JOURNAL OF
EMERGING INVESTIGATORS

Article

The efficacy of spent green tea leaves and coffee grounds on the growth of *Ocimum basilicum*

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SUMMARY

As increased waste production leads to concerns with recycling and waste management in society today, scientists are looking for methods to combat this, such as composting and organic fertilizers. We sought to determine the effectiveness of used green tea leaves and coffee grounds as a fertilizer substitute, as determined by the height, number of leaves, and fresh and dry weight of basil plants. In our experiment, dried green tea leaves, dried coffee grounds, synthetic fertilizer, and a control group with nothing added were mixed into the soil of 20 basil plants. We hypothesized that both tea leaves and synthetic fertilizer would promote the growth of height and mass compared to the control, but coffee would be similar to the control. We found that the application of coffee grounds significantly lessened the growth of the basil plants. According to our results, there was no significant difference between adding tea leaves and adding nothing, while adding coffee grounds is detrimental to basil plant growth and produces significantly worse results than the control plants in height and fresh weight. These results only supported some of our hypotheses, however, they show that the commonly added fertilizer of coffee grounds may not be as effective as many may suggest.

INTRODUCTION

Food waste is a vastly significant problem in our ecosystem and society. A 2023 study from the Environmental Protection Agency stated that 58% of the methane emissions released into the air from landfills are consequences of food waste, and this number has been on the rise (1). This is important, since food waste accounts for 20% of all municipal solid waste in landfills (1). The best way to mitigate this is to reduce food waste from the start, as more than one-third of the food supply goes unused in the United States (1). Another way to tackle food waste is by composting. This allows the minerals and nutrients in food to be reused as fertilizer in the soil, instead of taking up valuable space in landfills. Using this strategy not only addresses the problem of keeping food out of landfills, but also offers an organic fertilizer option to replace synthetic fertilizers.

Some specific food wastes that go unnoticed are tea leaves and coffee grounds. According to a 2024 report, tea is the most consumed beverage in the world after water, and coffee follows closely behind (2). These are very common items that, when discarded as trash, unnecessarily increase landfill waste (3). Tea leaves and coffee grounds are particularly well known for their use as biofertilizers due to their high nutrient content, particularly nitrogen (4). This information calls attention to the possibilities of the uses of coffee grounds and tea leaves on dirt health, and therefore plant health as well.

We wanted to determine whether green tea leaves or coffee grounds affect the growth of basil plants, and whether this effect is comparable to that of synthetic fertilizer. We chose basil due to its fast germination rate and its role as a typical household plant. While we are aware that both tea leaves and spent coffee grounds contain vital nutrients such as nitrogen, phosphorus, and potassium, whether these nutrients play a large enough role is still in question. Despite the nutrients provided by tea and coffee, their caffeine content may be detrimental to plant growth, Unused green tea leaves contain about 2.35% caffeine which is even more than the 1.1-2.2% in coffee beans, however much of this caffeine becomes soluble and leaves during the heating process of making coffee or tea (5). Beyond caffeine, some researchers claim that due to other toxins and compounds found in spent coffee grounds, such as tannins and chlorogenic acids, their application potentially creates more harm than help (4). Furthermore, the pH of coffee tends to be more acidic, averaging 5.4, and the pH of the tea leaves is closer to neutral, about 7.2 (6, 7). Basil plants prefer neutral soil that has a pH of around 6-7.5 (8).

We hypothesized that green tea leaves would promote the height and weight of the basil plants (*Ocimum basilicum*) when compared to an untreated control, due to the leaves' high nutrient content and more neutral pH. We further hypothesized that the growth of plants treated with coffee would be comparable to the untreated control due to its lower pH as compared to tea and presence of toxins. Finally, we hypothesized that synthetic fertilizer would produce similar results to the green tea leaves due to its neutral pH, absence of caffeine, and the fact that it is designed specifically to help plant growth. In sum, the primary objective was to determine if adding these natural fertilizers had an impact on basil growth. While none of the final growth results of the natural fertilizers were significantly improved over the untreated control, more research should be conducted to discover more utilizations of these untapped nutrients in coffee grounds and tea leaves.

RESULTS

To test our hypothesis that tea leaves and coffee would help the growth of basil plants, we determined the height and number of leaves throughout the growth period, as well as the final dry weight, wet weight, height, and number of leaves of basil plants treated with dried green tea leaves, dried spent coffee grounds, and a control with no added fertilizer.

https://doi.org/10.59720/24-173

The synthetic fertilizer, Miracle Gro, was originally one of our sample groups, but in trial one the plants died after the second fertilizer dosage and there were not enough living plants in trial two to perform statistical analyses.

Our results from trial one showed that there were overall significant differences between the final heights (in mm) of the plants (one-way ANOVA, p = 0.000396). Specifically, the height of the plants treated with tea (Mean = 112.806, SD = 21.128) and coffee (Mean = 73.933, SD = 16.245) were significantly different (Tukey's HSD, p=0.000001), as was the height of the plants in the control (Mean = 108.386, SD = 19.001) and coffee groups (Tukey's HSD, p = 0.00003). However, the height of the plants in the control and tea groups were not significantly different (Tukey's HSD, p=0.79867). While we only statistically tested the final measurements at the end of the growth period, we still tracked and recorded the height at different timepoints over the 40-day period for a better grasp on the data (**Figure 1**). This allows us to see growth trends and predict patterns for possible future research.

We also measured the fresh mass of the plant matter in grams, which produced overall significant results that were similar to those of the final height results above. (ANOVA, p = 0.00001, **Figure 2**). The fresh weight of the plants between the tea (Mean = 0.369, SD = 0.126) and coffee (Mean = 0.183, SD = 0.062) groups was significant (Tukey's HSD, p = 0.00001), as was between the plants in the control (Mean = 0.326, SD = 0.082) and coffee groups (Tukey's HSD, p=0.00043). The effects of tea and the control were not significant (Tukey's HSD, p = 0.43247). We also recorded the leaf count per plant as the basil grew, yet among all of the added fertilizers of tea (Mean = 7.2, SD = 1.549), coffee (Mean = 6.467, SD = 1.060), and the control (Mean = 7, SD = 1.195), the total number of leaves did not differ significantly (one-way ANOVA, p = 0.06489, **Figure 3**).

In the second trial of the experiment, the plants were exposed to different elements than the first trial and there were fewer samples, so the results are not as robust as those of the first trial. Between the height of the tea samples (Mean = 89.675, SD = 25.353), coffee samples (Mean = 84.644, SD = 29.119) and the control samples (Mean = 105.330, SD = 21.896), there were no significant difference across treatment groups (one-way ANOVA, p=0.202537, **Figure 4**). Likewise, between the final wet weight in grams of tea (Mean = 0.234, SD = 0.148), coffee (Mean = 0.13, SD = 0.074), and the control (Mean = 0.2, SD = 0.099), there was no significant difference (one-way ANOVA, p=0.152912). Finally, in the final number of leaves of Trial 2 in tea (Mean = 6.25, SD = 1.581), coffee (Mean = 5.333, SD = 1), and the control (Mean = 5.889, SD = 1.616), there was no significance (one-way ANOVA, p=0.418567).

The application of tea leaves to the soil did not impact the height, leaf number, or wet or dry mass of basil plants when compared to the control. The application of coffee grounds did, however, negatively affect the height and wet mass of basil plants compared to the control and tea leaves.

DISCUSSION

We conducted this experiment to determine the fertilization abilities of synthetic fertilizer, dried green tea leaves, and dried coffee grounds. We hypothesized that green tea leaves would assist the growth of basil plants similar to the Miracle Gro, but that coffee would produce growth similar to the control sample. The results showed that the basil plants given green tea leaves as fertilizer had a higher mean height (112.81 mm) and fresh weight (0.37 g) as compared to all other fertilizers, but this data is statistically insignificant compared to the control. Coffee promoted significantly less growth compared to the control and tea as measured by both height and wet weight. Miracle Gro lacked data and died before the experiment's conclusion, so we could not compare results. The final number of leaves results among all sample groups were not significant; however, this was most likely due to there being a low, finite number of leaves, such that there was not as much variation in data values (**Figure 3**). This could be attributed to the short growth period, which did not allow for the development of a high number of leaves.

Due to the nature of this experiment, it was not possible to pinpoint why tea performed better than coffee, or why Miracle Gro was deadly to the basil plants. This is partially due to limited resources, especially the lack of soil-testing equipment to measure the pH and exact nutrient values. Nevertheless, there are many factors that could provide explanations for our results. Coffee has a pH of approximately 5.4, which could have acidified the sample's soil (7). This would be detrimental, as basil plants prefer a neutral environment of approximately

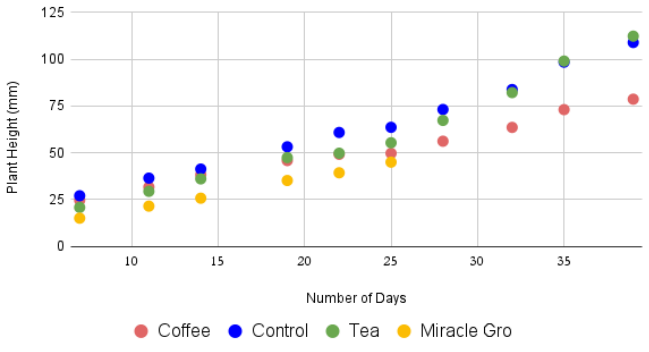

Figure 1. Average plant height in trial 1. Final average height in mm over 40 days of basil plants treated with the indicated fertilizer (n = 6). Basil plants treated with Miracle Gro all died by day 25. The final height between coffee, control, and tea is significant, (one-way ANOVA, p = 0.000396).

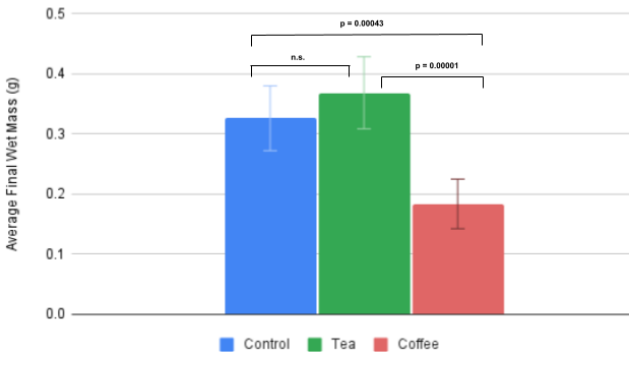

Figure 2. Average final wet mass in trial 1. Average final wet mass in grams over 40 days of basil plants treated with the indicated fertilizer. Data is shown as mean ± standard deviation, n = 6 for each group. The final mass among the overall groups of control, tea, and coffee is significant, (one-way ANOVA, p = 0.00001).

https://doi.org/10.59720/24-173

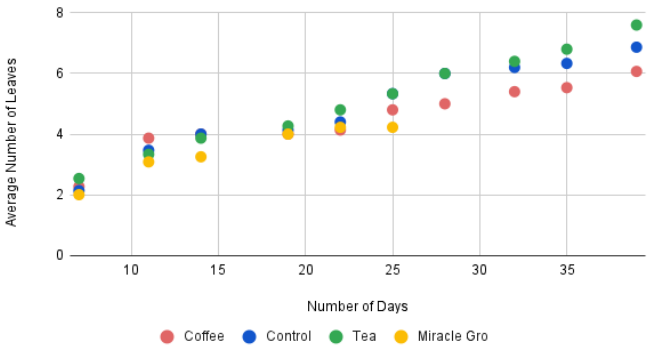

Figure 3. Average number of leaves in trial 1. Average number of leaves over 40 days of basil plants treated with the indicated fertilizer (n = 6). Basil plants treated with Miracle Gro all died by day 25. The total amount of leaves among the groups of coffee, control, and tea is not significant, (one-way ANOVA, p = 0.0.06489).

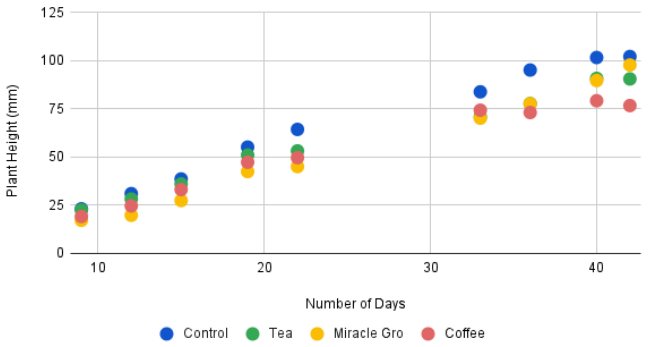

Figure 4. Average plant height in trial 2. Average height in mm over 42 days of basil plants treated with the indicated fertilizer (n=4). The final height among the groups of control, tea, Miracle Gro, and coffee is not significant, (one-way ANOVA, p=0.202537).

6-7.5 (8). Furthermore, coffee contains toxins and acids which could cause even further harm to the basil plants. For these reasons, it appears that fresh coffee grounds could cause harm to young basil plants. In a previous study that determined the impact of coffee grounds on lettuce plants, a 2.5% concentration of fresh coffee grounds significantly improved lettuce dry weight; however, as the concentration of coffee grounds increased, the dry weight fell (4). While this experiment used lettuce plants, its results do show that coffee does stunt growth, just at higher concentrations than what we applied, which was approximately 1% of mass. Miracle Gro also performed significantly worse than tea and the control, perhaps due to our testing of only basil plants. If we tested on a variety of plants, there is a possibility that Miracle Gro would yield more optimal results. Tea was shown to perform comparably to the control, possibly due to its neutral pH. The nutrients found in tea may not have had a large enough effect to cause significant growth.

Our experiment was limited by lack of resources and working around school breaks. We were unable to analyze specific quantities of nitrogen, phosphorus, and potassium, which would have helped explain the data better. Due to various lapses in the school calendar, there were slight inconsistencies with watering and lighting during both trials. In multiple instances in trial two, the basil plants had to spend time in a vehicle which created inconsistent temperature and lighting. During this same trial, the lid to the plants slid off and damaged the basil slightly. Due to trial two having suffered more turmoil, we harvested the plants two days later than we harvested the first to attempt to account for these stress factors and setbacks as described above.

If this experiment were to be replicated, we would extend the growing period. Instead of 40 days, we would monitor the plants across 70 days or more. The growth of basil with added tea leaves accelerated at the end of the trial while the growth of basil with coffee flattened out (**Figure 1**). It would be intriguing to see if the trend continues and becomes significant. Another part of the experiment that could be changed when replicated would be to use a different type of Miracle Gro. Since our samples all died with the synthetic fertilizer, we did not know if the organic fertilizer results would be comparable. In the future, therefore, we would use a fertilizer designed specifically for basil plants. Overall, the findings of our study offer a possible solution for an individual to live more sustainably, and further research should be conducted on this topic.

MATERIALS AND METHODS

In this experiment, we conducted two rounds of trials that included four different sample groups: used coffee grounds, used tea leaves, Miracle Gro 10-5-15 (10% nitrogen, 5% phosphorus, and 15% potassium), and a control with no added fertilizer. Before the growing process began, we collected soil that was a mixture of mineral-heavy yard soil and forest soil from Williamston, Michigan, to use for planting. We opted for this as opposed to store-bought soil, which usually contains many pre-added nutrients, to have the lowest content of organic material as possible. This was to ensure that there were fewer variables acting upon the basil plants. In the first trial, we used 24 nursery pots (6 for each sample). In the second trial, 16 pots were used (4 for each sample). These were set up in two small greenhouse habitats with heating mats at 80°F and a grow light for 8 hours per day, which helped maintain a humid, consistent environment.

To produce the used tea leaves, 1 L of boiling tap water was poured into a glass beaker. Eight green tea bags were added to the beaker and allowed to steep for three minutes, with stirring every 30 seconds. After three minutes, the tea bags were taken out and the leaf contents removed. The wet tea leaves were spread out on bench paper to air dry for a day and stored in a dry container. To prepare the spent coffee grounds, we brewed regular organic medium roast coffee following the instructions of the coffee brewer present. After, the coffee grounds were removed from the filter and were dried and packaged as described with the green tea leaves.

We calculated the specific amounts of tea leaves, coffee grounds, and Miracle Gro to contain similar levels of nitrogen, phosphorus, and potassium (NPK). These NPK levels approximately matched the Miracle Gro recommended dosage. After setup, we mixed our initial fertilizers into 205 g soil mixture per pot. We used 4.00 g of dried used tea leaves, 3.97 g of dried used coffee grounds, and 0.48 g of Miracle Gro. These figures were formulated using known values of NPK in coffee grounds and tea leaves (4, 9).

We then planted 10 basil seeds 1 cm deep in each pot and covered lightly with our soil mixture. The pots were then immediately watered with 30 mL of faucet water. After the basil

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seedlings sprouted, all the sprouts were removed except the three tallest in each pot. This process was utilized to ensure that the seedlings used were all similar and healthy, making the conditions among the various samples equal. Initially, the plants were watered with 15 mL three times a week, but after the second week, they were given 20 mL until the conclusion of the experiment.

After three weeks of growth, we applied a second dose of fertilizer at half of the initial amounts. The coffee and tea were mixed into the top centimeter of soil, whereas the Miracle Gro was dissolved in water and then administered. This process was repeated every two weeks until the end of the experiment. Trial one lasted 40 days, while trial two lasted 42 days to account for stress factors such as cold temperatures and inconsistent lighting encountered during the trial.

To measure the plants' progress throughout the growth period, the height (mm) and the number of leaves were recorded twice a week. At the end of the growth period, the dry and wet mass were additionally calculated. To harvest, plants were cut at the soil level and the final height as well as the total wet weight was recorded for each individual plant. The plants were then laid out on bench paper over a heating mat at 80°F, where they dried out for 144 hours. After the drying process, the weight was again measured; however, these values were so small and unreliable that the data was unusable.

At the conclusion of the experiment, the data was analyzed, and all samples were found to be normally distributed. Therefore, we chose to use a one-way ANOVA statistical significance test with a Post Hoc Tukey HSD test to obtain pairwise comparisons among the samples. The results were considered significant if the resulting p-value was less than 0.05. All statistical tests were figured using the Social Science Statistics Calculator (10).

ACKNOWLEDGMENTS

We would like to thank the brilliant Dr. Kurt Guter for encouraging and guiding us throughout this experiment and learning process.

Received: June 5, 2024
Accepted: October 28, 2024
Published: August 12, 2025

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