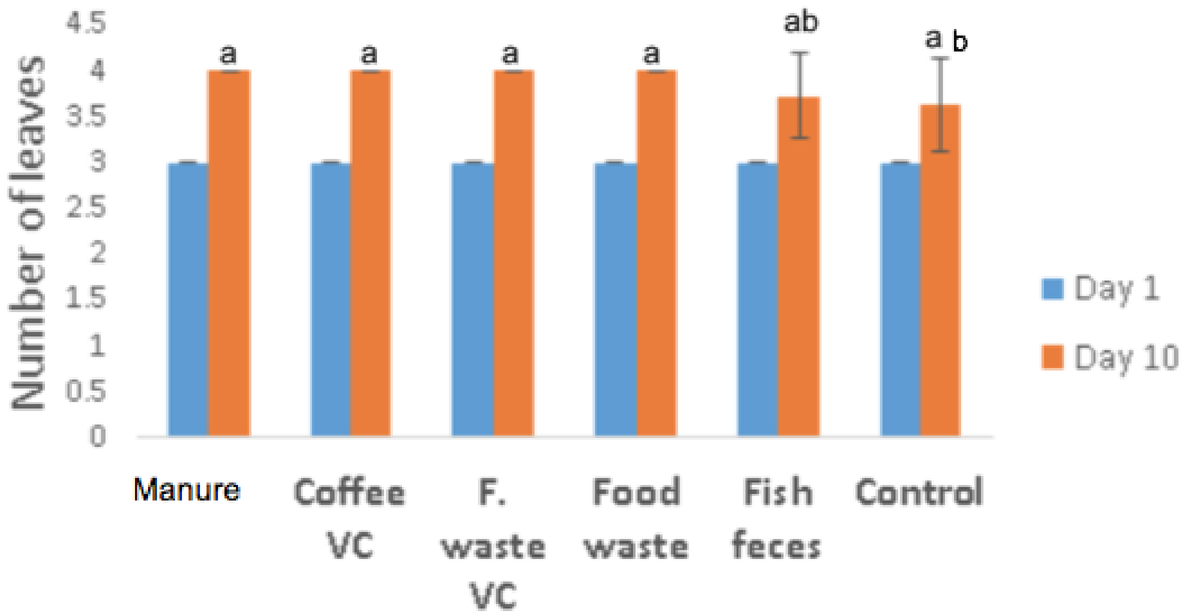

Figure 1: Number of cilantro leaves before and after 10 days of treatment. Treatments with the same letters, indicates that they are not significantly different from another on the last day that measurements were taken.

Most of the lettuce seedlings started out with an average of 7.86 (SD±0.39) leaves. On the last day of measurements, the manure treatment had an average of 7.1 (SD±0.83) leaves, coffee vermicompost treatment had an average of 5.7 (SD±0.65) leaves, food waste vermicompost treatment had an average of 7.5 (SD±1.21) leaves, food waste compost treatment had an average of 7.7 (SD±0.77) leaves, fish feces treatment had an average of 5.5 (SD±0.52) leaves, and the control had an average of 6.2 (SD±0.98) leaves (Figure 2, $F_{(5,60)}=13.23$, $p<0.0001$). The food waste compost and food waste vermicompost did not have a significant difference in leaf number. Both food waste compost and food waste vermicompost treatments had a significantly greater number of leaves than the coffee vermicompost, fish feces, and control treatments. The manure treatment had a significantly greater number of leaves than the coffee vermicompost and fish feces treatments, but it did not have a significant difference between food waste vermicompost, food waste compost, and the control treatments.

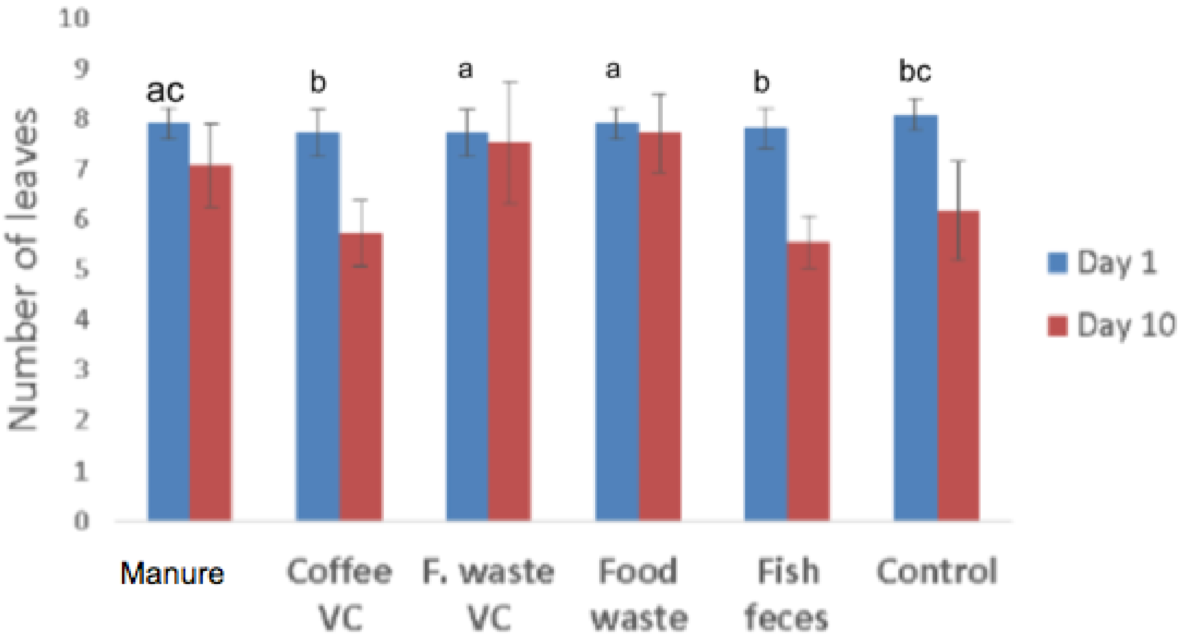

Figure 2: Number of lettuce leaves before and after 10 days of treatment. Treatments with the same letters, indicates that they are not significantly different from another on the last day that measurements were taken.

I measured the difference between the final and initial heights for each of the seedlings. For the lettuce seedlings, the manure treatment had an average difference of 4.9 (SD±1.07) cm, coffee vermicompost treatment had an average difference of 2.5 (SD±1.3) cm, food waste vermicompost treatment had an average difference of 6.4 (SD±1.4) cm, food waste compost treatment had an average difference of 5.6 (SD±1.04) cm, the fish feces treatment had an average difference of 2.4 (SD±0.87) cm, and the control had an average difference of 2.8 (SD±0.78) cm (Figure 3, $F_{(5,60)}=48.63$, $p<0.0001$). There was no significant height difference between food waste vermicompost and food waste compost. Food waste compost did not have a significant height difference with manure compost, but food waste vermicompost was significantly taller than manure compost. Food waste vermicompost and food waste compost were significantly taller than coffee vermicompost, fish feces, and the control.

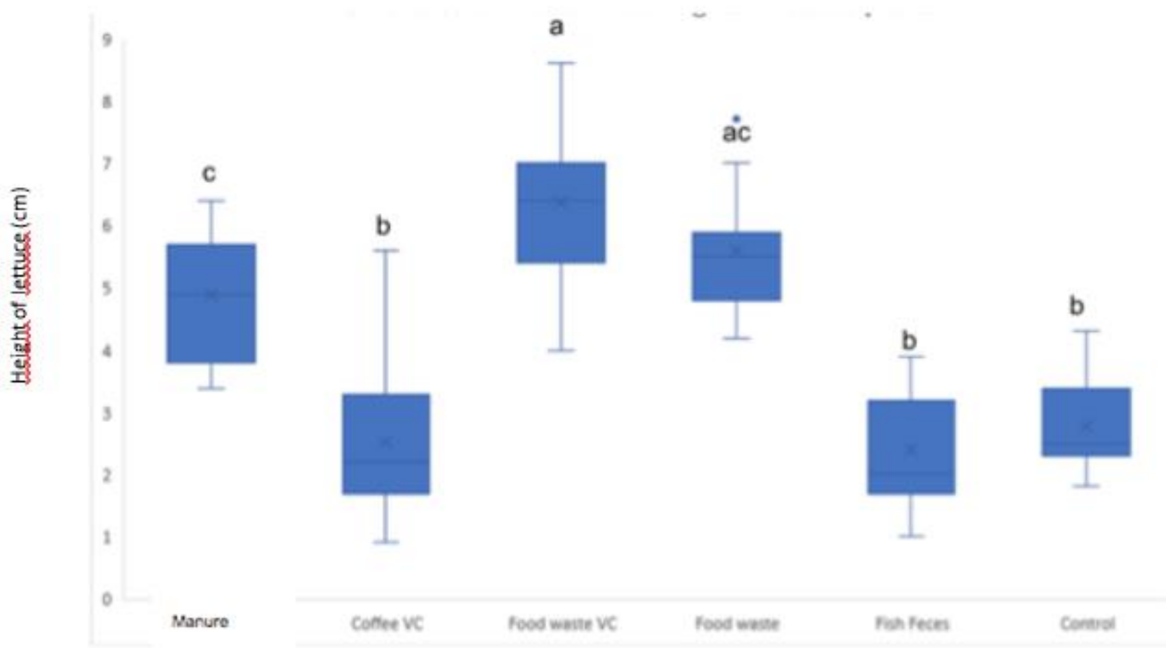

Figure 3: Height difference of lettuce before and after 10 days of treatment. Treatments with the same letters, indicates that they are not significantly different from each other.

For the height of the cilantro seedlings, manure compost had an average difference of 2.5 (SD±0.68) cm, coffee vermicompost treatment had an average difference of 2.7 (SD±0.61) cm, food waste vermicompost had an average difference of 3.4 (SD±0.54) cm, food waste compost had an average difference of 2.5 (SD±0.69) cm, the fish feces treatment had an average difference of 2.3 (SD±0.49) cm, and the control had an average difference of 2.2 (SD±0.71) cm (Figure 4, $F_{(5,60)}$,=5.09, $p<0.0006$). There was no significant height difference between coffee vermicompost and food waste vermicompost. Food waste vermicompost was significantly taller than manure compost, food waste compost, fish feces, and control treatments. The manure compost, coffee vermicompost, food waste compost, fish feces, and control treatments all had no significant height difference between them.

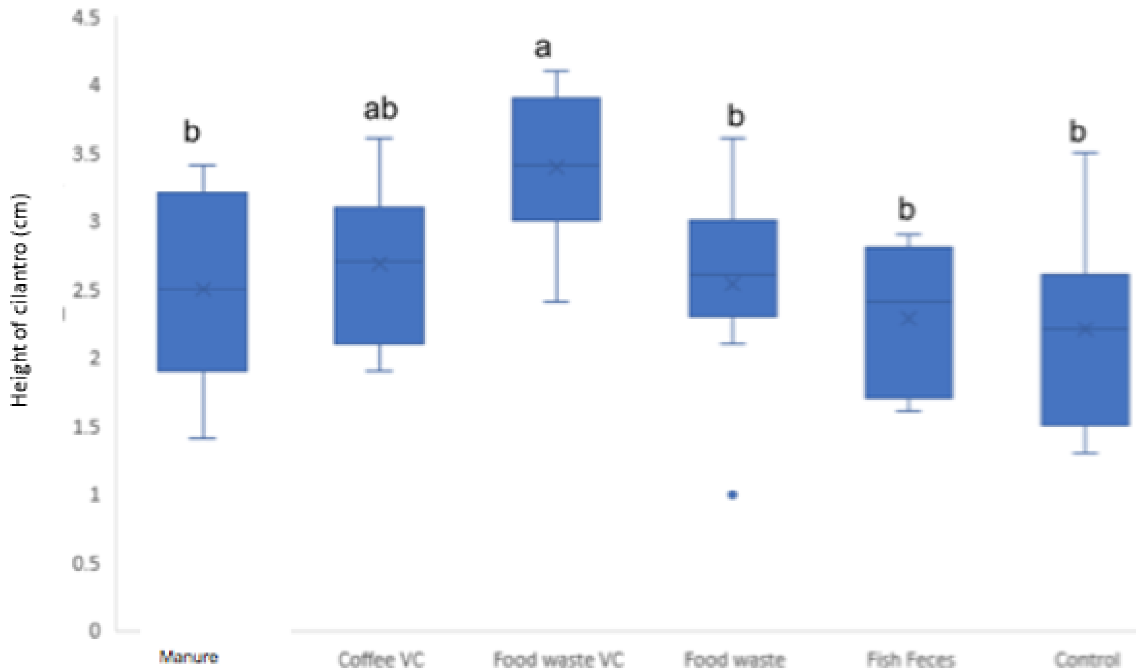

Figure 4: Height difference of cilantro seedlings before and after 10 days of treatment. Treatments with the same letters indicates that they are not significantly different from each other.

DISCUSSION

The food waste compost and the food waste vermicompost treatments had the greatest growth in all of the treatments, except for cilantro height where coffee vermicompost was slightly taller than food waste compost. Both the food waste compost and food waste vermicompost first underwent bokashi fermentation then underwent aerobic decomposition. In a study by Boechat, et al (2013) fermented bokashi compost accelerated the mineralization of nitrogen, which turns it into a more usable form for plants. Furthermore, Boechat et al's study (2013) concluded that fermented bokashi compost with added effective microorganisms accelerated the decomposition of organic matter, increasing the soil fertility. The increased soil fertility of bokashi compost may have resulted the food waste compost and food waste vermicompost to have high leaf and height growth.

Furthermore, the food waste compost and food waste vermicompost underwent aerobic decomposition. In aerobic decomposition, microorganisms including, bacteria, fungi, and actinomycetes, feed on the organic matter converting nitrogen, phosphorus, and carbon into more usable forms for the plant. Nitrogen is excreted as ammonium, which may oxidize into nitrate under favorable conditions (*Aggie-Horticulture.tamu.edu*). Aerobic decomposition break down the organic material even further after bokashi fermentation, which allow even more nutrients to become available to plants.

After the process of aerobic decomposition, the food waste vermicompost was further decomposed by passing through the gut of earthworms. The food waste compost did not go through this additional step of decomposition, and subsequently had lower growth than the food waste vermicompost. The food waste vermicompost also had the greatest plant height for both cilantro and lettuce and the greatest number of lettuce leaves. The coffee vermicompost treatment had greater cilantro plant heights than all of the rest of the treatments, except for the food waste compost. Earthworms break down the organic matter further which allows more nutrients to become available to the plant. Earthworms improve the physical soil quality. Earthworm excrements increase soil water retention and infiltration (Lee, 1985). Earthworms also improve the availability of nutrients in the soil, since their excrements also have a much higher organic carbon and nutrient content than the surrounding soil. They also increase the organic carbon in the soil by 21.0 to 43.0 percent (Zhang and Schrader, 1993). Earthworms excrete significant amounts of nitrogen as ammonium and in the urine (Lee, 1985). Bouche and Ferrie (1986) found that ^{15}N labelled nitrogen from earthworm was rapidly and almost entirely taken up by plants. The ammonium and urea from earthworms is rapidly mineralized, making it a significant source of readily available nitrogen. Nitrogen is a major component of chloroplasts (Mosaic crop nutrition). Photosynthesis occurs in chloroplasts, where carbon dioxide, water, and light are converted into glucose which is used to provide energy for the plant (BBC, 2014). Seedlings undergo very rapid vegetative growth, so it is crucial that they have enough nitrogen to support photosynthesis. Earthworms also increase the availability of phosphorus (Syers and Springett, 1984), potassium (Basker et al. 1993), calcium, and magnesium (Edwards, 1982), by converting these nutrients into exchangeable forms. This increases the overall nutrients in the soil. Increases in available carbon, nitrogen, phosphorus, potassium, calcium, and magnesium nutrients allows the plant to increase in growth.

The coffee vermicompost treatment had the second tallest cilantro seedlings, but had very low growth for lettuce. The coffee vermicompost would have all of the benefits from the earthworms as in the food waste vermicompost, however food waste vermicompost still yielded significantly greater growth. The food waste vermicompost underwent two different decomposition processes before vermicomposting, which would have led to a greater amount of the nutrients to be converted into usable forms. The food waste vermicompost also had a wide range of ingredients, while the coffee vermicompost only contained the outer peel of coffee. The wide range of ingredients in the food waste vermicompost would yield a greater variety of nutrients.

The control and the fish feces treatments had very low height and leaf growth in both of the cilantro and lettuce plants. This is likely due to a lack of nutrients available to the plant. The soil obtained from the ground was dry and brittle and did not appear to have any organic material, except for some thick roots. Fish feces has a high content of N, P, Ca, and Mg, however there might have not been enough fish feces in the water. The green-brown sludge at the bottom of the pond was a mixture of leaves, sticks, fish feces, and algae. I used a mixture of algae and fish feces in a large amount of water. There might have not been enough feces in the water to have positive growth in the plants.

I grew the seedlings of each compost type grouped together in a long line along a wall. I did not notice any difference in amount of sunlight among the groups of seedlings, but there still might have been slight variations in sunlight throughout the day that might have affected plant growth.

The production of compost is at the crossroad between municipal organic waste management and organic agriculture production. Households and restaurants produce food waste and organic agriculture utilizes this food waste for organic fertilizer. Organic agriculture production requires compost that contains all of the required nutrients, is of ideal texture, and contains microbes. It is important to understand what composition of compost yields the greatest growth in plants, in order to maximize crop yields, and most efficiently utilize the municipal solid waste available. The capacity of organic waste management systems is dependent on cost efficiency and time efficiency. The compost producer, Justin Welch, created a composting facility to manage municipal solid waste in Monteverde, Costa Rica. He is able to use some of the food waste produced in Monteverde, but much of it still goes to the landfill. Finding the most effective composition of compost will allow primary compost inputs to be most effectively allocated. In order to expand Welch's facility and utilize more food waste, his processing must become more time efficient and cost efficient at dealing with larger loads of food waste. Future studies could measure nutrient contents in various composts in order to get a more precise ideal composition for growing seedlings. Future studies could also compare the growth of mature plants, such as coffee trees, with composts types used in this study with growing mature plants. Different plants at different life stages may have different nutritional requirements and also have different ideal soil textures for growth.

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