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The Impact of Traffic Noise Pollution on Plant Growth Within Urban Community Gardens

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ABSTRACT

This experiment was conducted to inquire the impact of traffic noise pollution on plant growth within urban community gardens. In acknowledgment of urbanization concerns and the increase of noise within cities, the study was devised to determine if this type of pollution was impacting plants, in addition to animals and humans. To achieve the research goal, two conditional groups with identical set-ups were placed in adjacent rooms. One group contained traffic noises while the other contained natural noises. Plants were grown over six weeks and data was collected both throughout the experiment and at its conclusion. At the conclusion of the experiment, the average plant height for the control group was 104.2 millimeters and 65.6 millimeters for the experimental group. Additionally, the average plant weight for the control group was 1.31 grams and .85 grams for the experimental group. The results yielded T-values of 3.74661 and 1.89107, respectively. With 95-percent confidence, the results showed a statistically significant difference in average plant height and weight between the two conditional groups. The data yielded an answer to the question proposed by the research and fulfilled the purpose of experimentation. A deteriorating effect was found and the impact calls upon city leaders to research the topic further. The results stress the need for a solution involving the reduction of noise to protect the benefits provided by community gardens and the plants within them.

Introduction

Throughout the majority of human history, people across the world have chosen to reside in small communities. Over the past few centuries, however, urbanization has increasingly become a major occurrence. Urbanization refers to the population shift from rural to urban areas. The trend began in the early 1800s during the Industrial Revolution. Agricultural advancements, including the McCormick Reaper and Cotton Gin, increased agricultural efficiency, resulting in fewer rural jobs. During this period, workers moved toward cities and towns in search of manufacturing employment (Urbanization, 2018). Additionally, the Second Industrial Revolution introduced steel and electricity as superior to iron and steam power. These products proved to be cost-effective, allowing for the mass production of railroads and machinery (Second, 2017). As technology and machinery advance, a larger demand is being placed on city operation, which contributes to the urban shift. Currently, there are more than three billion urban dwellers. Moreover, by 2030, it is projected that 75% of the world's population will live in urban areas (Louiza et al., 2016).

As urban areas become more populated, a greater demand is placed on transportation. The expansion of cities has led to transportation problems as jobs are not within walking distance from workers' housing. While public transportation is an option, many citizens prefer to avoid the hassle. Urban dwellers have commented on the constant stops and unreliable pick-up times. Therefore, many prefer to drive themselves to work, fueling what is known as the "all to the car" movement (Louiza et al., 2016).

With elevating noise levels as a result of human presence, the sound has begun to have a lasting impact on the environment. The disruption of noise caused the World Health Organization to declare noise as a pollutant in 1972. Since then, urban noise is considered to be the main source of pollution (de Paiva et al., 2015). There are a variety of sources that contribute to noise pollution within urban environments, but three main sources include: residential, industrial, and traffic (Noise, 2020). As the "all to the car" movement continues, the noise emitted from traffic will only escalate, causing traffic noise pollution to become the greatest source of noise pollution within cities.

As urbanization and its issues are becoming identified, solutions have been implemented to better the quality of life for urban dwellers. One such improvement is the creation of community gardens. Oftentimes, urban dwellers are confined to small apartments with little to no outdoor space for themselves. Community gardens are created as an opportunity for residents to grow crops on a small plot of shared land. There are a variety of benefits to community gardens, including getting people active, growing fresh and healthy options, relieving stress, and providing social opportunities (Dubová and Macháč, 2019). However, these gardens are generally located in areas polluted by traffic noise, allowing one to ponder what impact the noise may be having on plant growth. This thought led to the development of the research question: To what extent does traffic noise pollution impact plant growth within urban community gardens?

The goal of this study is to answer the preceding research question and determine whether or not traffic noise pollution is having an impact on plant growth within community gardens. While this effect is not currently known, the development of a visible detriment to plant growth could kick-start a movement toward global change. Not only do community gardens better the lives of urban dwellers, but the plants within these gardens also better the environment. Urban plant life provides benefits including the increase of local food and nutrition security, the increase of urban biodiversity, climate change mitigation, filters for particle and gas pollutants, the improvement of physical and mental health, the regulation of water flow, and the reduction of carbon emissions (Building, 2016). Once attention is brought to the importance of healthy plant life, immediate measures may be taken to reduce the level of urban traffic noise.

Literary Review

While the impact of traffic noise pollution on plant growth has not been directly studied, current research has encompassed a plant's interaction to sound. Plants do not have ears, but they respond to noise through vibrations. There is debate over what mechanisms allow plants to differentiate wind from attackers; however, many suspect that these "ears" of plants take the form of proteins known as mechanoreceptors (Rayman, 2014). Biologists from the University of Michigan have found that a plant's defense system can be triggered by a sound alone. They mimicked a caterpillar attack by playing a noise of caterpillar chewing. Plants exposed to chewing noises produced a greater amount of insecticide-like chemicals than the silent group (Appel and Cocroft, 2014). If plants are affected by vibrations, one may question what response they have to vibrations given off by traffic noise.

In addition to sounds in natural environments, scientists have looked at the impact of other audible noises on plant growth. For example, a study published in the International Journal of Agricultural & Biological Engineering altered audible noises to promote plant growth. The study did not involve the playing of noise at extreme volumes; moreover, the research shows how certain noises can promote plant growth (Cai et al., 2015). This allows one to further question if disruptive traffic noise would have the opposite effect.

The closest any research has come to the topic of this study involves the effect of noise pollution on other organisms, which then affect plant growth. The National Public Radio did a podcast surrounding research that discovered that constant racket within urban areas caused birds to migrate elsewhere. The study revealed how birds would spread seeds to quiet areas and not noisy ones. Consequently, plant reproduction was diminished as their seeds lacked dispersion within the area (LaCapra, 2012). The indirect effects are what dominates the conversation in this area, allowing the study's proposed topic to address the direct effect.

Lastly, most of the research done on noise pollution surrounds its impact on humans. Noise pollution is affecting sleep, mental health, and physical health of humans (Bronzaft, 1996). Correspondingly, studies have been conducted to stress the importance of a silent environment on brain development. Specifically, learning skills specialist Terry Small found various advantages of silence, including the growth of brain cells, rest for the brain, and relaxation (Small, 2019). While plants may not have the same organs as humans, their cells may similarly experience this growth.

Clearly, traffic noise pollution would end this silence and disrupt cell growth. The lack of research involving the direct impact of traffic noise pollution on plants, not animals or humans, has allowed for the development of a topic to answer the previously stated research question.

Methods

Participant Characteristics

The plant grown throughout the experiment was basil. Basil, *Ocimum basilicum*, is an herb of the mint family. Basil is grown for its aromatic leaves that are used to flavor salads, sauces, meats, and fish. Leaves are arranged oppositely along the square stems and can be harvested individually by pinching or cutting. Basil was chosen for experimentation because of its popularity within community gardens. According to the University of Minnesota, basil is one of the most popular culinary herbs to grow (Kooyman, 2018). Basil's popularity is rooted in its ease and short growing season. Basil germinates within seven to fourteen days and is ready to be harvested within six to eight weeks. The herb grows to be six to eight inches tall, so it does not take up excessive space in the home or garden. Lastly, when growing from seed, up to three seeds can be planted in small cells, increasing the yield and success over the first few weeks (How, 2020).

To ensure the plants were grown under the same conditions, they had to be grown from seed. If the plants were bought as seedlings, there would be no control of the conditions they were exposed to before experimentation started. Some plants may have been placed in better situations to increase survival. Growth from seedlings would have a preventable negative impact on experimentation. Additionally, exposure to noise may have impacted the germination rate. Some of the seeds may have never sprouted with exposure to one of the conditional groups. Lastly, the beginning weeks of growth would not be impacted by the noise and this is not conducive to city environments. In this study, the seeds were exposed to the noise levels from the moment they were planted.

Sample Size

Within each experimental group, 56 seeds were planted. The 56 seeds were divided among 28 seedling starter cells, containing two seeds per cell. While MicracleGro's directions for basil growth advised the planting of three seeds in each starter cell, only two seeds were planted for experimental purposes (How, 2020). The basil was grown in adherence to directions provided by MiracleGro as urban gardeners are likely to follow directions when planting in community gardens. MiracleGro was the chosen source because it was the soil purchased for the plants. Because the plants would remain in starter cells throughout the entire experiment, without the removal of any plants, no more than two plants were wanted.

The seeds were planted in small starter cells that were originally bought in trays. Each tray consisted of four rows of five cells. The trays were cut apart to allow for easier access to individual plants. Individual plants were able to be picked up if needed, but they were always returned to the same position. The plants were not rotated in any means to avoid confusion of plant growth hormones as they extend toward light sources.

Conditions and Design

The experiment consisted of two conditional groups: a control and an experimental. The control group involved the playing of subtle nature noises on a Sonos speaker. The speaker was placed at 25-percent volume, equating to 50 decibels. According to the American Academy of Audiology, moderate rainfall lies within the 50-decibel range (Level, 2009). The volume was chosen to match sounds played on the nature loops. Loops were found on platforms such as Apple Music, Spotify, Pandora, and Youtube. The loops varied each day as noises would in a natural setting. On the other hand, the experimental group involved the playing of roaring traffic noises on a Sonos speaker. The speaker was placed at 80-percent volume, equating to 110 decibels. The 110-decibel noise level is comparable to the American Academy of Audiology's classification of car horns (Level, 2009). The volume was chosen to match the noises found on the traffic noise playlist, like the control group. Unlike nature noise loops, traffic noise loops are scarce on the speaker system's compatible platforms. Therefore, a playlist was created to combat this difficulty and ensure that proper noises were played throughout the day. The playlist was created on Apple Music and consisted of every traffic sound available on the platform. A list of the playlist's sounds can be found in Appendix B. The playlist was duplicated to last eight hours and seven minutes, encompassing the entire time the noise needed to be played. To create a daily shuffle, like the control group, songs were shuffled so a different order would occur every day.

Both conditional groups were placed in two secluded rooms with similar settings. The settings had to remain equivalent to eliminate the effect of confounding variables and guarantee that noise was the variable being studied. To do this, the house remained at a constant temperature of 72 degrees. Additionally, the rooms were adjacent to one another and of identical size. Both rooms contained a small window against the back wall, allowing for similar angles and the amount of light to shine through. The rooms were downstairs and in a remote location at the back of the house to avoid other noise from within the house. People rarely entered the rooms for purposes other than measuring and watering. Lastly, plant groups each received the same equipment for growth and development. The speaker system, soil, seeds, seedling starter cells, heating mats, and grow lights were all purchased from the same brands and remained consistent throughout the experiment.

To begin experimentation, the cut cells were numbered 1 through 28 for each conditional group. Following the numbering, 20 grams of MiracleGro soil was measured in a cup and added to each cell. MiracleGro was the chosen soil and source of direction because it is a well-known and highly marketed product that urban gardeners are likely to be aware of and choose. The product is cheap and advertised as being a nutrient-rich potting soil. Because MiracleGro advised for the plantation of seeds one-half inch deep, each seed was planted at a depth of one-half inch (How, 2020). The measurement was marked on a finger that pushed the proper depth of soil away. Two holes were created two inches away from one another and in opposite corners of the cell. One seed was planted in each hole and the soil was recovered. Following the plantation of the seeds, 20 milliliters of water were added to each of the cells.

The set-up for each conditional group consisted of a small television table, heating mat, grow lights, and speaker. In each room, a television table was placed up against the window, level with the bottom of the window sill. The heating mat was then placed on top of the television table and pushed toward the window. The speaker was placed at the front end of the television table, opposite the window. Additionally, the grow lights contained a clip that was clasped onto the end of the table. Each grow light consisted of three long lights. The three lights were adjusted to be an equal distance from one another and oriented to split the mat into thirds. Lastly, the plants were individually placed on top of the heating mat. The plants labeled 1-7 were placed from left to right in the first row, furthest from the window. Correspondingly, cell numbers 8-14 were found in row two, 15-21 in row 3, and 22-28 in row 4.

Once the seeds were planted and conditional groups were set-up, the same steps were completed on a daily basis. Every morning at seven, the grow lights and noise were turned on. Grow lights were utilized throughout the experiment to ensure that plants were obtaining the light spectrums necessary for photosynthesis. Plants produce the most energy by absorbing blue and purple lights. Grow lights provided these light spectrums to better the chance of survival. Upon returning from school and work, the grow lights and noise were turned off at three in the afternoon. The lights and noise were left on for eight hours, MiracleGro's instructed exposure to sunlight. The noise was left on during this time because plants gather materials needed for growth during the day. During the day, plants undergo photosynthesis to produce energy for the night, when plants experience most of their growth. Additionally, from seven in the morning to three in the afternoon, urban dwellers are likely to be traveling to and from work, making the most impactful noise. Lastly, after the grow lights and noise is turned off, the plants are watered. MiracleGro does not leave instructions for watering basil, so basic gardening tips were found on another reliable source, as urban gardeners would look to. The University of Vermont's Department of Plant and Soil Science advised against using the same amount of water each day. Enough water should be applied so leftover water floods from the bottom of the planting cells.

Furthermore, the top layer of soil should always be moist, but never in a pool of water (Perry, n.d.). The amount of water varied each day in accordance with the department's instructions, but the amount remained consistent for every plant within both groups.

Measures

There were three measurements taken every other day throughout experimentation. The measurements consisted of plant height, leaf count, and day sprouted. These were the only feasible measurements to be taken on a daily basis. In addition to these measures, the time that measurements were made was noted to show consistency in between measurements. The measures taken at the conclusion of experimentation include plant weight, total leaf weight, largest leaf size, and stem diameter. The measurements of each individual plant at every point in time is included in Appendix A. The plant weight and total leaf weight would be best accomplished through the destruction of the plant and placing of the parts on a scale. On the other hand, the largest leaf size and stem diameter would be too timely to measure every other day. The largest leaf may have varied from day to day and the change in stem diameter would be too little. All the measures taken were chosen to determine how well the plants grew. The plant's growth would be represented by these values, which would ultimately determine how the growth of plants is impacted by traffic noise.

Data Collection

Measurements were collected every other day as opposed to every day because change on a daily basis is extremely minimal. However, they were still measured consistently to show change over time. Plant height was measured in millimeters using a ruler. The ruler was placed at the base of the plant and the measurement was taken at the end of the stem. Additionally, the number of leaves was counted, and when each plant sprouted, the day was noted.

The final day of experimentation consisted of another set of measures. Experimentation lasted six weeks because MiracleGro stated that basil is ready to harvest at that point in time. The first measurement taken was the stem diameter. This was measured using a ruler and to the nearest millimeter. At the conclusion of this, the largest leaf was identified and measured. The leaves were measured in millimeters, using the same ruler. After these measurements were taken, plants were pulled from the soil and cut just above the root. The roots were unable to be measured because they were nearly impossible to entirely gather from the ground. Therefore, they were cut off. The plant itself was placed on a chemistry scale that measured to two decimal places. The weight of the plant was measured in grams and recorded. Lastly, the leaves were pinched off and placed on the scale together. The total weight of the leaves was measured in grams and recorded. Because the leaves are the herb that is used in recipes, measuring this yield is an accurate determination of growth.

Quality of Measurements

To ensure that the plants were measured the same way throughout experimentation, the same person was used for all measurements. This way there would be no room for extreme error in the process by which measurements were taken. On top of this, one outside person was used to assist with the measurements. The assistant was used to make the process more efficient. The person taking measurements could call off the numbers for the assistant to record. Lastly, final measurements were double-checked and measurements taken every other day were compared to earlier measurements to ensure accuracy. The shrinking of plants is unlikely, so if a plant decreased in height, it was measured again.

Analysis

The measures taken at the conclusion of the experiment are displayed in Table 1. While plant height and leaf count were measured throughout the experiment, the final values are contained within the table. Each value, aside from the proportions, is the mean value, taken from the sprouted plants within each group. The measures and their corresponding units are listed on the left, while the values for both the control and experimental groups can be found on the right.

Table 1. Effect of Traffic Noise Pollution on Final Plant Measures

Final Measures	Control Group Mean Values	Experimental Group Mean Values
Plant Height (mm)	104.219	65.600
Plant Weight (g)	1.312	0.849
Leaf Count	8.195	5.650
Total Leaf Weight (g)	0.931	0.561
Largest Leaf Size (mm)	46.634	35.550
Stem Diameter (mm)	2.537	2.050
Day Sprouted	8.927	8.500
Proportion of Sprouted Plants to Seeds Planted	0.732	0.357
Proportion of Deceased Plants to Plants Sprouted	0.024	0.200

Two graphs were created to illustrate the difference in plant height and leaf count between the two conditional groups over time. The blue lines represent the control group and the red lines represent the experimental group. Figure 1 shows the mean plant height over time, while Figure 2 shows the mean leaf count over time. These graphs were constructed for a simple comparison between mean plant height and leaf count of the control and experimental groups as the experiment progressed.

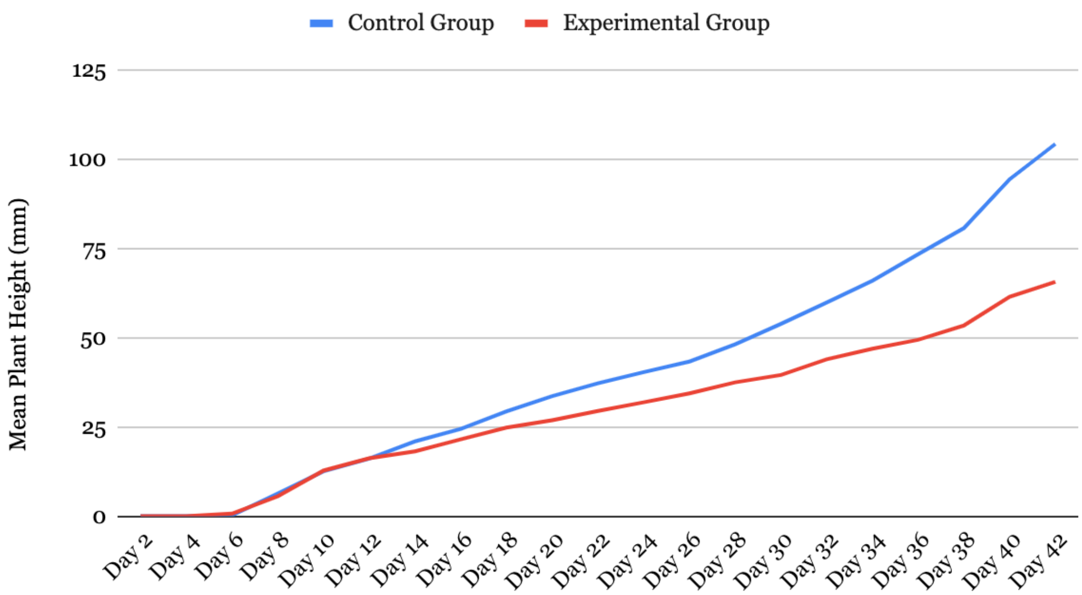

Figure 1. Effect of Traffic Noise Pollution on Plant Height Over Six Weeks

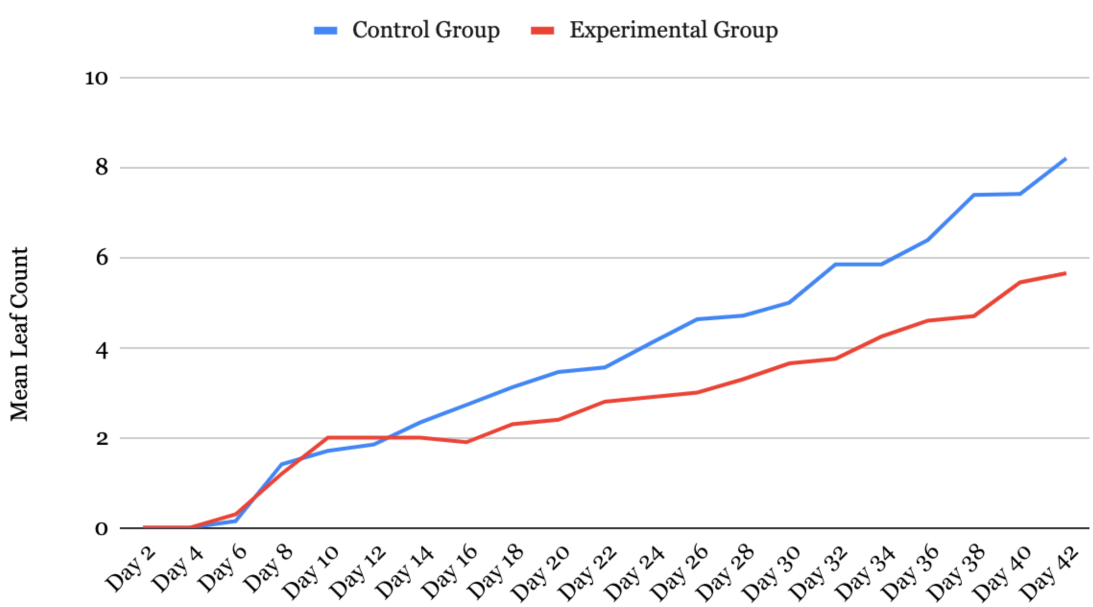

Figure 2. Effect of Traffic Noise Pollution on Leaf Count Over Six Weeks

Discussion

As shown by the control and experimental group results, the final measures were greater within the control group for every measure except the deceased plant proportion. Plant height, plant weight, leaf count, total leaf weight, largest leaf size, stem diameter, day sprouted, and proportion sprouted were all greater within the control group. Additionally, the two constructed graphs indicate greater plant height and leaf count within the control group throughout the experiment. For both plant height and leaf count, the two groups had similar means until a diverge at day 12 and day 8, respectively. The control group had a greater mean plant height throughout every day of experimentation. Conversely, when it comes to leaf count, the experimental group surpasses the control group from day 8 to day 12, but the control group surpasses the experimental group for the rest of experimentation. Both graphs indicate a greater general slope for the control group, causing the lines to increasingly diverge as time passes. At this point, the results indicate greater growth within the control group, both throughout experimentation and at its conclusion. To prove that the collected data is statistically significant, however, statistical analyses must be conducted.

To determine if the control group's increase in final plant measures was statistically significant, one-tailed difference of means and proportions tests were run on each of the final measures. The null hypotheses stated that there would be no statistically significant difference in the final measures between the control and experimental groups. Every statistical test conducted on the final measures, except day sprouted, rejected with a p-value of less than .05. Moreover, plant height, leaf count, sprouted proportion, and deceased proportion were able to reject with a p-value less than .01. The tests were run using an online statistics calculator, and results are displayed in Table 2 (Social Science Statistics, n.d.). The statistical tests reject the null hypotheses and show that with at least 95 percent confidence, one can claim that all final measures are larger in the control group, except the deceased proportion which is smaller in the control group. Therefore, the data is shown to be correlated and not occurring by chance. On the other hand, day sprouted was unable to reject and show this correlation. The results indicate that traffic noise did not affect the day plants sprouted, but did affect the growth plants experienced, lessening the growth of plants that were exposed.

Table 2. Results of Difference of Means and Proportions Statistical Tests on Final Measures

Final Measures	T-Value/Z-Value	P-Value
Plant Height (mm)	3.7466	.00021
Plant Weight (g)	1.8911	.03176
Leaf Count	3.1959	.00112
Total Leaf Weight (g)	-2.0910	.02042
Largest Leaf Size (mm)	2.1235	.01896
Stem Diameter (mm)	1.7525	.04245
Day Sprouted	0.7086	.24069
Proportion of Sprouted Plants to Seeds Planted	3.9742	.00004
Proportion of Deceased Plants to Plants Sprouted	-2.3558	.00914

Conclusion

The experimental results of this study conclude that traffic noise pollution is negatively impacting plant growth within urban community gardens. This can be concluded through the tests that show statistical significance on the measured values that ideally constitute for plant growth. One-tailed tests were used to show that the values were statistically greater in one group and smaller in another. On top of this, the data displayed in the graphs show an increasing diverge in the plant height and leaf count over time. The resulting data answers the research question and fulfills the purpose of experimentation. A deteriorating effect was found and calls upon city leaders to research the topic further and develop solutions.

Limitations, Recommendations, and Implications

While the data resulted in a strong correlation linking traffic noise pollution to the deterioration of plant growth, experimental error is inevitable in many studies. Some sources of error may have occurred in the watering, measurement, location of conditional groups, time and space constraints, and ability to mimic a city environment. First of all, because each cell received the same amount of water daily, cells with two plants or large plants may not have been receiving a sufficient amount of water. On the other hand, smaller plants may have been drowning in a surplus of water. Additionally, human error is unavoidable in the measurements involved with the study. These measurements include the initial soil amounts and daily watering as well as the measurements taken throughout and after experimentation. While the measurements may not have been exact, precautions were taken to double-check and ensure that the measurements were not far off. Another limitation placed on the study involves the placement of conditional groups in two separate rooms. This placement may have allowed for one conditional group to be situated in a more favorable environment. While the rooms contained similar conditions, the angle of direct sunlight would have slightly varied as a result of the groups being beside one another. Moreover, experimentation was limited by time and space. Time limited the number of trials that could be run and space limited the number of plants that could be grown. Lastly, an experimental error results in the inability to properly mimic a city's environment. Sounds played over a speaker system cannot property imitate the vibrations and other factors that result from the city. Because the plants were grown within the household, human residency impacted the length with which the noise could be played. However, there is no true way to know the volume and amount of noise at different times of the day unless the plants were grown within a city.

Looking at the limitations that were placed on this study, some recommendations can be made in the event of future studies. To begin, the watering of plants could be based on their measured heights for that day. A proper amount of water for a certain height could be established and the amounts determined in connection to this. Furthermore, in a setting where time is not a factor, conditional groups in the two separate rooms could have been switched to guarantee that one room was not more favorable. More trials could be run to ensure that these results did not occur by chance or in error. If space was not an issue, different types of plants could be grown to show that basil is not the only impacted type. Moreover, the plants could be grown in a laboratory setting where times for noises to be played and household noises would not be an issue. Finally, if one was able to gain access to more resources, they could grow the plants in an authentic city environment. To accomplish this, one must have the resources to filter out other city pollutants that may impact growth. Specifically, city air is largely polluted and could also impact plant growth. The control group would be placed in a natural environment away from city noise and air pollution, so the settings would have to be the same. Experimenting without having to mimic a city environment would be the most accurate way to proceed with further experimentation.

This study sparks new ideas for further studies involving the effects of urbanization on plant growth. After seeing the results of traffic noise pollution on plant growth, one may question what impact other sources of noise pollution have. Furthermore, other city conditions and forms of pollution may be influencing plant growth in similar ways. Some of these conditions include air quality and temperature. This study is only the beginning of experimentation on the negative effects of urbanization on plant growth.

Overall, despite the possible areas for experimental error, the study still yields critical results. While the study only utilized basil as its participant, the growth of basil can be generalized to other plants grown in community gardens. Each of these plants have a similar structure and grow using the same mechanisms. Therefore, an assumption can be made in regards to extending the results found with one plant to all plants within community gardens. The findings of this experiment prompt city leaders to look into a solution that protects the benefits of the community gardens and the plants being grown within them. Without success in community gardens, their use can be discouraging. Even if plants successfully grow, their yield may be less. In an area where healthy options are not always affordable, citizens may rely on the yield from community gardens. While many residents believe traffic noise is inevitable, this notion is far from the truth. Cities can reduce traffic noise by constructing sound barriers, maintaining roads, enforcing illegal vehicle modifications, reducing vehicle speeds, carefully routing freight trucks, choosing electric buses, and increasing the use of public transit, bicycles, and walking (Bhatia, 2014). Even in densely populated regions, steps can be taken to limit the noise. City leaders can begin by making some of these accommodations and citizens can take part in the actions involving them. Many cities already have laws that restrict noise in residential areas, but these laws are rarely enforced. City law officials can take control by cracking down on these laws and drafting stricter versions. After considering the importance of healthy plants and a space to plant them, the need for a solution that reduces traffic noise pollution is imminent.

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