Comparing the Effects of Various Fertilizers on the Germination Rates of Various Herb Species

Taylor R. Simkins, Maureen Cagnon, Sarah Greeley, Kavon Salehi, Sarah Schmidt, Joshua Schuman, Tyler Tischler, and Alyssa Yerkeson.

University of Cincinnati

21 April 2021

Abstract

There is little published research on growing indoor plants. Homeowners want to know how various fertilizers will affect herb species, as well as the best germination method. In this study, we will compare the individual effects of nitrogen, potassium, and phosphorus fertilizer on the germination stages of oregano, parsley, basil, and sage in an indoor setting. Germination was conducted in two parts: one part with seeds in homemade germination trays and the other part includes planting seeds directly into pots. We additionally compared grow lights versus natural window lighting, application of fertilizer in rock form versus diluted with water, and compost versus soil bedding. The focus of the study is to examine these different aspects of indoor gardening with the aim to educate homeowners of the best practice to pursue when growing indoor herbs. At the conclusion of the study, we discovered the different preferences of germination setting for each of the herb species.

Introduction

Today, sustainable, and regenerative practices are arguably more important than they have ever been, especially in agriculture. Fortunately, there is extensive amounts of research when it comes to growing crops, which fertilizers to use, and what is most effective overall for each crop to thrive. If you explore for studies on growing indoor plants or herbs, there is little research conducted. To promote sustainable practices within homes, there needs to be an easy-to-read guide of what is best for indoor herbs and plants. Not only do homeowners want to know which fertilizers to use, they also want to know which lighting option is best for their plant growth. These variables are most important when it comes to producing the highest yield of herbs.

The composition of fertilizers consists mainly of the three major macronutrients: Nitrogen, Potassium, and Phosphorus. These three nutrients are what ensures plants will have optimal growth, give the highest yield, and grow to their full potential. There is no dispute as to whether utilizing them works or not. The science field has already established that they have a very necessary place when it comes to growing crops, or any plant for that matter. Specifically, what we already know is that nitrogen will help a plant maintain their health and promote photosynthesis. This includes the formation of chlorophyll and the growth of the plant cells and tissue (Duran-Lara, 2020). We already know that phosphorus helps a plant convert other nutrients into usable building blocks to grow. If the plant is small, not producing flowers, or has a weak root system, it is probably because there is a phosphorus deficiency. Furthermore, we know that potassium is not used in the structural synthesis of biochemically important molecules but is found within the plant cell that maintains the turgor pressure of the cell. It also allows water vapor and waste to escape through the bottom of leaves. If a plant starts to yellow or crinkle, it probably needs more potassium (Bloodnick, 2021).

With that being said, the purpose of the experiment was not to study the effects of what nitrogen, phosphorus, and potassium fertilizers do but to study how each of these nutrients might optimize the growth of various indoor herbs. This study will focus on a small scale, indoor use for all people. To provide a wide range of data, we investigated comparison between germinating under grow lights versus natural window lighting, germinating in a layer of kitchen compost versus potting soil, and germinating seeds in homemade germination trays. By the end of the study, the germination rate will be calculated per tray and pot. Each of the fertilizers added are predicted to have different effects on the growth rate of each of the herb species. The various herb species that are examined during this study include oregano, basil, parsley, and sage. Each of these herbs are popularly chosen for indoor gardening.

Methodology

Germination Trays

For the first part of the experiment, the seeds were germinated in homemade germination trays. Payamani et al. performed germination experiments for hedge parsley by lining a petri dish with a moistened filter paper (2018). In our study, each participant took four plastic containers and lined the bottom of the containers with a damp paper towel, sprinkling 40 seeds on top of the paper towels. One of the germination trays contained only seeds and the paper towel. This grouping is referred to as the control group. The three other germination trays each contained different fertilizers: one contained Urea Nitrogen fertilizer, another contained

Easy Peasy Plants Potassium fertilizer, and the third contained Triple Super Phosphorus fertilizer. One teaspoon of each fertilizer was added straight from the bag in rock form to the separate germination trays.

Eight participants made up the group, so everyone was paired with another to compare the effects of grow lights versus natural window lighting. One partner pair germinated oregano, another partner pair germinated basil. The third partner pair germination parsley, and the fourth pair germinated sage. The grow lights were set at high power for 12 hours a day. The participants germinating with natural window lighting chose a room that contained moisture and humidity with 12-hours of indirect lighting daily. All trays were sprayed with a spray bottle 5 times daily to keep the paper towel moist. Additionally, there were some participants that covered their trays with plastic cling-wrap and some participants didn’t cover their trays at all.

For the four oregano germination trays under grow lights, the average temperature was 68- to 70-degrees Fahrenheit. The other four oregano germination trays were placed on a counter 4-feet from an east-facing window. The temperature of the room remained between 70- and 73-degrees Fahrenheit throughout the day. All eight germination trays experimenting with oregano had plastic cling-wrap placed over top of the trays.

The four basil germination trays under grow lights stayed in a room with a temperature range of 70- to 73-degrees Fahrenheit throughout the day. The other four germination trays for basil were placed a few feet from a southwest-facing window to receive indirect lighting. The average temperature was 70-degrees Fahrenheit. All eight germination trays were covered with plastic in some way.

For the germination of parsley, none of the eight trays were covered. The four trays under grow lights stayed in a room that maintained 68-degrees Fahrenheit. The other four trays were placed 2-feet away from a northeast-facing window that maintained an average temperature of 67-degrees Fahrenheit.

Lastly, the germination trays experimenting with sage were inconsistently tested because four were covered with plastic cling-wrap and four were uncovered. The four trays that were covered were placed 6-inches away from a south-facing window. The average temperature of the room was 70-degrees Fahrenheit. The four trays that were left uncovered were under grow lights in a room with the temperature between 68- and 70-degrees Fahrenheit.

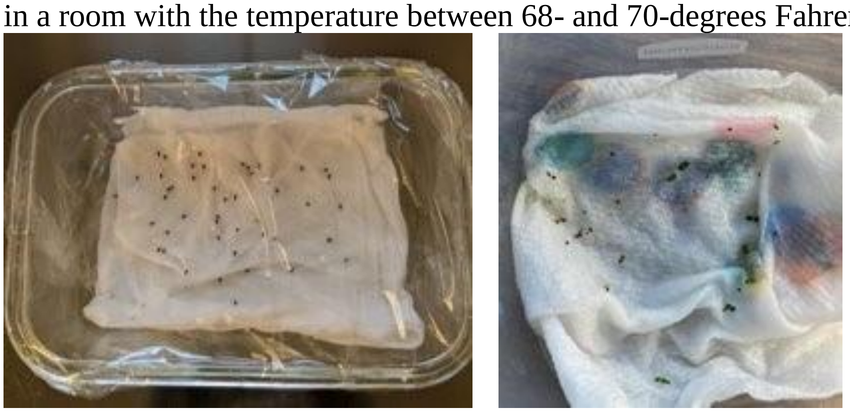

Fig 1. Experimental design of germination trays.

Planting in Pots

For the second part of the experiment, the group performed another germination process that involved planting the seeds directly into 6-inch flowering pots. Each pot had 1 cup of pebbles as the bottom layer, with 5 cups of Expert Gardener Potting Mix. This type of indoor and outdoor potting soil contains nitrogen, phosphate, and soluble potash. All pots were set directly next to the window that received 12 hours of light each day.

We also compared the effects of compost versus potting soil during the experiment. Half of the group performed their experiments with another cup of potting soil as the top layer. The other half of the group performed their experiments with 1 cup of kitchen compost as their top layer. The kitchen compost mainly consists of eggshells, wood chips, banana peels, broccoli stems, peppers, onion peels, and leaves. All pots had approximately 10 seeds planted ¼-inch below the top layer.

Each of the fertilizers tested were diluted with water before applying to the newly planted seeds. The dilution ratio was 1 tablespoon per half gallon of water, shaken thoroughly before applying. Every day of the week, we watered the pots. One pot was designated to receive no diluted fertilizer, while each of the other three were split up by the diluted fertilizer that was added to them every Wednesday and Sunday morning. On the first day of the experiment after planting, we watered with 200 milliliters. Some individuals found that this was too much so as a group, we decided to lower the amount of water to $1/4^{th}$ a cup. To avoid over watering, we felt the soil's moisture by finger before applying the water each morning.

One partner pair germinated oregano. The four pots with only potting soil sat in an east-facing window with the temperature between 68- and 70-degrees Fahrenheit. The four compost additive pots sat in an east-facing window as well, with a 70- to 73-degrees Fahrenheit range.

Another partner pair germinated basil. The potting soil only pots for this pair sat in a north-facing window with a 70- to 73-degree temperature range. The compost pots sat in a south-west-facing window with an average of 70-degrees Fahrenheit throughout the day.

Parsley is known to take 5-6 weeks to germinate (Albert) so for the sake of time, the partner pair that performed the germination of parsley in the germination trays, switched to germinating sage for the germination in pots experiment. Eight pots contained potting soil only and eight pots contained potting soil plus a layer of compost. Four of the potting soil pots sat in an east-facing window with the average temperature at 67-degrees Fahrenheit. The other four potting soil pots sat in a south-west-facing window. The temperature was an average of 68-degrees Fahrenheit. Four of the compost additive pots sat in a west-facing window with a temperature range of 68- to 70-degrees Fahrenheit. The other four compost additive pots sat in a south-facing window with an average temperature of 70-degrees Fahrenheit.

Figure 2. Experimental design for germination within flowering pots with compost and/or potting soil. (Left) Pots sat in window that received 12-hours of light. (Right) Example of the separate water gallons for each pot.

Results

Germination Trays

28 days after planting the seeds, all the herb species germination trays calculated their germination rate. For oregano, both the control under grow lights and the control under natural window lighting successfully showed signs of life. The first seeds germinated after 7 days for the control tray under grow lights. At the end of the study, there was a 75% germination rate. There was a 50% germination rate for the control tray under natural light. The first sprout occurred 8 days after planting for this pot. All other trays with fertilizer additive for both grow lights and natural light had 0% germination rates. The total percentage of seeds that didn't sprout for all oregano trays was 84%.

The basil experiments were all successful. First, we will look at the germination trays under the grow lights. Both the nitrogen fertilizer tray and phosphorus fertilizer tray sprouted on day 9. The nitrogen fertilizer tray had 10% germinate, and all died after 3 days. The phosphorus fertilizer tray had a 5% germination rate. For the control tray, the first sprout appeared after 5 days. There was a 100% germination rate for the control tray after 28 days. The basil with potassium fertilizer additive had 0% germination. Next, we will examine the germination trays for basil under indirect natural window lighting. The control tray had its first sprout after 5 days, with 100% germination after 28 days. The nitrogen fertilizer tray sprouted after 13 days, with 3 sprouts. After 2 days, the sprouts browned and died. The phosphorus and potassium trays did not germinate.

Unfortunately, all the parsley and sage germination trays did not show growth after 28 days.

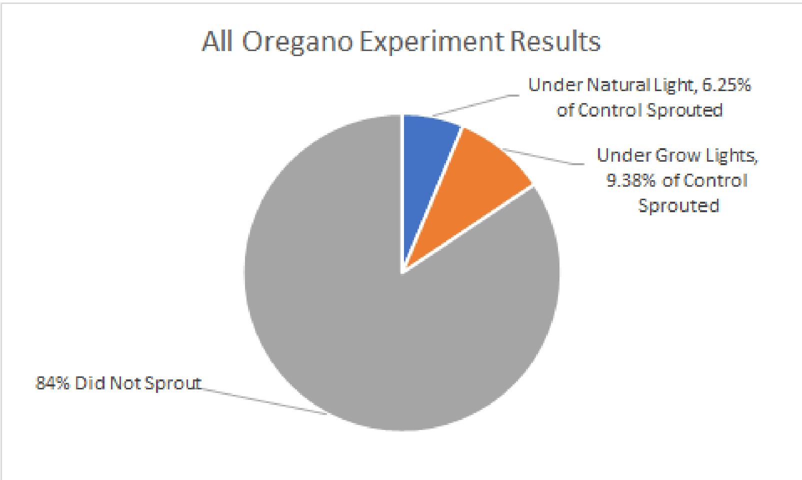

Figure 3. This graph depicts the overall results of all oregano germination trays. The percentage of sprouts out of total seeds throughout all trays are displayed. The 84% that did not sprout includes all fertilizer trays plus the few that didn't sprout in both control tray experiments.

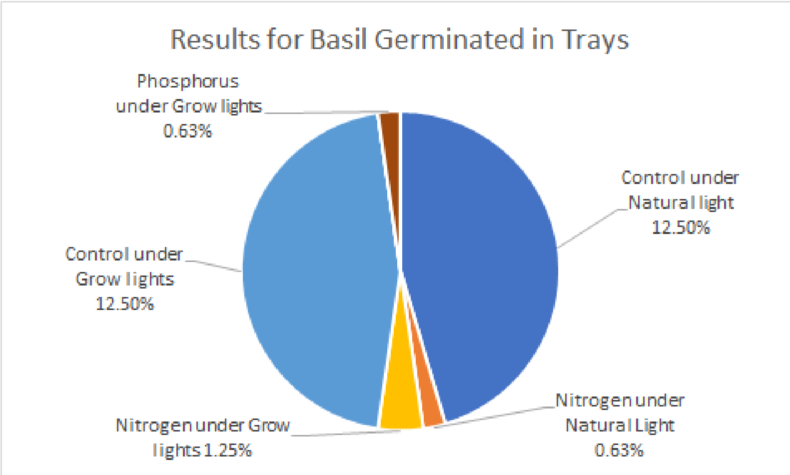

Figure 4. This graph depicts the overall results for all basil germination trays that did sprout. There were 320 seeds expected to germinate. Each section reflects the percentage of total seeds per tray tested.

Planting in Pots

Observations ended 24 days after originally planting the seeds into the compost or potting soil.

Both oregano in potting soil and in compost did not sprout from their nitrogen pots. Although, all other pots showed some sprouting. The control pot without fertilizer was the first to sprout for both groups. Laid out as a timeline, the compost control sprouted after 6 days. Next to show growth were the compost potassium and phosphorus pots that sprouted on day 11. On day 13, the potting soil control and phosphorus pots sprouted. Finally, on day 14, the potting soil potassium showed growth. We compared the germination rates of compost pots to potting soil pots and found that oregano yielded better results in compost. 100% of the seeds planted in compost phosphorus pot sprouted while, 30% germinated in the potting soil phosphorus pot. The compost control pot surpassed the potting soil control pot by 50% more (compost control pot: 80%; potting soil control pot: 30%). Lastly, the potting soil potassium pot did better than the compost potassium pot (potting soil K pot: 40%; compost K pot: 20%).

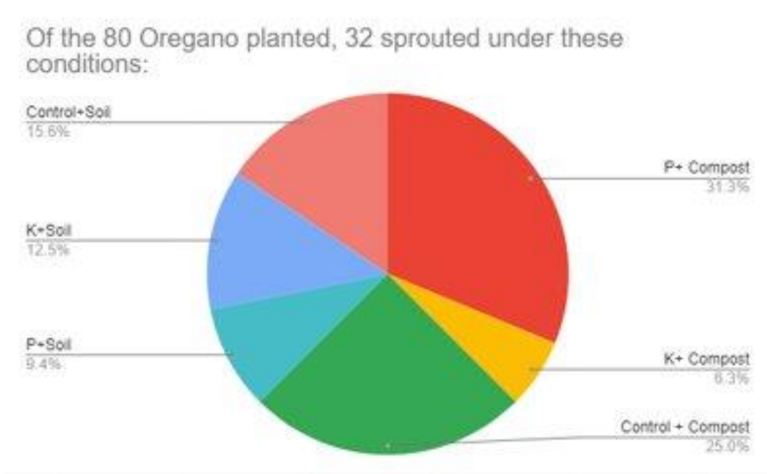

Figure 5. This graph depicts the data collected from all oregano experiments that were potted. Out of the total number of seeds that sprouted, each percentage correlates with the conditions of each experiment component.

All basil experiments without fertilizer and with fertilizers applied showed growth after 24 days. The first to sprouts appeared on day 6 from the compost phosphorus pot, the potting soil control pot, and the potting soil phosphorus pot. The next sprouts appeared on day 7 from the compost control pot and the potting soil nitrogen pot. The potting soil potassium pot sprouted on day 8 and the compost nitrogen sprouted on day 10. Lastly, the compost potassium pot sprouted on the 12th day of the experiment. We compared the germination rates of compost pots to potting soil pots and found that basil seeds preferred potassium when planted in the soil but preferred no fertilizer or nitrogen additive when planted in kitchen compost. The potting soil pots' germination rates are as follows: 100% germination from potassium pot, 60% germination from control pot, 10% germination from nitrogen pot, and lastly, 4% germination from the phosphorus pot. As for the compost pots, there was a 100% germination rate from both the control pot and nitrogen pot. 80% of the seeds germinated in the potassium pot and lastly, 70% germinated in the phosphorus pot.

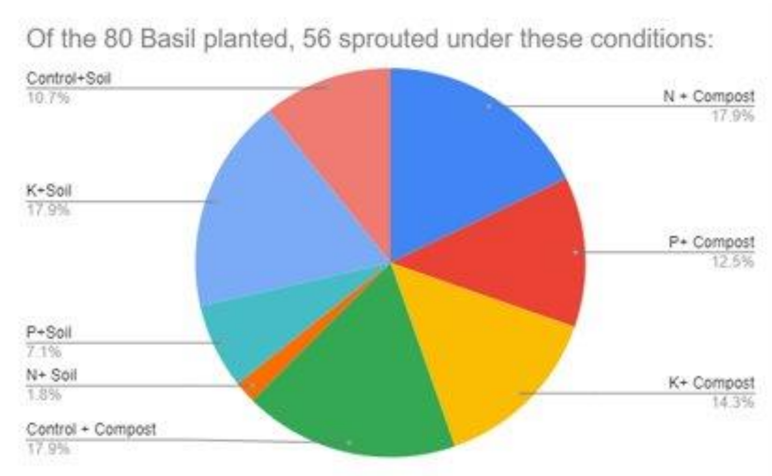

Figure 6. Out of the total number of seeds that germinated for the basil experiment, the graph shows a visual representation of the percentage of germination that occurred under each experimental condition.

As a reference, there were four experimental conditions that the sage seeds underwent: planted in potting soil and placed in a northeast-facing window, planted in potting soil and placed in a west-facing window, and two experiment groups planted in compost and placed in a south-facing window. The sage seeds planted in potting soil did better without fertilizer added. On day 14, the first sprout appeared in the potting soil control in the west-facing window. On day 16, the next sprouts appeared in the potting soil control pot and the potting soil phosphorus pot both in the northeast-facing window and the potting soil phosphorus pot in the west-facing window. Both the potting soil pots with potassium fertilizer additive sprouted on day 19. Lastly, the potting soil nitrogen pot in the west-facing window sprouted after 20 days. The potting soil nitrogen pot in the northeast-facing window had a 0% germination rate. The nitrogen pot in the northeast-facing window died after a few days so the germination rate became 0%. The germination rates of the other pots in the northeast-facing window are as follows: 4% germination from potting soil phosphorus pot, 2% germination from potting soil control, and 1% germination from potting soil potassium pot. For the sage pots in the west-facing window, the potting soil control pot had a 9% germination rate, the potting soil phosphorus pot had a 7% germination rate, and the potting soil potassium pot had a 5% germination rate.

The sage seeds planted in compost showed a higher yield than those in the potting soil. Both compost experiments were placed in a south-facing window. One of the experiments only yielded sprouts from the compost control pot and no sprouts from the fertilizer pots. For this compost control, the first sprout was after 18 days. The first to show a sprout from the other group was from the compost control pot, occurring on day 16 after planting. The next to show sprouts were the compost potassium and compost phosphorus pots after 17 days. The last to sprout was compost nitrogen pot on day 18. The highest germination rate was from the pots without fertilizer. One experiment yielded a 20% germination rate and the other only 9% germination. The compost phosphorus pot yielded a 7% germination rate, and the compost potassium pot had a 5% germination rate. Lastly, the sprouts in the compost nitrogen pot died, causing a 0% germination rate after 24 days.

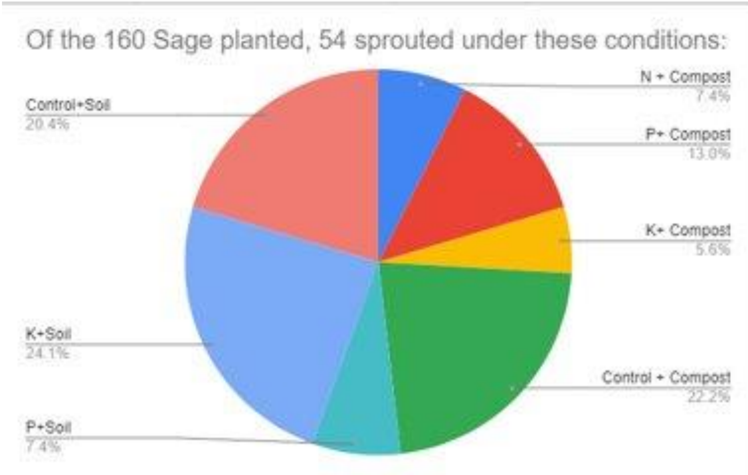

Figure 7. The graph shows the comparison of sage germination under each experimental condition.

Discussion

Originally, performing each experiment under the conditions of each participant's home was thought to be ideal to produce results that the average homeowner could recreate. The COVID-19 restrictions also supported this idea since we could not use a lab on campus. Unfortunately, the different conditions of everyone's home caused complications. The temperature and humidity of each room that the experiments were held in were not measured using tools other than a thermostat and majority of the experiment locations did not have the same temperature range. The group tried to control this variable by using space heaters. An important factor that was not discussed prior to the start of the study was the adequacy of the different buildings. Two of the buildings were older and a draft could cool the room that the seeds were in when the temperature drops outside. Another condition that was hard to control included the window that each experiment was placed in. Each participant chose the window that received specifically, 12 hours of light each day. Some group pairs were able to coordinate but others did not have that option. Although each experiment had slightly different living conditions, there is a benefit to having all this information.

A homeowner that is exploring growing indoor herbs can examine the specific characteristics of each living condition and how the herbs were taken care of to gain knowledge on what suits their home lifestyle. For example, oregano in potting soil took slightly longer to germinate than oregano in compost. The temperature range was slightly lower so the temperature difference could have affected the germination rate.

Germination Trays

Additionally, there were some participants that covered their trays with plastic cling-wrap and some participants didn't cover their trays at all. The individuals that did cover their trays with plastic cling-wrap and had growth, noticed that their seeds browned and died. Although mold wasn't directly observed with the naked eye, a prediction that damping-off fungi was present within the germination trays. "Damping-off fungi is a problem in cold soils with poor drainage, and in conjunction with overwatering" (Cain, n.d.). Although the seeds were in germination trays with a damp paper towel and not soil, one can predict that the seeds received too much moisture or might not have received enough humidity to evaporate the water sprayed on the seeds.

The fertilizer was added to the trays directly from the bag in rock formation. The group knew that fertilizer could be applied as a solid, solution, or a foliar spray (U of Minnesota Extension, 2018). After many of the experimental germination trays did not appear to sprout, I have predicted that this was a result of overnutrition of nutrients to the seedlings.

Planting in Pots

After 4 days, some of the individuals with compost noticed a spider mite and fungus gnat infestation. Google was used to find a quick solution to control this pest control and found that "using 3% hydrogen peroxide, adding 1 teaspoon per cup of water in a spray bottle and misting the plant" will aid in getting rid of the pests (Grant, 2020).

Mold growth showed presence only with 3 out of the 32 total pots. All pots were under natural lighting. One case appeared to be with sage pot without any added fertilizer. Two other cases appeared in the basil experiments: once in the control pot and the other in the phosphorus pot. Once the mold growth was observed, each participant removed the mold with a paper towel and didn't water the pot for the day.

Conclusion and future prospective

Growing these herbs indoors under the conditions described above showed valuable results. When germinating in homemade germination trays, adding fertilizer in rock form was predicted to inhibit germination of oregano seeds. For basil seeds germinating in trays, the seeds preferred to have no fertilizer applied to them. The oregano seeds were more prosperous in the compost bedding and sprouted at a faster rate than the oregano seeds in potting soil. Basil seeds yielded a higher germination rate in compost than potting soil without fertilizer applied. Adding diluted phosphorus fertilizer to the seeds showed to cause sprouting faster, but not necessarily resulted in the highest germination rate. Of the total seeds that germinated, the highest germination rates for sage were observed in potting soil potassium pot (24.1%), compost control pot (22.2%) and potting soil control pot (20.4%).

Currently, there is little scientific research on growing indoor herbs and how to create the best condition to optimize the germination rates. This study can contribute to knowledge on different species of herbs and their responses to a combination of nutrient-based fertilizers. The work that has been conducted expands on a wide range of environmental conditions that can be taken to implement in the homes choosing to conduct indoor gardening. Using the results found, a guide or chart can be created that elaborates on each herb species, as well as the response to fertilizer, lighting, germination processes, and bedding type. If further research were to be conducted, observations on height of each herb species under each condition would be noted, as well as how many leaves per herb and the color shade of stems and leaves. Consideration of having all the herb experiments conducted in one home would be ideal for replication to control the other factors that might have contributed to the results we got, aside from the factors being tested (ex. temperature of room).

Acknowledgements

Thank you to Dr. Susanna T.Y. Tong, Professor and Director of Environmental Studies Program, and Dr. Teri Jacobs, Professor and Director of EVST Undergraduate Studies. Both overwatched the project and provided helpful insight that guided the direction of the study.

References

Albert, Steve. "How To Grow Parsley." *Harvest to Table, https://harvesttotable.com/how-to-grow-parsley/*

Baeten L, Vanhellemont M, De Frenne P, De Schrijver A, Hermy M, Verheyen K. "Plasticity in response to phosphorus and light availability in four forest herbs." Oecologia. 2010 Aug;163(4):1021-32. doi: 10.1007/s00442-010-1599-z. Epub 2010 Mar 19. PMID: 20300776.

Bloodnick, Ed. "Role of Potassium in Plant Culture." *Promix*, 3 February 2021. https://www.pthorticulture.com/en/training-center/role-of-potassium-in-plant-culture/

Cain, Bob. "Why Did My Seedling Die?" *Washington State University Extension Master Gardener Program*, pp. 1-2. https://s3.wp.wsu.edu/uploads/sites/2069/2013/05/04-21-2011-Why-Did-My-Seedling-Die-_This-Weeks-Garden_.pdf

Ditta, Arshad, Zahir and Jamil. "Comparative Efficacy of Rock Phosphate Enriched Organic Fertilizer vs. Mineral Phosphate Fertilizer for Nodulation, Growth and Yield of Lentil." *International Journal of Agriculture and Biology*, vol. 17, no. 3, 2015, pp. 589-595.

Duran-Lara, Esteban F., Aly Valderrama, and Adolfo Marican. "Natural Organic Compounds for Application in Organic Farming." *Agriculture (Basel)*, vol. 10, no. 2, 2020, pp. 41.

Grant, Amy. "Garden Uses For Hydrogen Peroxide: Will Hydrogen Peroxide Hurt Plants." *Gardening Know How*, 12 March 2020. https://www.gardeningknowhow.com/garden-how-to/soil-fertilizers/using-hydrogen-peroxide-in-garden.htm

"Herbs in Containers and Growing Indoors." *University of Maryland Extension*, extension.umd.edu/hgic/topics/herbs-containers-and-growing-indoors.

Payamani, Rezvan, et al. "Variations in the Germination Characteristics in Response to Environmental Factors between the Hairy and Spiny Seeds of Hedge Parsley (Torilis Arvensis Huds.)." *Weed Biology & Management*, vol. 18, no. 4, Dec. 2018, pp. 176–183. *EBSCOhost*, doi:10.1111/wbm.12165.

Roba, T. B. (2018). Review on: The Effect of Mixing Organic and Inorganic Fertilizer on Productivity and Soil Fertility. Open Access Library Journal, 5(6), 1-11. doi: 10.4236/oalib.1104618.

Shiffler, Amanda. "Fertilizer for herbs: Benefits, types, and how to fertilizer." *Herbs at Home*, 29 May 2019. https://herbsathome.co/fertilizer-for-herbs/

University of Minnesota Extension. "Fertilizer urea." *University of Minnesota Extension*, 2018. https://www.extension.umn.edu/nitrogen/fertilizer-urea#advantages-755161

"Why Do Plants Need Nitrogen? (And How to Tell When They Need More)." *The Practical Planter*, 7 October 2020. https://thepracticalplanter.com/why-do-plants-need-nitrogen/#:~:text=Nitrogen%20is%20a%20substance%20that%20allows%20plants%20to,helps%20plants%20to%20be%20able%20to%20form%20chlorophyll.