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Article

A juxtaposition of the effects of natural and chemical fertilizers on *Ocimum basilicum*

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SUMMARY

Fertilizers can act as a lifeline to farms in areas with low nutrient levels or provide a boost to crops in otherwise well-off areas. One of the biggest decisions a farmer has to make when it comes to fertilizing is whether to use chemical or natural fertilizer. In this study, we applied two unique fertilizers of both varieties to *Ocimum basilicum* (basil) plants to determine which fertilizer best aided plant growth. We grew basil over the course of 40 days in multiple experiments. We recorded measurements of plant height, leaf length, and leaf width three times each week. We originally hypothesized that the plants treated with chemical fertilizers would have better growth in each of the measurement categories than the plants treated with natural fertilizers. There was no significant difference between *Miracle-Gro* and fish fertilizer for plant height and leaf length, but there was for leaf width. We also found the plants treated with chicken manure to be significantly smaller than those treated with *JR Peters* in each of the three categories. Results indicated that natural fertilizers provided no apparent benefit to plant growth, while chemical fertilizers performed slightly better but did not result in increased plant growth over no fertilization.

INTRODUCTION

One of mankind's basic needs is food and one of our biggest sources of food is the agricultural industry. With the increasing world population comes a greater demand for food. Farms are struggling to keep up with the growing demand (1). On top of that, poor soil conservation and growing pollution have led to lower crop yields in many locations; this is something farmers are trying to remedy (2). A popular method to bolster plant growth is through the application of fertilizers (3). Fertilizers bolster plant growth by supplying nutrients necessary for plant growth. Nutrients necessary for plant growth are split into three different categories: primary, secondary, and neutral. The primary nutrients for plant growth are carbon, oxygen, hydrogen, nitrogen, phosphorous, and potassium (4). Fertilizers have become so popular that throughout the world, more than 80 percent of commercial agriculture uses some form of fertilizer (5). Chemical fertilizers are produced by combining certain elements necessary for plant growth, most commonly potassium, nitrogen, and phosphorous (3). While chemical fertilizers can assist plant growth, they can also have negative environmental effects. As they have become more popular, environmental concerns are more prominent in areas where these fertilizers are used due to the potential for runoff into surrounding habitats and waterways (6). They can also exhaust the soil of nutrients and hinder soil recovery because chemical fertilizers contribute to soil acidification; this results in contamination of the environment (3). Additionally, when applied, chemical fertilizers are often overused, amplifying the negative environmental impacts (7). As a result, some argue that their application harms crops more than they boost growth (8). On the other hand, chemical fertilizers provide an inexpensive boost to plants which is proven to increase plant growth and yield. The nutrients in chemical fertilizers are already inorganic, which allows the plants to utilize them as soon as the fertilizer is applied (8).

An alternative to chemical fertilizer is natural fertilizer. Natural fertilizers are attractive because of their positive impact on the environment by improving soil health (8). Oftentimes, natural fertilizers have a wider variety of nutrients compared to chemical fertilizers. Furthermore, natural fertilizers' slow release of nutrients can promote plant growth for years after application (9). Contrary to the immediate impact of chemical fertilizer, natural fertilizers, especially manures, release their nutrients over time because most of their nutrients are organic, so plants cannot use them until the nutrients are mineralized and become inorganic (9). Thus, plants often do not reap the benefits of natural fertilizers until much later in the growing season. However, natural fertilizers are often more expensive than chemical fertilizers.

This research sought to find the best type of fertilizer for aiding plant growth. While there is ample research conducted on the effects of different fertilizers on soil health, there is relatively little on the effect of fertilizers on plant growth and crop yield. As such, this research explored the effects of different chemical and natural fertilizers on the growth of *Ocimum basilicum* (basil plants). We chose *Ocimum basilicum* due to its quick growth period, minimal space requirements, and easily measurable physical characteristics. We grew basil plants for 40 days and treated them with different fertilizers and amounts of water. Three times per week, we measured the plant height, leaf width, and leaf length to compare growth between groups.

We hypothesized that the basil treated with chemical fertilizers would grow larger in all measurement categories than the basil grown with natural fertilizers. We also hypothesized that plants that received more water would grow more than those receiving less water.

RESULTS

The goal of this experiment was to determine the optimal fertilizer for aiding the growth of basil. To do this, we first planted 50 basil plants. 20 were treated with *Miracle-Gro*, 20 were treated with fish fertilizer, and 10 were control plants.

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Because soil is a potentially confounding variable, it was not used; instead, perlite was the growth medium, as perlite allowed for studying benefits of the fertilizer and not how the fertilizer interacted with and possibly aided the soil. Also, perlite had no preexisting nutrients, so there was no possible variability in nutrient content. To further prevent confounding variables, a control group was used. We chose *Miracle-Gro* because it is one of the most common commercially available fertilizers and we chose fish fertilizer because it was one of the few natural fertilizers available at a local greenhouse. We found that the plant height and leaf length was consistent between the three groups ($p > 0.05$) (**Figure 1**). However, the control group did have significantly wider leaves, compared to both the natural and chemical fertilizer group ($p < 0.05$, $p < 0.05$ respectively).

Next, we asked if altering the chemical or natural fertilizer would change our results. As such, we used *JR Peters* for the chemical fertilizer because it had equal parts of nitrogen, potassium, and phosphorus. We used chicken manure for the natural fertilizer because of prior experience with it and it was the other natural fertilizer at a local greenhouse. This experiment was conducted in the exact manner as the previous experiment with the exception of the different fertilizers. We found the height of plants treated with chicken manure to be significantly smaller than plants treated with *JR Peters* or no fertilizer ($p < 0.01$). We found significant differences in leaf length, with the control group having significantly longer leaves than the chemical group and natural group ($p = 0.0375$ and $p = 0.0001$, respectively). Additionally, the control and chemical groups had significantly wider leaves than plants treated with chicken manure (both $p < 0.01$).

Since the plants in the second experiment (*JR Peters*, chicken manure) did not grow as well as they had in the previous experiment (*Miracle-Gro*, fish fertilizer), concerns of whether we were watering the plants enough arose. We decided to conduct a third experiment by adding another variable of increased watering which consisted of 20 plants treated with chicken manure, 10 treated with *JR Peters* fertilizer, and 10 control plants. We used 40 plants in this experiment instead of 50 because we only had 40 plant pots available for this experiment as opposed to the 50 we had for the previous experiments. We also decreased the amount of chicken manure per plant from 2.5 tbsp to 1.25 tsp because we suspected that we had over-fertilized the plants in this group. Here we found the plants treated with the chicken manure to have significantly smaller heights, leaf lengths, and leaf widths than control plants and plants treated with *JR Peters* ($p < 0.01$) (**Figures 2 and 3**). Control plants and plants treated with *JR Peters* fertilizer were not significantly different in any of the measurements ($p > 0.05$).

When we altered the watering frequency during the second experiment, we thought that it would result in more viable plants. We increased watering from 75mL, two days per week to 75mL, four days per week. As a result, on average, 50% more of the seeds planted survived in the third experiment in the control and chemical groups compared to those plants in the second experiment (**Table 1**).

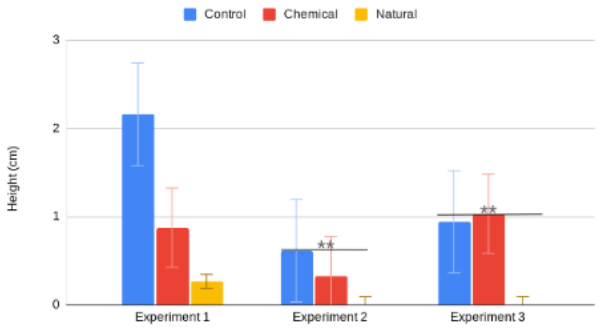

Figure 1. Mean plant height of basil plants treated with chemical or natural fertilizers after 40 days. A bar graph showing the mean plant height for each treatment and experiment on day 40. Plants were treated with either a chemical fertilizer (experiment one: *Miracle-Gro*, experiment two: *JR Peters*), natural fertilizer (experiment one: fish fertilizer, experiments two and three: chicken manure), or no fertilizer for three separate experiments. Error bars represent mean ± standard error. * $p<0.05$, ** $p<0.01$).

DISCUSSION

Based on our results, we determined that the *JR Peters* and *Miracle-Gro* chemical fertilizers are better than natural fertilizers for aiding basil growth. The chicken manure yielded no viable plants, so the *JR Peters* fertilizer greatly outperformed it. However, plants that received no fertilizer also grew better than those treated with natural fertilizer. By observation, even though no significance was found, it appeared that the plants treated with both chemical fertilizers grew taller than those not treated with fertilizer, but a greater proportion of plants that received no fertilizer survived compared to those that received any fertilizer. With these results in mind, one cannot say for sure that either of the chemical fertilizers truly aided plant growth because of the greater number of dead plants. Instead, we might infer that natural fertilizers inhibited plant growth. As to why the plants treated with the chicken fertilizer did not grow, we did not find any clear reasons. We initially thought that either the plants did not receive enough water or were too heavily fertilized. That is why we replanted them with a greater amount of water and less manure applied to each plant pot. Since none of the plants grew after the adjustments, it is compelling to say that the manure is not a good fertilizer for basil. However, when accounting for the nutrients in chicken manure, NPK (Nitrogen, Phosphorous, Potassium) values were normal, but calcium levels were very high. According to the package, chicken manure had an eight percent calcium content, which was higher than each of the NPK values. While calcium is necessary for plant growth, the high levels could have had a negative impact on the plants (9).

	Control	Chemical	Natural
Experiment 1	0.9 (10 plants)	0.5 (20 plants)	0.55 (20 plants)
Experiment 2	0.2 (10 plants)	0.1 (20 plants)	0 (20 plants)
Experiment 3	0.75 (10 plants)	0.6875 (10 plants)	0 (20 plants)

Table 1. Plant survival rates. The table shows the survival rates of basil plants for each treatment and experiment. Basil plants were grown for 40 days with either a chemical fertilizer, natural fertilizer, or no fertilizer.

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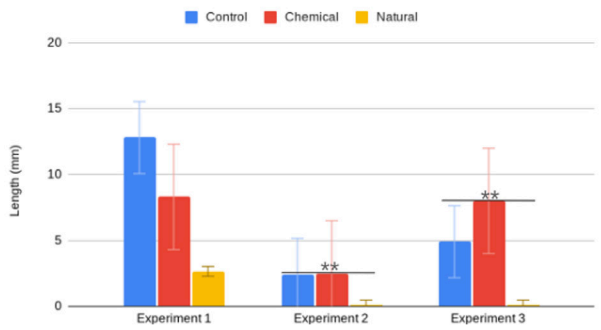

Figure 2. Mean leaf length of basil plants treated with chemical or natural fertilizers after 40 days. A bar graph showing the mean leaf length for each treatment and experiment on day 40. Plants were treated with either a chemical fertilizer (experiment one: *Miracle-Gro*, experiment two: *JR Peters*), natural fertilizer (experiment one: fish fertilizer, experiments two and three: chicken manure) or no fertilizer for three separate experiments. Error bars represent mean ± standard error (* p<0.05, ** p<0.01).

We took measurements of leaf length and leaf width in addition to plant height because different fertilizers can affect plants in different ways due to their nutrient makeup (10). For instance, it was interesting that the leaf length test for the *JR Peters* fertilizer and chicken manure experiment showed that the control group had significantly longer leaves than those that were fertilized with either fertilizer. We believe this is due to 18 plants dying in the group treated with the *JR Peters* fertilizer and 20 dying in the group treated with the chicken manure compared to eight deaths in the control group. Every plant that died counted as a zero during our tests which results in lowered means for the measurements. Leaf length tests for experiments with chicken manure and *JR Peters* as fertilizers were impacted similarly. Fertilizers can benefit plants in various ways but since nutrients come in a very concentrated amount, plants (especially seedlings) can burn so one must be careful with how much fertilizer they use (11). Fertilizers are often less hazardous when they are water-soluble because the fertilizer solution decreases the concentration of nutrients (11). The water-solubility may be another reason why plants treated with chicken manure could not grow, as the chicken manure was the only fertilizer used that was not water-soluble.

I f we used a different plant, we do not think the results would change much since the nutrients necessary for plant growth are quite similar for most crop-producing plants (4). However, a hardier plant than basil may have been able to withstand the chicken manure, which may have yielded different results. Staple crops that are more popular in the United States, such as corn or soybeans, would be better to use for this project.

The primary limitation of this study was the time allotted. Since the experiment took place over four months, there was not enough time to conduct two experiments of full two-and-a-half-month growing periods. Instead, there were 40 days for each experiment. This time constraint limited the capacity to which the plants' reactions to their assigned fertilizers could be observed. Furthermore, with more time, we could have conducted more experiments and obtained a larger sample size. Larger sample size would have resulted in more viable results since, for some tests, the sample size was only 10.

If this research were to be continued, more sampling and treatments would be needed. Many more fertilizers of each type would need to be tested because results cannot be generalized to the entire populations if only two treatments of chemical and natural fertilizers are used. Furthermore, we recommend using a different growth medium because perlite is supposed to be a soil amendment not the sole medium a plant is grown in. Changing the medium would ideally result in higher plant viability. Peat is a growth medium similar to perlite. Peats have better water-retention properties and have more nutrients compared to perlite. Both mediums have been used on farms as a soil amendment. A recent study conducted found that perlite and peats had no significant differences in impact on plant growth but had different properties pertaining to nutrients and carbon dioxide retention that could have an impact (12). Overall, our results indicated that chemical fertilizers better assist plant-growth than natural fertilizers, but chemical fertilizers do not provide a significant benefit over plants not treated with fertilizer. Our results suggest that fertilizers are unnecessary and that farms could save lots of money without using fertilizers. However, we do know that fertilizers do have a positive effect on plant growth due to the numerous published studies that prove the benefits of fertilizers. Our results, while valid, cannot be extrapolated to commercial farms because we grew our plants with a different method compared to commercial farms. Our research is important because it shows that plants can grow solely by being watered and without gaining nutrients from soil or fertilizer.

MATERIALS AND METHODS

In this study, the effectiveness of chemical (Miracle-Gro® Water Soluble All Purpose Plant Food and JR Peters 52008 Jacks Classic 20-20-20 All Purpose Fertilizer) and natural fertilizers (Espoma Organic Chicken Manure and Neptune's Harvest Organic Fish Fertilizer) on *Ocimum basilicum* was tested. Three experiments were conducted, with the difference between the second and third experiments being altered watering frequencies and chicken manure amounts. For each experiment, plastic plant pots were filled (3.5 in x

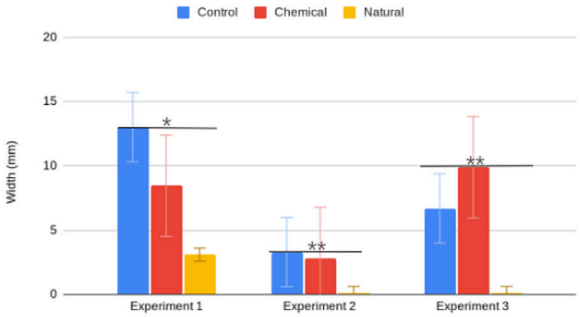

Figure 3. Mean leaf width of basil plants treated with chemical or natural fertilizers after 40 days. Bar graph showing mean leaf width for each treatment and experiment on day 40. Plants were treated with either a chemical fertilizer (experiment one: *Miracle-Gro*, experiment two: *JR Peters*), natural fertilizer (experiment one: fish fertilizer, experiments two and three: chicken manure), or no fertilizer for three separate experiments. Error bars represent mean ± standard error (* p<0.05, ** p<0.01).

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3.5 in x 5 in) with Vigoro Organic Perlite Soil Amendment up to one inch from the top. The plant pots were arranged inside three Super Sprouter Deluxe Propagation Kits (20 in x 10 in x 7 in) containing 18-inch T5 grow lights. The grow lights were connected to timers, which were set to be on for 12 hours per day. The kits were placed on top of a BN-LINK Heat Pad set at 73 °F to maintain consistent temperatures. To start each experiment, the basil seeds were soaked in lukewarm water for 12 hours prior to planting to improve germination rates (13). Then, one soaked seed was planted one-half inch under the surface of the perlite and watered with 50 mL of water for each pot. If a seed had been planted for two weeks and did not sprout, it was recognized as dead.

For each experiment, a sprouted plant was considered dead if it had dried out and withered. Measurements of plant height (base to top in cm), leaf length (stem to tip in mm), and leaf width (widest part of the leaf in mm) were taken three times per week. The leaf measurements were cumulative for all of the leaves of each plant. All values were recorded in a spreadsheet that calculated the mean and standard deviation from each treatment group. After each experiment, pots were emptied and cleaned to prevent skewed results from fertilizer residue.

For experiment one, 20 plants were treated with natural fertilizer, 20 were treated with chemical fertilizer, and 10 were control plants. The fertilizers used for experiment one were Neptune's Harvest Organic Fish Fertilizer and Miracle-Gro® Water Soluble All Purpose Plant Food. Both fertilizers used in experiment one were water soluble, allowing for simultaneous fertilization and watering of the plants on the second watering of the week. Fertilization amount was determined by package directions, amounting to once a week for both the *Miracle-Gro* (0.5 tsp per gallon) and the fish fertilizer (1.5 tsp per gallon). Control plants received the same amount of unaltered water on watering days. In the first experiment, each plant was watered with 50 mL twice a week for the first week and then 75 mL for the rest of the growing period. This first experiment lasted for 40 days.

For experiment two, different fertilizer treatments were tested. Here, the JR Peters fertilizer was used as a chemical fertilizer, and the Espoma Organic Chicken Manure was used as the natural fertilizer. 20 plants treated with chicken manure, 20 plants treated with the JR Peters, and 10 control plants were planted. To apply the chicken manure, 2.5 tbsp was placed on top of the perlite one time after the soaked seeds were planted. The chemical fertilizer was applied once every two weeks, per package directions. The control group procedure was unchanged. After two weeks, none of the plants treated with chicken manure had sprouted, so this led to new plants and adjusted manure amount of 1.25 tsp per pot, mixed with the perlite before any seed was planted.

In the third experiment, the fertilizers were kept the same, but all of the dead plants in the chicken manure group was replanted (seeds were still soaked beforehand). For this new experiment, 20 seeds were planted with 1.25 tsp of chicken manure mixed throughout the perlite and watering was increased to four days of 75 mL. After two weeks, none of the plants treated with the chicken fertilizer grew, so those were discarded, and 20 new plants, with the increased watering, were planted (10 control and 10 treated with the chemical fertilizer). Measurements were again recorded three times per week.

The three major measurements (plant height, leaf length, and leaf width) were all examined with a one-way ANOVA, followed by the Tukey HSD test.

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