Team Advisors

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# Mission Folder: View Mission for 'Whiz Kids'

| | |
|---|---|
| **State** | Michigan |
| **Grade** | 8th |
| **Mission Challenge** | Environment |
| **Method** | Scientific Inquiry using Scientific Practices |
| **Students** | |

## Team Collaboration

***(1) Describe the plan your team used to complete your Mission Folder. Be sure to explain the role of each team member and how you shared and assigned responsibilities. Describe your team's process to ensure that assignments were completed on time and deadlines were met.***

Please see the attached document. We wanted to include our figures and tables with the text.

Uploaded Files:

- [ View ] **Team Collaboration** (By: Advisor, 02/21/2017, .pdf)

  *Team Collaboration text with figures and tables.*

## Scientific Inquiry

Problem Statement

***(1) What problem in your community did your team investigate? Why is this problem important to your community?***

Stamp sand is an abundant material in our community due to the mining that took place many years ago. There are some areas along Lake Superior and Torch Lake that are covered in stamp sand. Though the EPA (Environmental Protection Agency) has cleaned up some of the areas, by spreading topsoil over the stamp sand and making a disc golf course or nature trails (LSSI), there are some areas that need remediation. The traditional method of remediating the stamp sands is to place topsoil on the sands (6 in was done for the initial remediation of the Torch Lake Stamp Sands, but now it is 12 in) followed by planting hardy plants (trefoil, fescue, red clover and alfalfa) (Meingast and Kafcznski). This process is very expensive. If less topsoil is used, the cost is reduced. This could mean that more stamp sand could be remediated for either the same cost or for a decreased cost. If the stamp sand and topsoil are mixed via a plowing/cultivating process, there is less stratification of the stamp sand/topsoil mixture.

Our team wanted to find out if there was a way to reduce the amount of topsoil, but still achieve good plant growth. The stamp sands are deposited along the lake shore. This means that the water table is relatively high. The Keweenaw Peninsula juts out into Lake Superior which frequently results in high winds. Many people like to ride bikes and four-wheelers along the stamp sands. We think this would result in erosion and poor plant growth. Therefore, we wanted to know if soil stressors (wind, a high water table or cycling/four-wheeling) affected plant growth on the stamp sands. We developed two experiments to test these impacts:

1. Plant trefoil, fescue, red clover and alfalfa in soils with different ratios of stamp sand to topsoil (100% stamp sand, 75% stamp sand, 50% stamp sand, 25% stamp sand and 0% stamp sand with the remaining fraction being topsoil). We would observe which plant type grew the best in which soil mixture.

2. To determine the effect of wind, high water table and cycling/four-wheeling, we used two of the plants that grew well in a given soil mixture to test the effect. We placed soil containers with the plant already growing in a container of water to simulate a high water table. We exposed a second set of plants to a daily four hour wind event. In a third set, we "drove" a wheel over the center of the container to simulate a bike or four-wheeler travelling across the soil. For each of these, we monitored plant growth.

We plan on discussing our results with the Lake Superior Stewardship Initiative and the Lake Linden Village Council to determine if we could test our results in a 10 ft x 10 ft plot during the summer of 2017.

***(2) List at least 10 resources you used to complete your research (e.g., websites, professional journals, periodicals, subject matter experts). Use multiple types of resources and do not limit yourself to only websites.***

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***(3) Describe what you learned in your research.***

This section is included in the uploaded Scientific Inquiry document because we had formatting in the section that did not copy into the text box.

Hypothesis

***(4) State your hypothesis. Describe how your hypothesis could help investigate your problem.***

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***(5) Identify the independent variables and the dependent variables in your hypothesis.***

This section is included in the uploaded Scientific Inquiry document because we had formatting in the section that did not copy into the text box.

***(6) When you developed your hypothesis how did you know it could be tested AND could be proven false by testing?***

See the Uploaded File, Experimental Procedures.

Experimental Design

***(7) List the materials you used in your experiment. Include technologies you used (e.g., scientific equipment, internet resources, computer programs, multimedia, etc.).***

See the Uploaded File, Experimental Procedures.

***(8) Identify the control group and the constants in your experiment.***

This section is included in the uploaded Scientific Inquiry document because we had formatting in the section that did not copy into the text box.

***(9) What was your experimental process? Include each of the steps in your experiment. Include all safety precautions used by your team as step one.***

See the uploaded documents for Experiment 1 and 2, along with the Scientific Inquiry document.

Data Collection and Analysis

***(10) Present the data you collected and observed in your testing. The use of data tables, charts, and/or graph is encouraged.***

See the uploaded documents: Soil Characteristics and Experiment 1 and 2 Data.

***(11) Analyze the data you collected and observed in your testing. Does your data support or refute your hypothesis? Do not answer with a yes or no. Explain your answer using one of the following prompts: 'Our data supports/refutes the hypothesis because...'***

This section is included in the uploaded Scientific Inquiry document because we had formatting in the section that did not copy into the text box.

***(12) Explain any sources of error and how these could have affected your results.***

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Drawing Conclusions

***(13) Interpret and evaluate your results and write a conclusion statement that includes the following: Describe what you would do if you wanted to retest or further test your hypothesis. Evaluate the usefulness of the data your team collected. What changes would you make to your hypothesis and/or experimental design in the future, if any?***

This section is included in the uploaded Scientific Inquiry document because we had formatting in the section that did not copy into the text box.

Uploaded Files:

- [ **View** ] **Experimental Materials and Procedures** (By: Advisor, 02/06/2017, .pdf)

  *The file contains the procedures and materials used on our experiments.*
- [ **View** ] **Experiment 1 Data Figures and Tables** (By: Advisor, 02/09/2017, .pdf)

  *Experiment 1 Data Figures and Tables*
- [ **View** ] **Experiment 2 Data Figures and Tables** (By: Advisor, 02/15/2017, .pdf)

  *Experiment 2 Data Figures and Tables*
- [ **View** ] **Soil Characteristics** (By: Advisor, 02/15/2017, .pdf)

  *Soil properties (chemical and physical)*
- [ **View** ] **Whiz Kids Scientific Inquiry** (By: Advisor, 02/21/2017, .pdf)

  *This document contains the Scientific Inquiry sections (this was done because we had significant formatting throughout the document)*

## Community Benefit

***(1) How could your experiments and data help solve your problem and benefit your community? Describe next steps for further research/experimentation and how you have or how you could implement your solution in the future.***

Stamp sand is an abundant material in our community. Due to the mining that took place in our community there are some areas of stamp sand along Lake Superior and on Torch Lake near our town. Though the Environmental Protection Agency has remediated some areas by spreading topsoil over the stamp sands and planting plants, there are some areas still with exposed stamp sand.

When learning about stamp sands and where they are located, we took a trip to the stamp sands in the town of Gay Michigan. We looked at the vegetation that was growing on the stamp sand. This relates to our experiment because we are trying to test which type of plant will grow in the least amount of topsoil. On this trip, we saw where plants were already growing in the sands, but we also noticed that there were a lot of barren areas. The regions where plants grew where water pooled or flowed into the area bringing not only water, but nutrients too.

Our school participates in the Lake Superior Stewardship Initiative (LSSI). This program " brings together schools and community partners to prepare K-12 students to become knowledgeable citizens concerned about the Lake Superior watershed and actively engaged in stewardship projects in their community." (LSSI) Students in different science classes at our school sample water and soil as part of the Torch Lake Remediation Monitoring program.

Because our school is located on Torch Lake where over 50% of the lake's volume was filled with stamp sand and our school does work monitoring the chemicals in the soil and water, our team felt an obligation to complete a project that would have an impact on our school and the greater community. To meet this goal, our team developed a cost effective and practical way of remediating the stamp sands.

Our process involved determining which plants would grow best on stamp sands with the least amount of topsoil added. We found that both fescue and red clover grew in 100% stamp sand. This finding could greatly change how the sands are remediated. Instead of covering the exposed stamp sand with 12 inches of topsoil, which is the current method, these plants could be directly planted in the sand. This process would greatly decrease the cost of remediating the sands because the application of topsoil would be eliminated.

Our second experiment involved simulating some of the natural and man-made impacts that can occur on the stamp sands that affect plant growth. We found that the plants that were exposed to wind were drier than the others. Many of the plants were wilted and dry. Our wind simulation was actually more intense than what occurs in nature because we had wind every day for four hours and no rain. The moisture from rain would have moistened the leaves allowing them to still grow in the presence of wind. The alfalfa plants in the high water table were yellow and began to die; while the fescue plants were fine. This would mean that fescue could be planted in a stamp sand area where there was a high water table. When a wheel was driven across the stamp sand and plants, as expected the plants died. This would mean that if a stamp sand area was to be remediated and bike/four wheelers were expected to drive across them, there would have to be specific trails. The remediation plan could include paths where the stamp sand was covered with paving leaving the sides available for plant growth.

Since our school is part of the LSSI, we will be working with them to set up two 10 ft x 10 ft plant test plots (one for Red Fescue and the other for Alfalfa). This work will also be presented to the Lake Linden Village Council because they own the land where we would like to have the test plots. Both the LSSI and the village have been supportive of student projects in the past. We feel they will be interested in our work and willing to support the testing we developed. The plants would be sown in June and we would monitor their growth throughout the summer. If the plants grow like they did in our experiment, we would like to talk with the Michigan Department of Environmental Quality to discuss this type of planting method with them.

We would monitor plant growth, along with weather conditions (rain and wind). We would contact the Houghton County Health Department to find the water table depth. If we had plots with different water table depths, we could plant fescue at the location with the higher water table and alfalfa at the lower one.

The results of this large-scale experiment could change the way stamp sands are remediated that would be much less expensive. Currently, the method to remediate stamp sand is to cover the sand with 12 in of topsoil and then plant the seeds. Our method would much less expensive because there would be no topsoil layer. The major cost would be obtaining the seeds and sowing them into the soil.

The Whiz Kids completed experiments investigating the direct application of seeds onto stamp sand. We found that alfalfa and fescue would grow well in 100% stamp sand. This process has the potential to change how stamp sands are remediated in our area because the seeds could be directly applied without the addition of topsoil.

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## Mission Verification

***(1) Does your Mission Folder project involve vertebrate testing, defined as animals with backbones and spinal columns (which include humans)? If yes, team must complete and attach an IRB approval form.***

No

***(2) Did your team use a survey for any part of your project? If yes, team must complete and attach a survey approval form.***

No

***(3) You will need to include an abstract of 250 words or less. As part of the abstract you will need to describe your project and explain how you used STEM (Science, Technology, Engineering and Mathematics) to improve your community***

Stamp sand is a byproduct of copper mining and was left on the ground. We wanted to determine if red clover, alfalfa, fescue and trefoil could grow on the sands and how soil stressors (wind, water table and wheels) affect plant growth. Our procedure involved five soil mixtures of topsoil and stamp sand. Alfalfa and fescue grew well in 100% stamp sand which they would grow stamp sand without adding topsoil. Using these plants, we tested how they would grow when the water table was high, there was wind, and when wheels travel across the sand . Wind caused the plants and the soil to dry out; the high water table caused alfalfa to turn yellow, but had little impact on fescue, and the wheels caused both plants to bend/compact. Since the plants grew in stamp sand and fairly well when they were stressed, we will discuss a test plot proposal for this summer with Lake Linden and the Lake Superior Stewardship Initiative. If this is successful, we will propose this process to the Michigan Department of Environmental Quality as a way to remediate the sands.

We used SCIENCE to develop our procedure and complete research. We used TECHNOLOGY when we used the soil test kits and we completed our calculations. Our ENGINEERING skills improved when we designed (and re-designed) our wheel structure and figured out how to analyze soils. MATH was everywhere in our project. We did many calculations on the soils which improved our math and spreadsheet skills.

## Whiz Kids Team Collaboration

Our team is comprised of three students, Siona Beaudoin, Beau Hakala, and Gabriel Poirier. We are eighth graders at Lake Linden-Hubbell High School. Our school is a small, rural school that has about 40 people per grade. Lake Linden is located on the Keweenaw Peninsula of Michigan, which means that we are practically in Lake Superior (See the blue star in the figure below.).

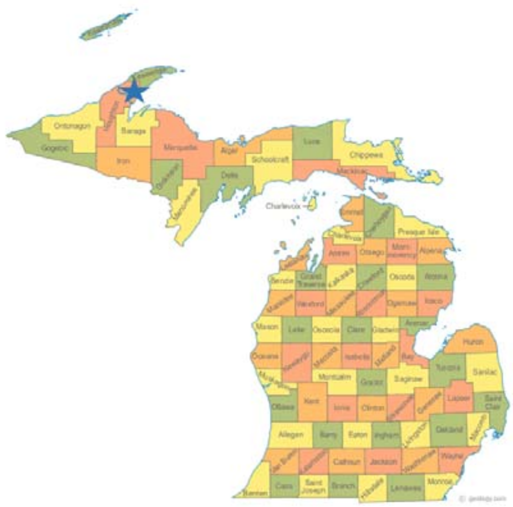



**Figure 1.1. Location of the Whiz Kids eCybermission Team and Team Picture (Michigan Map Collection)**

Last year, we participated in eCYBERMISSION for the first time. We researched a process to remove copper from stamp sands so that the copper could be re-used. This year, our project focused on what plants grow best in stamp sand and how soil stressors affect plant growth. This ideas was developed over the summer and when we discussed possible projects, we thought this would be the most interesting.

At the beginning of the experiment (December 2016), we were a four person team. Then one member decided that he did not want to be on the team. This makes it harder for us not only because each of us has to do more work, but when we go to the Michigan Technological University Science Fair, one of us will have to be on our own. On on the positive side, this has made us work harder and more efficiently. When he quit, our adviser asked us if we wanted to continue. She made sure we knew that if we lost another teammate, we would not be able to continue. We all were interested in the project and enjoyed eCybermission last year. We all wanted to keep the project going.

To begin our project, we wanted to see the impact of stamp sands on our area. Our adviser took us to Gay, MI which is fifteen minutes from our school. Gay is a town where it is estimated that 30 million tons of stamp sands were deposited on the shore of Lake Superior (The Stamp Sands at Gay, Michigan, in the Upper Peninsula). When our team went to Gay, we saw lots of ruins that were left over from the copper mining and a desert-like area. All along the lakeshore there was the grey/brown stamp sand. Figure 1.2 illustrates how big the stamp sand deposits are. There were only small clumps of plants found in certain areas of the stamp sand. This trip really showed us the impact of copper mining in our area and the importance of finding a way to cover the stamp sands.

**Figure 1.2. Gay Stamp Sands**

Our team had to work our schedule around the many activities that all of our team members did. The following table shows the main activities that we are involved in. One of the major issues was scheduling our team meetings around practice schedules. For example, in November, there are 6 middle school and high school basketball teams that need to use the elementary and high school gyms for practice. The practice schedule rotates and changes each week. Consequently, we had to adjust our meeting times frequently.

| **Table 1.1: Whiz Kids Outside Activities** | | | | |
|---|---|---|---|---|
| Siona Beaudoin | Band | Volleyball | 4-H | Student Council |
| Beau Hakala | Band | | Basketball | |
| Gabriel Poirier | Band | | Religion class | |

We learned that each of us had different skills that we brought to this project. Therefore, each team member was in charge of ensuring we accomplished our goals. S. Beaudoin is the best writer in our group. B. Hakala enjoyed doing the experiment the most. G. Poirier was the silent observer that gave feedback when there were errors. Our leaders then for the major tasks were as follows:

- Team Specialist (the person who kept us on task): G. Poirier
- Documentation Specialist (ensured the various documents were completed): S. Beaudoin
- Experiment Specialist (verified the procedures and process): B. Hakala

We did come up with a plan to complete our project. We knew it would take a long time because we were growing plants. We knew that without a plan, our project would not get done. Table 1.2 shows how we completed our project. Although the table below lists who was responsible, we all would help each other when needed to get the project done.

**Table 1.2. Whiz Kids eCybermission Project Timeline**

| Task | Start | End | Team Member Responsible |
|---|---|---|---|
| Research plants that grow in stamp sands and how to design our experiment to test how they grow with and without stressors. | October 2016 | November 2016 | S. Beaudoin, B. Hakala, G. Poirier |
| Hypotheses and Experimental Procedures | October 2016 | November 1, 2016 | B. Hakala |
| Mix the soil types. Prepare the soil and containers for the experiments. | November 1, 2016 | November 15, 2016 | S. Beaudoin, G. Poirier |
| Begin growing four plants in five different soil types. | November 15, 2016 | January 5, 2016 | S. Beaudoin, B. Hakala, G. Poirier |
| Complete chemical and physical tests on the soils to characterize them. | December 6, 2016 | December 15, 2016 | S. Beaudoin, G. Poirier |
| Begin growing plants in soil for soil stressor testing | January 5, 2017 | February 2, 2017 | S. Beaudoin, G. Poirier |
| Team Collaboration | We worked on these items throughout the project. | January 24, 2017 | S. Beaudoin |
| Scientific Inquiry | | February 14, 2017 | S. Beaudoin, B. Hakala, G. Poirier |
| Abstract | | February 16, 2017 | B. Hakala |

Most of the time we met twice a week, and on the second day we met in a week we would decide what we needed to get done over the weekend. Much of our research was completed during the weekends. Because of the nature of our experiment, we had to check the plants and water them every school day. We would also talk during the day about our project because we have similar class schedules. To make the project fun, we had several game nights. We met at our houses during the weekend and played games and hung out outside. Sometimes when we planned to work a long time, we would take a short break and get pizza. Then we would get back to work.

Since our experiment involved looking at what plants grew well in stamp sands, we had to get the plants to germinate and grow. This meant that we had to water and check the plants every school day during lunch. We live in a region where we get an average of 300 inches of snow per year. Sometimes we have so much snow that the plows cannot get the roads cleared in time for school or the snow is blowing so much that it is dangerous for the buses to run. This happened in December 2016 where we had 3 snow days in a row. Our school has the rule that students cannot be on campus when school is cancelled. We could not water the plants on snow days and this was not built into our watering schedule. We did not come in and water the plants on weekends, either. Over winter break, Gabriel's family watered the plants because he lives about four blocks from the school and his mom works at the school. At the end of the break, Gabriel's family had an emergency and the plants were not watered for a few days because Gabriel's family had the key to the room that we were using.

This project took much longer than we thought it would. We spent over two months watering the plants for the first experiment (determining what plants grew well in different mixtures of stamp sand and topsoil). We began growing the plants for the first experiment on November 17. We stopped growing the first round of plants on December 16 (control and trefoil) and January 5 (alfalfa, red clover and fescue). We stopped the control and the plant that was not growing well on December 16 so that we would have enough room under the grow lights to get the plants growing for our second experiment (how do soil stressors affect plant growth in stamp sand).

We are a team because we work well together. We were able to complete our project because we each took on roles and tasks that we were good at. Our project interested us because we wanted to learn more about our area and we wanted a project that could have a lasting impact on our community.

**Experimental Procedure 1: Which plant grows adequately in a mixture of Stamp Sand and Topsoil?**

Safety Precautions:

- We used safety goggles and latex gloves when completing the soil chemical analysis tests.
- When drying the soils in the oven, we used insulated gloves when putting them in or removing them from the oven.
- We used several standard experimental procedures. We followed these methods explicitly. These are listed in our references and cited within our procedures.
- We completed our experiments after school in Mr. Squires' Science Classroom. This room has laboratory style tables along with various glassware, scales and equipment that we used for our experiments.
- Our adviser was present whenever we were working on the experiments to ensure we completed everything safely.

1. Gather materials:
    - 5 gal Stamp sand
    - 5 gal Topsoil from local farms
    - Grow lights (Grow Crew, 120V, 60 Hz, Max 8A, 4 - 54 W lamps)
    - Metric Ruler
    - Balance (150 g +/- 0.01 g, 5,500 g +/- 0.1 g)
    - Multiple beaker sizes for measuring the volume of soil
    - 25 - ½ gallon juice cartons
    - ¼ lb Seeds (Alfalfa, Trefoil, Red Clover, Fescue)
    - Plastic mixing container
    - Gardening spade
    - Graduated cylinder for measuring the water for the plants
    - Electronic timer for grow lights
    - Electronic room thermometer
2. Make the five mixtures in plastic mixing container:

| **Stamp Sand** | **Topsoil** | **Exact Volume (mL)** | | **Extra Volume (mL)** | |
|---|---|---|---|---|---|
| | | **Stamp Sand** | **Topsoil** | **Stamp Sand** | **Topsoil** |
| 100% | 0% | 1420 | 0 | 1800 | 0 |
| 75% | 25% | 1065 | 355 | 1350 | 450 |
| 50% | 50% | 710 | 710 | 900 | 90 |
| 25% | 75% | 355 | 1065 | 450 | 1350 |
| 0% | 100% | 0 | 1420 | 0 | 1800 |

3. For each soil type, measure the pH, nitrogen phosphorus, and potassium using the standard procedures with the LaMotte Macronutrient soil test kit. (model AM-31). The procedures are in our attached documents. (Lake Linden-Hubbell High School, pH, Nitrogen, Phosphorus and Potassium)
4. Measure the soil porosity using the Environmental Engineering: Lesson 3, How Full? activity-Porosity Worksheet. (American Geosciences Institute)
5. Complete Sieve Analysis Test using the Sieve Analysis Test procedure. (University of Texas, Arlington)
6. Measure the initial soil moisture content and the final soil moisture content, using the soil survey standard test method. (Department of Sustainable Natural Resources)
7. Determine the soil texture using the soil texture/soil triangle procedure. (Soil Science Lab Manual)
8. Evenly cut and tape juice cartons to form a rectangular prism with an open top.
9. Label the containers with soil mixture and seed type.
10. Distribute 1.4 L of the soil mixtures into their labeled containers.
11. Level out the soil.
12. Measure 10 g of seeds. Broadcast the seeds (10 g).
13. Water the seeds with 75 mL of water.
14. Water when the dirt seems dry or the weekend is coming up.
15. Put under grow lights until the plants emerge and grow for several days.
16. Use a timer such that the lights are on for 12 hours a day, from 5:00 AM to 5:00 PM.
17. Monitor the plant growth, list any observation, monitor the days the plants were watered, the room temperature, and plant level temperature.
18. After two weeks, divide the soil into three compartments. Measure the cross sectional area of each section in $cm^2$
19. To remove the plants and soil, cut the side of the carton.
20. Separate the three sections of soil.
21. Count the number of plants in each section. When divided by the cross-sectional area, this will yield the plant density.
22. Gently separate out each plant. Measure the longest and shortest length of grass. This establishes the range of the plant growth. Also record any observations about how the roots grew.
23. Measure the plant length of 3 plants randomLy selected. This will establish the average plant growth.
24. Measure the root length of the 3 plants. This will establish the average root growth.

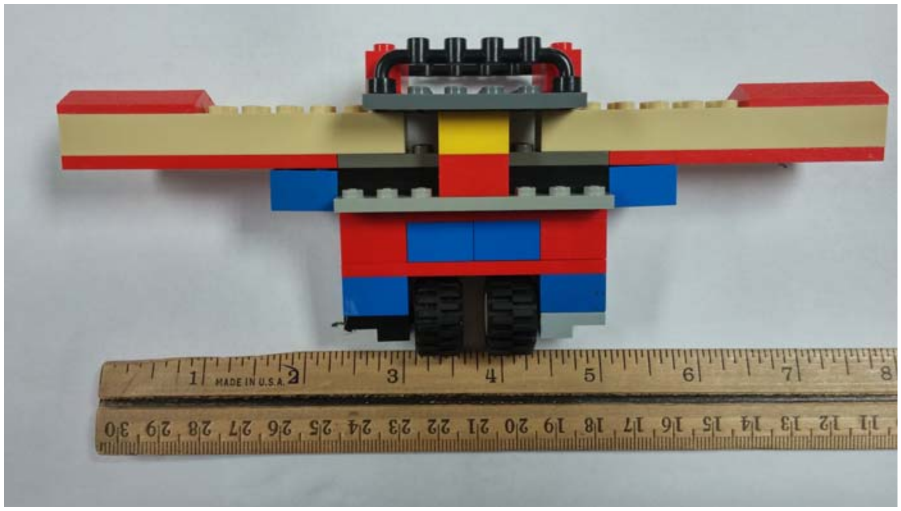
**Experimental Procedure 2: How will a plant grow in a mixture of Stamp Sand and Topsoil when the plant is stressed?**

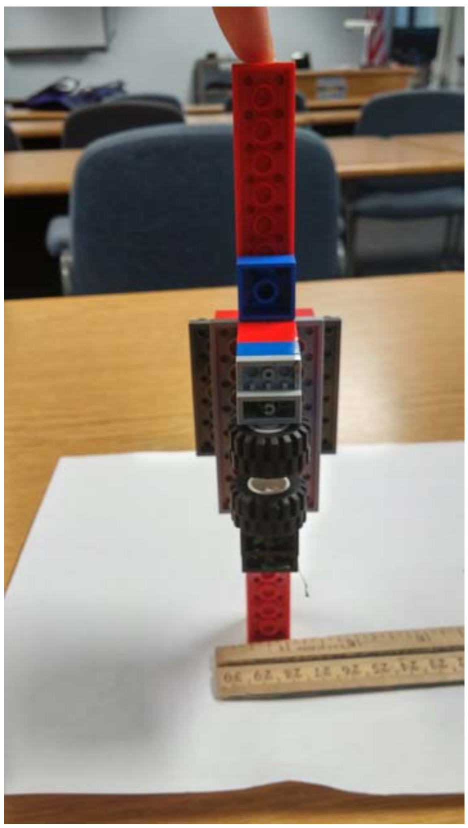
Safety Precautions:

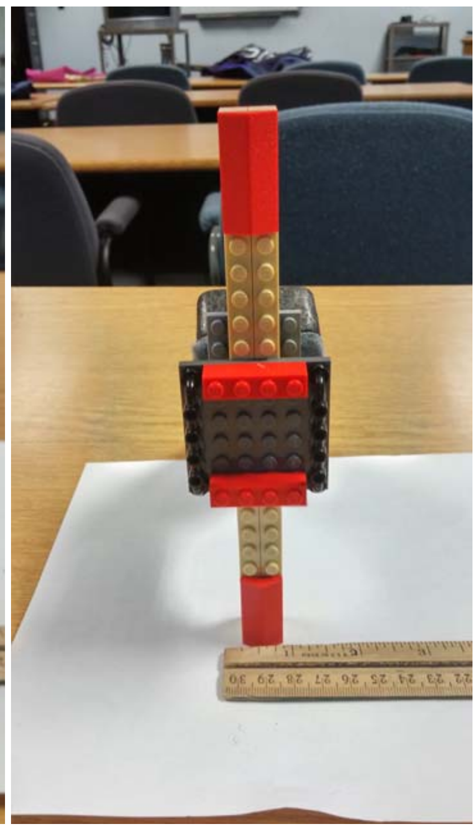
- We used safety goggles and latex gloves when completing the soil chemical analysis tests.
- When drying the soils in the oven, we used insulated gloves when putting them in or removing them from the oven.
- We used several standard experimental procedures. We followed these methods explicitly. These are listed in our references and cited within our procedures.
- We completed our experiments after school in Mr. Squires' Science Classroom. This room has laboratory style tables along with various glassware, scales and equipment that we used for our experiments.
- Our adviser was present whenever we were working on the experiments to ensure we completed everything safely.

Gather materials:

- Box Fan
- Water
- 8 ½ gal Juice cartons (modified as described in Experiment 1)
- ¼ lb Fescue and Alfalfa seeds
- A maximum of 12 L of Topsoil
- A maximum of 12 L Stamp sand
- Balance (150 g +/- 0.01 g, 5,500 g +/- 0.1 g)
- 100 mL Graduated cylinder
- 1,000 mL Beaker
- Garden spade
- 200 g mass
- Lego Wheel (diameter = 2.5 cm)
- Lego parts (See below for our wheel mechanism)







- Grow Light (Grow Crew, 120V, 60 Hz, Max 8A, 4 - 54 W lamps)
- Electronic Timer for grow lights and fan
- Anemometer to measure the wind velocity
- Electronic room thermometer
- Container for the water table experiment (must hold two soil containers)

1. Prepare 12L of the soil mixture that resulted in acceptable plant yields. (See Experimental Procedure 1) We used 100% stamp sand for this experiment.
2. Prepare the 4 cartons for soil by taking the top and folding it down to make a prism.

3. Fill each carton with 1,300 mL of the soil mixture. Keep approximately 100 mL for spreading over the seeds.
4. Measure 10g of seeds. Broadcast the seeds (10 g) evenly and spread a layer of soil over the seeds using the soil leftover from Step 3.
5. Water the soil with 75 mL. Place them under a grow light and monitor the plant growth. If the watering volume changes, note it in the observations.
6. After growing for a minimum 15 days, begin the soil disturbances (wind, water table and wheel). The intent is to see the effect of plant growth when the plants are stressed. Apply the stress over two weeks. Record plant growth, temperature and observations.
    - Using a standard box fan and timer, have the wind blow across the soil for 4 hours per day.
    - To simulate a high water table:
        i. Make small holes in the soil container approximately 3 cm apart.
        ii. Place the soil container in another container with 2 cm water depth. Add water to this container as needed to maintain the water depth.
    - To simulate a wheel from a bike:
        i. Hold ice cube trays to the sides of the containers. This will establish a uniform height for driving the wheel.(See figure below)

        ii. Attach a Lego wheel to a support structure (See figure in the materials list). Add a weight to the tire to simulate the mass of a bike and rider.
        iii. Run the tire lengthwise across the soil in the middle of the carton. The test was not completed on the weekends because the school was closed.
7. Divide the soil into three compartments. Measure the cross sectional area of each section in $cm^2$.
8. To remove the plants and soil, cut the side of the carton.
9. Separate the three sections of soil.
10. Count the number of plants in each section. When divided by the cross-sectional area, this will yield the plant density.

11. Gently separate out each plant. Measure the longest and shortest length of grass, along with the longest and shortest root length. This establishes the range of the plant growth. Also record any observations about how the roots grew.
12. Measure the plant length of 3 plants randomly selected. This will establish the average plant growth.
13. Measure the root length of the 3 plants. This will establish the average root growth.

**Table 2.7. Experiment 1: Mass of Each Seed Type Planted**

| | Mass of Seeds Planted (g) | | | | |
|---|---|---|---|---|---|
| **Stamp Sand** | **0%** | **25%** | **50%** | **75%** | **100%** |
| **Trefoil** | 5.05 | 5.06 | 5.06 | 4.98 | 4.89 |
| **Alfalfa** | 5.05 | 5.01 | 5.02 | 5.01 | 5.02 |
| **Red Clover** | 5.04 | 4.98 | 5.01 | 5.04 | 5.01 |
| **Red Fescue** | 5.08 | 5.03 | 4.97 | 5.06 | 5.00 |

**Table 2.8. Experiment 1 Data and Observations**

**Plant Type: Control**

| Day | Date | Temp (°C) | Number of Plants in Soil Type (denoted by % Stamp Sand) | | | | | Amount of Water (mL) | Observations |
|---|---|---|---|---|---|---|---|---|---|
| | | | 100% | 75% | 50% | 25% | 0% | | |
| 1 | Nov.15 | 22.4 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 2 | Nov.16 | 23.1 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 3 | Nov.17 | 23.3 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 4 | Nov18 | 19.3 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 8 | Nov.21 | 17.4 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 9 | Nov.22 | 30.5 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 10 | Nov.23 | 26.3 | 1 | 2 | 1 | 0 | 0 | 50 | |
| 11 | Nov.25 | 19.8 | 0 | 3 | 0 | 0 | 0 | 50 | |
| 13 | Nov.27 | 17.9 | 0 | 1 | 0 | 0 | 0 | 0 | |
| 14 | Nov.28 | 22.9 | 0 | 1 | 0 | 0 | 0 | 0 | |
| 15 | Nov.29 | 19.5 | 0 | 1 | 0 | 0 | 0 | 50 | |
| 16 | Nov.30 | 19.5 | 0 | 1 | 0 | 0 | 0 | 50 | |
| 17 | Dec.1 | 19.5 | 0 | 1 | 0 | 0 | 0 | 0 | |
| 18 | Dec.2 | 18.1 | 0 | 2 | 0 | 0 | 0 | 30 | |
| 21 | Dec.5 | 27.7 | 0 | 1 | 0 | 0 | 0 | 0 | |
| 22 | Dec.6 | 20.3 | 0 | 1 | 0 | 0 | 0 | 30 | |
| 23 | Dec.7 | 20.8 | 1 | 1 | 0 | 0 | 0 | 30 | |
| 24 | Dec. 8 | 21.4 | 1 | 1 | 0 | 0 | 0 | 50 | |
| 25 | Dec. 9 | 22.6 | 1 | 1 | 0 | 0 | 0 | 20 | |
| 26 | Dec. 10 | 23.3 | 1 | 1 | 0 | 0 | 0 | 50 | |
| 30 | Dec. 14 | 23 | 1 | 1 | 0 | 0 | 0 | 50 | |
| 32 | Dec. 16 | 23.5 | 1 | 1 | 0 | 0 | 0 | 75 | |

**Plant Type: Trefoil**

| Day | Date | Temp (°C) | Plant Height (cm) in Soil Type (denoted by % Stamp Sand) | | | | | Amount of Water (mL) | Observations |
|---|---|---|---|---|---|---|---|---|---|
| | | | 100% | 75% | 50% | 25% | 0% | | |
| 1 | Nov.15 | 22.4 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 2 | Nov.16 | 23.1 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 3 | Nov.17 | 23.3 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 4 | Nov18 | 19.3 | 0 | 0 | 0 | 0 | 0 | 50 | Few plants |
| 8 | Nov.21 | 17.4 | 2 | 2 | 2 | 2 | 2 | 50 | Few plants |
| 9 | Nov.22 | 30.5 | 1 | 1 | 1 | 1 | 1 | 50 | Few plants |
| 10 | Nov.23 | 26.3 | 2 | 2 | 2 | 2 | 2 | 50 | Few plants |
| 11 | Nov.25 | 19.8 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 50 | Few plants |
| 13 | Nov.27 | 17.9 | 1.5 | 2 | 2 | 2 | 2 | 0 | Few plants |
| 14 | Nov.28 | 22.9 | 1.5 | 2 | 2 | 2 | 2 | 0 | Few plants |
| 15 | Nov.29 | 19.5 | 1.5 | 2 | 2 | 2 | 2 | 50 | Few plants |
| 16 | Nov.30 | 19.5 | 1.5 | 2.5 | 2.5 | 2.5 | 2.5 | 50 | Few plants |
| 17 | Dec.1 | 19.5 | 2 | 2 | 2.5 | 2 | 2.5 | 0 | Few plants |
| 18 | Dec.2 | 18.1 | 2 | 2.5 | 3 | 2.5 | 2.5 | 30 | Few plants |
| 21 | Dec.5 | 27.7 | 2 | 2.7 | 3 | 2.5 | 2.5 | 0 | Few plants |
| 22 | Dec.6 | 20.3 | 2.5 | 2.7 | 3 | 2.5 | 2.5 | 30 | Few plants |
| 23 | Dec.7 | 20.8 | 1.5 | 1 | 1 | 0.5 | 1 | 30 | Few plants |
| 24 | Dec. 8 | 21.4 | 1.6 | 1 | 1 | 0.6 | 1 | 50 | Few plants |
| 25 | Dec. 9 | 22.6 | 1.7 | 1 | 1 | 0.6 | 1 | 20 | Few plants |
| 26 | Dec. 10 | 23.3 | 1.7 | 1 | 1 | 0.6 | 1 | 50 | Few plants |
| 30 | Dec. 14 | 23 | 0.9 | 1.4 | 1.5 | 0.9 | 1.6 | 50 | Few plants |
| 32 | Dec. 16 | 23.5 | 0.9 | 1.4 | 1.5 | 0.9 | 1.6 | 75 | Few plants |

**Plant Type: Red Clover**

| Day | Date | Temp (°C) | Plant Height (cm) in Soil Type (denoted by % Stamp Sand) | | | | | Amount of Water(mL) | Observations |
|---|---|---|---|---|---|---|---|---|---|
| | | | 100% | 75% | 50% | 25% | 0% | | |
| 1 | Nov.15 | 22.4 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 2 | Nov.16 | 23.1 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 3 | Nov.17 | 23.3 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 4 | Nov.18 | 19.4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 50 | plants emerged |
| 8 | Nov.21 | 17.4 | 1 | 1 | 1 | 1 | 1 | 50 | plants |
| 9 | Nov.22 | 30.5 | 2 | 2 | 2 | 2 | 2 | 50 | plants |
| 10 | Nov.23 | 26.3 | 2 | 2 | 2 | 2 | 3 | 50 | plants |
| 11 | Nov.25 | 19.8 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 50 | plants |
| 13 | Nov.27 | 17.9 | 1.5 | 2 | 2 | 2 | 2 | 0 | plants |
| 14 | Nov.28 | 22.9 | 1.5 | 2 | 2 | 2 | 2 | 0 | plants |
| 15 | Nov.29 | 19.5 | 1.5 | 2 | 2 | 2 | 2 | 50 | plants |
| 16 | Nov.30 | 19.5 | 1.5 | 2.5 | 2.5 | 2.5 | 2.5 | 50 | plants |
| 17 | Dec.1 | 19.5 | 2 | 2 | 2.5 | 2 | 2.5 | 0 | plants |
| 18 | Dec.2 | 18.1 | 2.5 | 2.5 | 2.2 | 2.5 | 2.5 | 30 | plants |
| 21 | Dec.5 | 27.7 | 2.7 | 2.6 | 2.4 | 2.5 | 2.5 | 0 | plants |
| 22 | Dec.6 | 20.3 | 2.7 | 2.6 | 3 | 2.5 | 2.5 | 30 | plants |
| 23 | Dec.7 | 20.8 | 2.5 | 2.7 | 3.2 | 2.5 | 2.5 | 50 | plants |
| 24 | Dec. 8 | 21.4 | 2.5 | 2.7 | 3.2 | 2.6 | 2.5 | 20 | plants |
| 25 | Dec. 9 | 22.5 | 2.6 | 2.7 | 3.2 | 2.6 | 2.5 | 50 | plants |
| 26 | Dec. 10 | 23.3 | 2.6 | 2.7 | 3.2 | 2.6 | 2.5 | 50 | plants |
| 30 | Dec. 14 | 23 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 75 | plants |
| 32 | Dec. 16 | 23.5 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 75 | plants |
| 35 | Dec. 19 | 23.4 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 50 | plants |
| 36 | Dec. 20 | 25.3 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 75 | plants |
| 37 | Dec. 21 | 23.5 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 50 | plants |
| 40 | Dec. 24 | 21.3 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 50 | plants |
| 43 | Dec. 27 | 21.6 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 75 | plants |
| 46 | Dec 30 | 24.2 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 50 | plants |
| 51 | Jan. 4 | 25.7 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 50 | plants |
| 52 | Jan. 5 | 25.3 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 50 | plants |

**Plant Type: Alfalfa**

| Day | Date | Temp (°C) | Plant Height (cm) in Soil Type (denoted by % Stamp Sand) | | | | | Volume of Water (mL) | Observations |
|---|---|---|---|---|---|---|---|---|---|
| | | | 100% | 75% | 50% | 25% | 0% | | |
| 1 | Nov.15 | 22.4 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 2 | Nov.16 | 23.1 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 3 | Nov.17 | 23.3 | 0 | 0 | 0 | 0 | 0.1 | 50 | plant emerged |
| 4 | Nov.18 | 19.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 50 | all plants emerged |
| 8 | Nov.21 | 17.4 | 1 | 1 | 1 | 1 | 1 | 50 | |
| 9 | Nov.22 | 30.6 | 2 | 2 | 2 | 2 | 2 | 50 | plants continued to grow. |
| 10 | Nov.23 | 26.3 | 2 | 2 | 2 | 2 | 2 | 50 | continued to grow one plant |
| 11 | Nov.25 | 19.8 | 2 | 2 | 2 | 2 | 2 | 50 | plants |
| 13 | Nov.27 | 17.7 | 2.5 | 2 | 2 | 2 | 1 | 0 | plants |
| 14 | Nov.28 | 22.8 | 2.5 | 2 | 2 | 2 | 1 | 0 | plants |
| 15 | Nov.29 | 19.5 | 2.5 | 2 | 2 | 2 | 1.5 | 50 | plants |
| 16 | Nov.30 | 19.5 | 2 | 2 | 2 | 2 | 2 | 50 | plants |
| 17 | Dec.1 | 19.5 | 2 | 2 | 2 | 2 | 2 | 50 | plants |
| 18 | Dec.2 | 18.1 | 2.5 | 2 | 2 | 2 | 2 | 30 | plants |
| 21 | Dec.5 | 27.7 | 2.5 | 2 | 2 | 2 | 2 | 0 | plants |
| 22 | Dec. 6 | 20.3 | 2.5 | 2.3 | 2.2 | 2 | 2 | 30 | plants |
| 23 | Dec. 7 | 20.8 | 2.7 | 2.5 | 2.3 | 2.2 | 2 | 30 | plants |
| 24 | Dec. 8 | 21.4 | 2.9 | 2.4 | 2.2 | 2.1 | 2 | 50 | plants |
| 25 | Dec. 9 | 22.5 | 2.9 | 2.4 | 2.3 | 2.1 | 2 | 20 | plants |
| 26 | Dec. 10 | 25.3 | 2.9 | 2.4 | 2.3 | 2.1 | 2 | 50 | Watered on Saturday, due to weather predictions, snow days M & T |
| 30 | Dec. 14 | 23 | 3 | 2.5 | 2.7 | 2.5 | 2.2 | 50 | plants |
| 32 | Dec. 16 | 23.5 | 3 | 2.7 | 2.5 | 2.2 | 2.2 | 75 | plants |
| 35 | Dec. 19 | 23.4 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 75 | plants |
| 36 | Dec. 20 | 25.3 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 50 | plants |
| 37 | Dec. 21 | 23.5 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 75 | plants |
| 40 | Dec. 24 | 21.3 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 50 | plants |
| 43 | Dec. 27 | 21.6 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 50 | plants |
| 46 | Dec 30 | 24.3 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 75 | plants |
| 51 | Jan. 4 | 25.7 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 50 | plants |
| 52 | Jan. 5 | 25.3 | 2.4 | 2.3 | 3.5 | 3 | 2.7 | 50 | plants |

**Plant Type: Fescue**

| Day | Date | Temp (°C) | Plant Height (cm) in Soil Type (denoted by % Stamp Sand) | | | | | Amount Of Water (mL) | Observations |
|---|---|---|---|---|---|---|---|---|---|
| | | | 100% | 75% | 50% | 25% | 0% | | |
| 1 | Nov.15 | 22.4 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 2 | Nov.16 | 23.1 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 3 | Nov.17 | 23.3 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 4 | Nov.18 | 19.3 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 8 | Nov.21 | 30.5 | 0 | 0 | 0 | 0 | 0 | 50 | |
| 9 | Nov.22 | 26.3 | 1 | 1 | 1 | 1 | 1 | 50 | plants emerged |
| 10 | Nov.23 | 26.3 | 2 | 2 | 1 | 3 | 2.5 | 50 | plants continued to grow |
| 11 | Nov.25 | 19.8 | 2 | 2 | 2 | 3.5 | 3.5 | 50 | plants |
| 13 | Nov.27 | 18 | 4 | 4 | 4 | 4 | 4 | 0 | plants |
| 14 | Nov.28 | 22.9 | 4 | 4 | 4 | 4 | 4 | 0 | plants |
| 15 | Nov.29 | 19.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 50 | plants |
| 16 | Nov.30 | 19.5 | 4.5 | 4.5 | 3 | 3 | 3 | 50 | plants |
| 17 | Dec.1 | 19.5 | 4.5 | 4.5 | 4 | 4 | 4 | 50 | plants |
| 18 | Dec.2 | 18.1 | 5 | 4 | 4 | 4.5 | 4 | 30 | plants |
| 21 | Dec.5 | 27.7 | 5 | 4 | 4 | 4.7 | 4 | 0 | plants |
| 22 | Dec.6 | 20.3 | 5 | 4 | 4 | 4.7 | 4 | 30 | plants |
| 23 | Dec.7 | 20.8 | 5 | 4 | 4 | 4.8 | 4 | 30 | plants |
| 24 | Dec. 8 | 21.4 | 5 | 4 | 4.1 | 4.9 | 4 | 50 | plants |
| 25 | Dec. 9 | 22.5 | 5 | 4 | 4.2 | 4.9 | 4 | 20 | plants |
| 26 | Dec. 10 | 23.3 | 5 | 4 | 4.2 | 4.8 | 4 | 50 | plants |
| 30 | Dec. 14 | 23 | 5.5 | 5 | 5 | 5.1 | 5.3 | 50 | plants |
| 32 | Dec. 16 | 23.5 | 5.5 | 5 | 5 | 5.1 | 5.3 | 75 | plants |
| 35 | Dec. 19 | 23.4 | 5.5 | 5 | 5 | 5.1 | 5.3 | 75 | plants |
| 36 | Dec. 20 | 25.3 | 5.5 | 5 | 5 | 5.1 | 5.3 | 50 | plants |
| 37 | Dec. 21 | 23.5 | 5.5 | 5 | 5 | 5.1 | 5.3 | 75 | plants |
| 40 | Dec. 24 | 21.3 | 5.5 | 5 | 5 | 5.1 | 5.3 | 50 | plants |
| 43 | Dec. 27 | 21.6 | 5.5 | 5 | 5 | 5.1 | 5.3 | 50 | plants |
| 46 | Dec 30 | 24.2 | 5.5 | 5 | 5 | 5.1 | 5.3 | 75 | plants |
| 51 | Jan. 4 | 25.7 | 5.5 | 5 | 5 | 5.1 | 5.3 | 50 | plants |
| 52 | Jan. 5 | 25.3 | 5.5 | 5 | 5 | 5.1 | 5.3 | 50 | plants |

**Table 2.9. Experiment 1 Plant Measurements after the growing period ended**

| | Control | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100% Stamp Sand | | | | 75% Stamp Sand | | | | 50% Stamp Sand | | | | 25% Stamp Sand | | | | 0% Stamp Sand | | | |
| Growing Time (days) 32 | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average |
| Total Mass in Container (g) | 2344.2 | | | | 1948.5 | | | | 1756.4 | | | | 1474.9 | | | | 1193.4 | | | |
| Weighing Dish Mass (g) | 2.4 | 2.7 | 2.9 | 2.7 | 2.4 | 2.7 | 2.9 | 2.7 | 2.7 | 2.7 | 2.9 | 2.8 | 2.4 | 2.7 | 2.9 | 2.7 | 2.4 | 2.7 | 2.9 | 2.7 |
| Soil and Dish Mass (g) | 323.6 | 468.0 | 400.0 | 397.2 | 695.7 | 662.5 | 557.3 | 638.5 | 527.3 | 634.8 | 585.8 | 582.6 | 544.3 | 477.9 | 437.4 | 486.5 | 814.9 | 703.0 | 805.5 | 774.5 |
| Soil Mass (g) | 321.3 | 465.3 | 397.1 | 394.6 | 693.4 | 659.8 | 554.4 | 635.9 | 524.6 | 632.1 | 582.9 | 579.9 | 542.0 | 475.2 | 434.5 | 483.9 | 812.6 | 700.3 | 802.6 | 771.8 |
| Plant Mass (g) | - | - | - | - | - | - | - | - | - | - | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.1 | - | - | - | - |
| Overall Plant Length (cm) | 10.0 | - | 7.8 | 8.9 | - | - | - | - | - | - | 6.5 | 6.5 | 11.3 | 7.4 | 9.0 | 9.2 | - | - | - | - |
| Above Ground Plant Length (cm) | 4.5 | - | 2.5 | 3.5 | - | - | - | - | - | - | 1.5 | 1.5 | 1.3 | 2.1 | 4.0 | 2.5 | - | - | - | - |
| Root Length (cm) | 5.5 | - | 5.3 | 5.4 | - | – | – | - | - | - | 5.0 | 5.0 | 10.0 | 5.3 | 5.0 | 6.8 | - | - | - | - |
| Soil Area (cm2) | 53.5 | 54.5 | 61.4 | 56.4 | 48.8 | 65.3 | 49.7 | 54.6 | 55.5 | 50.8 | 60.2 | 55.5 | 65.0 | 53.4 | 58.2 | 58.8 | 57.8 | 68.6 | 60.8 | 62.4 |
| Number of Plants | 1 | - | 2 | 1.5 | 0 | 0 | 0 | 0.0 | 0 | 0 | 1 | 1.0 | 3 | 4 | 1 | 2.7 | 0 | 0 | 0 | 0.0 |
| Plant Density (# plants/cm2) | 0.02 | - | 0.03 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.05 | 0.07 | 0.02 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 |

| | Trefoil | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100% Stamp Sand | | | | 75% Stamp Sand | | | | 50% Stamp Sand | | | | 25% Stamp Sand | | | | 0% Stamp Sand | | | |
| Growing Time (days) 32 | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average |
| Total Mass in Container (g) | 2292.9 | | | | 1959.7 | | | | 1663.0 | | | | 1559.1 | | | | 1166.3 | | | |
| Weighing Dish Mass (g) | 209.7 | 289.4 | 342.0 | 280.4 | 209.7 | 289.4 | 342.0 | 280.4 | 209.7 | 289.4 | 342.0 | 280.4 | 209.7 | 289.4 | 342.0 | 280.4 | 209.7 | 289.4 | 342.0 | 280.4 |
| Soil and Dish Mass (g) | 896.8 | 1007.5 | 1212.4 | 1038.9 | 827.5 | 842.3 | 1122.1 | 930.6 | 645.5 | 923.8 | 916.8 | 828.7 | 671.0 | 831.2 | 876.6 | 792.9 | 517.6 | 628.8 | 818.7 | 655.0 |
| Soil Mass (g) | 687.1 | 718.1 | 870.4 | 758.5 | 617.8 | 552.9 | 780.1 | 650.3 | 435.8 | 634.4 | 574.8 | 548.3 | 461.3 | 541.8 | 534.6 | 512.6 | 307.9 | 339.4 | 476.7 | 374.7 |
| Plant Mass (g) | 0.5 | 0.3 | 0.1 | 0.3 | 0.1 | 0.4 | 0.3 | 0.2 | 0.1 | 0.0 | 1.5 | 0.6 | 0.4 | 0.6 | 1.7 | 0.9 | 1.1 | 3.3 | 8.0 | 4.2 |
| Overall Plant Length (cm) | 4.3 | 3.7 | 5.5 | 4.5 | 3.2 | 3.3 | 4.0 | 3.5 | 4.2 | 3.8 | 9.2 | 5.7 | 4.3 | 8.8 | 10.0 | 7.7 | 8.3 | 7.8 | 9.2 | 8.4 |
| Above Ground Plant Length (cm) | 0.8 | 1.0 | 0.7 | 0.8 | 0.5 | 1.0 | 1.0 | 0.8 | 1.3 | 0.8 | 2.0 | 1.4 | 1.2 | 1.8 | 2.0 | 1.7 | 1.3 | 1.5 | 2.5 | 1.8 |
| Root Length (cm) | 3.5 | 2.7 | 4.8 | 3.7 | 2.7 | 2.3 | 3.0 | 2.7 | 2.8 | 3.0 | 7.2 | 4.3 | 3.2 | 7.0 | 8.0 | 6.1 | 7.0 | 6.3 | 6.7 | 6.7 |
| Tallest Plant (cm) | 12.0 | 6.0 | 7.0 | 8.3 | 5.0 | 6.5 | 6.5 | 6.0 | 6.5 | 5.5 | 11.5 | 7.8 | 11.0 | 9.5 | 11.5 | 10.7 | 10.5 | 10.5 | 15.5 | 12.2 |
| Smallest Plant (cm) | 2.0 | 2.5 | 2.0 | 2.2 | 1.0 | 2.0 | 1.5 | 1.5 | 2.5 | 2.0 | 4.0 | 2.8 | 2.5 | 3.0 | 2.0 | 2.5 | 1.5 | 1.0 | 3.0 | 1.8 |
| Soil Area (cm2) | 55.8 | 54.9 | 53.1 | 54.6 | 56.1 | 57.0 | 58.9 | 57.3 | 53.0 | 71.4 | 60.2 | 61.5 | 56.8 | 62.7 | 53.9 | 57.8 | 49.9 | 74.9 | 15.8 | 46.9 |
| Number of Plants | 49.0 | 18.0 | 10.0 | 25.7 | 18.0 | 27.0 | 11.0 | 18.7 | 6.0 | 2.0 | 18.0 | 8.7 | 16.0 | 13.0 | 12.0 | 13.7 | 21.0 | 36.0 | 38.0 | 31.7 |
| Plant Density (# plants/cm2) | 0.9 | 0.3 | 0.2 | 0.5 | 0.3 | 0.5 | 0.2 | 0.3 | 0.1 | 0.0 | 0.3 | 0.1 | 0.3 | 0.2 | 0.2 | 0.2 | 0.4 | 0.5 | 2.4 | 1.1 |

| | | Alfalfa | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 100% Stamp Sand | | | | 75% Stamp Sand | | | | 50% Stamp Sand | | | | 25% Stamp Sand | | | | 0% Stamp Sand | | | |
| **Growing Time (days)** | **52** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** |
| **Total Mass in Container (g)** | | 2446.3 | | | | 1930.0 | | | | 1639.6 | | | | 1415.0 | | | | 1235.0 | | | |
| **Weighing Dish Mass (g)** | | 211.1 | 290.4 | 342.1 | 281.2 | 307.0 | 302.7 | 309.0 | 306.2 | 307.0 | 302.7 | 309.0 | 306.2 | 307.0 | 302.7 | 309.0 | 306.2 | 307.0 | 302.7 | 309.0 | 306.2 |
| **Soil and Dish Mass (g)** | | 798.7 | 1006.9 | 1282.8 | 1029.5 | 792.5 | 1005.9 | 1030.9 | 943.1 | 720.1 | 742.0 | 888.8 | 783.6 | 634.5 | 769.5 | 717.6 | 707.2 | 719.0 | - | 745.3 | 732.2 |
| **Soil Mass (g)** | | 587.6 | 716.5 | 940.7 | 748.3 | 485.5 | 703.2 | 721.9 | 636.9 | 413.1 | 439.3 | 579.8 | 477.4 | 327.5 | 466.8 | 408.6 | 401.0 | 412.0 | - | 436.3 | 424.2 |
| **Plant Mass (g)** | | 4.1 | 16.8 | 12.3 | 11.1 | 1.7 | 1.6 | 3.8 | 2.4 | 2.4 | 3.7 | 4.9 | 3.6 | 1.0 | 5.9 | 14.0 | 7.0 | 2.6 | 9.4 | 2.5 | 4.8 |
| **Overall Plant Length (cm)** | | 7.0 | 5.0 | 6.7 | 6.2 | 4.5 | 7.8 | 8.7 | 7.0 | 7.2 | 5.3 | 11.7 | 8.1 | 5.8 | 7.7 | 12.7 | 8.7 | 11.3 | 8.3 | 11.3 | 10.3 |
| **Above Ground Plant Length (cm)** | | 1.5 | 2.0 | 1.5 | 1.7 | 3.2 | 2.5 | 2.7 | 2.8 | 3.2 | 3.1 | 4.0 | 3.4 | 2.3 | 2.3 | 3.3 | 2.7 | 2.3 | 2.0 | 2.5 | 2.3 |
| **Root Length (cm)** | | 5.5 | 3.0 | 5.2 | 4.6 | 1.3 | 5.3 | 6.0 | 4.2 | 4.0 | 2.2 | 7.7 | 4.6 | 3.5 | 5.3 | 9.3 | 6.1 | 9.0 | 6.3 | 8.8 | 8.1 |
| **Tallest Plant (cm)** | | 10.5 | 16.0 | 11.0 | 12.5 | 8.5 | 12.0 | 11.0 | 10.5 | 20.0 | 15.0 | 17.5 | 17.5 | 8.0 | 21.0 | 23.0 | 17.3 | 15.5 | 15.0 | 17.5 | 16.0 |
| **Smallest Plant (cm)** | | 3.5 | 2.0 | 3.0 | 2.8 | 3.0 | 3.0 | 5.0 | 3.7 | 4.0 | 3.0 | 6.0 | 4.3 | 3.5 | 2.0 | 1.0 | 2.2 | 2.5 | 3.0 | 4.5 | 3.3 |
| **Soil Area (cm2)** | | 61.8 | 65.0 | 1086.5 | 404.4 | 57.0 | 57.0 | 66.5 | 60.2 | 65.0 | 65.0 | 65.0 | 65.0 | 65.0 | 65.0 | 65.0 | 65.0 | 63.0 | 65.0 | 70.0 | 66.0 |
| **Number of Plants** | | 74.0 | 122.0 | 133.0 | 109.7 | 43.0 | 77.0 | 57.0 | 59.0 | 57.0 | 26.0 | 47.0 | 43.3 | 42.0 | 53.0 | 32.0 | 42.3 | 43.0 | 24.0 | 47.0 | 38.0 |
| **Plant Density (# plants/cm2)** | | 1.2 | 1.9 | 0.1 | 1.1 | 0.8 | 1.4 | 0.9 | 1.0 | 0.9 | 0.4 | 0.7 | 0.7 | 0.6 | 0.8 | 0.5 | 0.7 | 0.7 | 0.4 | 0.7 | 0.6 |

| | | Red Clover | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 100% Stamp Sand | | | | 75% Stamp Sand | | | | 50% Stamp Sand | | | | 25% Stamp Sand | | | | 0% Stamp Sand | | | |
| **Growing Time (days)** | **52** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** |
| **Total Mass in Container (g)** | | 2309.6 | | | | 1862.6 | | | | 1604.2 | | | | 1456.2 | | | | 1221.2 | | | |
| **Weighing Dish Mass (g)** | | 211.1 | 290.4 | 342.1 | 281.2 | 211.1 | 290.4 | 342.1 | 281.2 | 211.1 | 290.4 | 342.1 | 281.2 | 211.1 | 290.4 | 342.1 | 281.2 | 211.1 | 290.4 | 342.1 | 281.2 |
| **Soil and Dish Mass (g)** | | 969.9 | 909.0 | 1222.1 | 1033.7 | 748.2 | 879.5 | 1022.6 | 883.4 | 657.4 | 803.8 | 924.4 | 795.2 | 594.2 | 802.8 | 834.8 | 743.9 | 542.1 | 742.7 | 710.1 | 665.0 |
| **Soil Mass (g)** | | 758.8 | 618.6 | 880.0 | 752.5 | 537.1 | 589.1 | 680.5 | 602.2 | 446.3 | 513.4 | 582.3 | 514.0 | 383.1 | 512.4 | 492.7 | 462.7 | 331.0 | 452.3 | 368.0 | 383.8 |
| **Plant Mass (g)** | | 5.0 | 3.2 | 3.3 | 3.8 | 2.9 | 4.4 | 3.4 | 3.6 | 7.4 | 10.3 | 9.0 | 8.9 | 4.2 | 9.9 | 24.9 | 13.0 | 5.8 | 15.4 | 12.5 | 11.3 |
| **Overall Plant Length (cm)** | | 4.0 | 4.3 | 5.5 | 4.6 | 3.8 | 3.3 | 5.0 | 4.1 | 4.8 | 5.2 | 9.7 | 6.6 | 9.0 | 11.3 | 11.0 | 10.4 | 9.2 | 8.3 | 11.3 | 9.6 |
| **Above Ground Plant Length (cm)** | | 1.5 | 1.0 | 1.7 | 1.4 | 1.5 | 1.3 | 1.5 | 1.4 | 1.5 | 1.5 | 2.0 | 1.7 | 2.2 | 3.5 | 3.0 | 2.9 | 3.3 | 4.3 | 3.8 | 3.8 |
| **Root Length (cm)** | | 2.5 | 3.3 | 3.8 | 3.2 | 2.3 | 2.0 | 3.5 | 2.6 | 3.3 | 3.7 | 7.7 | 4.9 | 6.8 | 7.8 | 8.0 | 7.6 | 5.8 | 4.0 | 7.5 | 5.8 |
| **Tallest Plant (cm)** | | 6.0 | 6.5 | 7.0 | 6.5 | 8.0 | 13.0 | 11.0 | 10.7 | 10.5 | 9.2 | 14.0 | 11.2 | 15.0 | 14.0 | 21.0 | 16.7 | 18.0 | 17.0 | 15.0 | 16.7 |
| **Smallest Plant (cm)** | | 2.0 | 1.5 | 2.0 | 1.8 | 1.0 | 1.5 | 1.5 | 1.3 | 1.5 | 1.0 | 1.5 | 1.3 | 3.0 | 2.0 | 2.5 | 2.5 | 6.0 | 0.9 | 5.0 | 4.0 |
| **Soil Area (cm2)** | | 65.0 | 65.0 | 67.0 | 65.7 | 61.2 | 87.8 | 62.6 | 70.5 | 64.3 | 67.3 | 64.9 | 65.5 | 71.4 | 67.2 | 69.3 | 69.3 | 65.1 | 66.2 | 67.2 | 66.2 |
| **Number of Plants** | | 118.0 | 198.0 | 115.0 | 143.7 | 94.0 | 127.0 | 153.0 | 124.7 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 |
| **Plant Density (# plants/cm2)** | | 1.8 | 3.0 | 1.7 | 2.2 | 1.5 | 1.4 | 2.4 | 1.8 | 3.1 | 3.0 | 3.1 | 3.1 | 2.8 | 3.0 | 2.9 | 2.9 | 3.1 | 3.0 | 3.0 | 3.0 |

| | | Fescue | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 100% Stamp Sand | | | | 75% Stamp Sand | | | | 50% Stamp Sand | | | | 25% Stamp Sand | | | | 0% Stamp Sand | | | |
| **Growing Time (days)** | **52** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** | **1** | **2** | **3** | **Average** |
| **Total Mass in Container (g)** | | 2301.6 | | | | 1944.9 | | | | 1728.5 | | | | 1450.1 | | | | 1230.7 | | | |
| **Weighing Dish Mass (g)** | | 305.4 | 306.7 | 300.0 | 304.0 | 305.4 | 306.7 | 300.0 | 304.0 | 305.4 | 306.7 | 300.0 | 304.0 | 305.4 | 306.7 | 300.0 | 304.0 | 305.4 | 306.7 | 300.0 | 304.0 |
| **Soil and Dish Mass (g)** | | 993.3 | 882.6 | 1220.0 | 1032.0 | 892.4 | 950.8 | 637.1 | 826.8 | 739.4 | 832.1 | 721.6 | 764.4 | 702.6 | 775.3 | 813.5 | 763.8 | 617.6 | 731.9 | 727.5 | 692.3 |
| **Soil Mass (g)** | | 687.9 | 575.9 | 920.0 | 727.9 | 587.0 | 644.1 | 337.1 | 522.7 | 434.0 | 525.4 | 421.6 | 460.3 | 397.2 | 468.6 | 513.5 | 459.8 | 312.2 | 425.2 | 427.5 | 388.3 |
| **Plant Mass (g)** | | 13.3 | 20.4 | 34.7 | 22.8 | 19.9 | 33.1 | 22.8 | 25.3 | 23.7 | 26.7 | 36.3 | 28.9 | 15.0 | 10.6 | 19.2 | 14.9 | 7.7 | 13.1 | 10.6 | 10.4 |
| **Overall Plant Length (cm)** | | 13.2 | 11.7 | 11.5 | 12.1 | 10.5 | 10.0 | 15.3 | 11.9 | 16.5 | 14.3 | 15.3 | 15.4 | 16.0 | 11.7 | 8.3 | 12.0 | 10.2 | 10.8 | 13.0 | 11.3 |
| **Above Ground Plant Length (cm)** | | 7.2 | 7.0 | 5.8 | 6.7 | 6.8 | 8.7 | 8.8 | 8.1 | 7.3 | 8.7 | 8.2 | 8.1 | 10.0 | 8.7 | 7.5 | 8.7 | 4.7 | 6.8 | 7.2 | 6.2 |
| **Root Length (cm)** | | 6.0 | 4.7 | 5.7 | 5.4 | 3.7 | 1.3 | 6.5 | 3.8 | 9.2 | 5.7 | 7.2 | 7.3 | 6.0 | 3.0 | 0.8 | 3.3 | 5.5 | 4.0 | 5.8 | 5.1 |
| **Tallest Plant (cm)** | | 15.5 | 20.0 | 15.0 | 16.8 | 17.0 | 13.0 | 18.0 | 16.0 | 18.0 | 19.5 | 23.5 | 20.3 | 18.5 | 15.0 | 12.0 | 15.2 | 22.0 | 18.0 | 19.5 | 19.8 |
| **Smallest Plant (cm)** | | 3.5 | 3.0 | 3.0 | 3.2 | 3.5 | 7.0 | 6.0 | 5.5 | 9.0 | 3.0 | 4.0 | 5.3 | 4.0 | 6.0 | 5.0 | 5.0 | 3.5 | 5.0 | 5.5 | 4.7 |
| **Soil Area (cm2)** | | 61.8 | 61.8 | 61.8 | 61.8 | 57.0 | 61.8 | 66.5 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 61.8 | 66.5 | 63.3 | 61.8 | 61.8 | 61.8 | 61.8 |
| **Number of Plants** | | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 |
| **Plant Density (# plants/cm2)** | | 3.2 | 3.2 | 3.2 | 3.2 | 3.5 | 3.2 | 3.0 | 3.3 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.0 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |

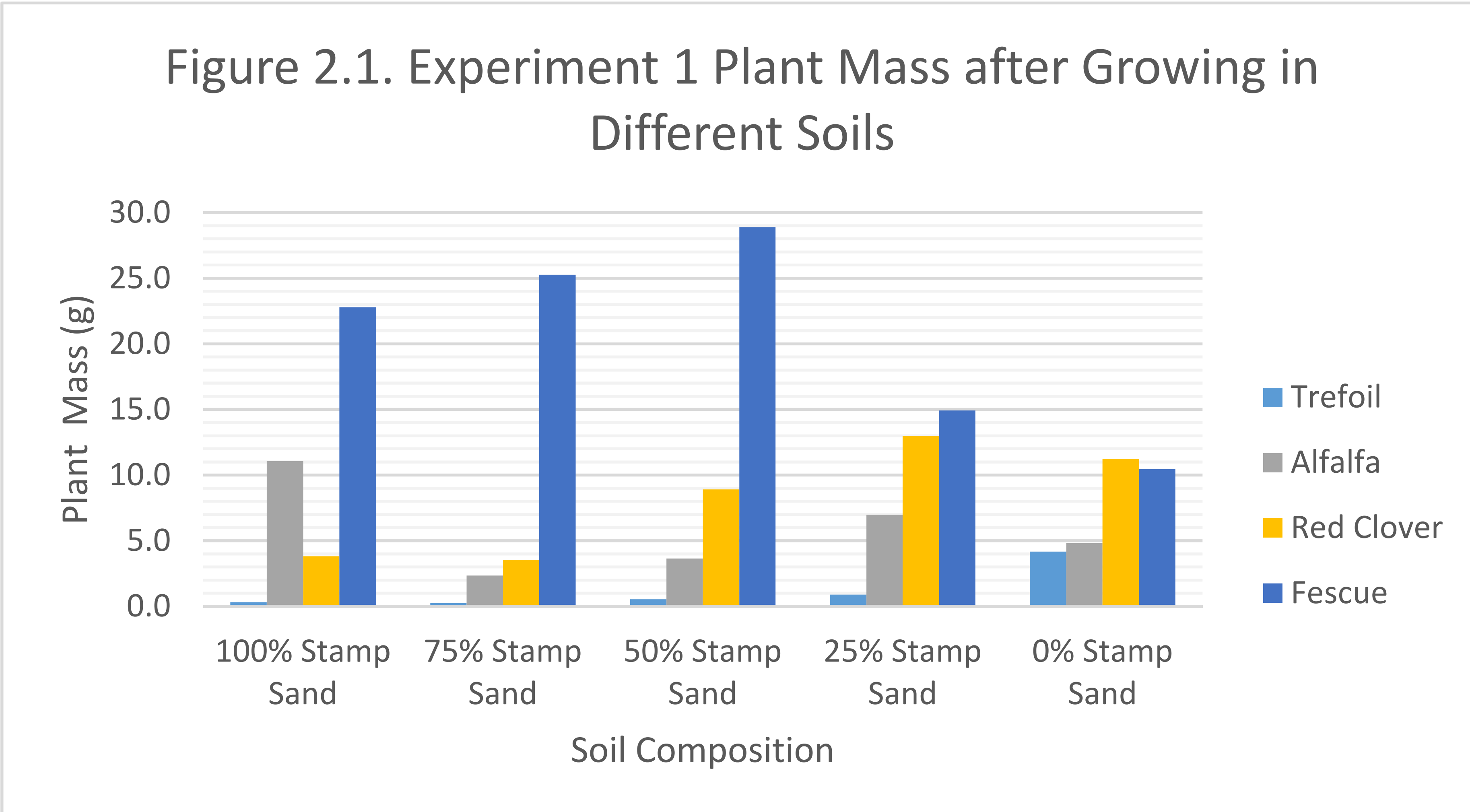


Figure 2.1. Experiment 1 Plant Mass after Growing in Different Soils
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Plant Mass (g)
100% Stamp Sand
75% Stamp Sand
50% Stamp Sand
25% Stamp Sand
0% Stamp Sand
Soil Composition
Trefoil
Alfalfa
Red Clover
Fescue

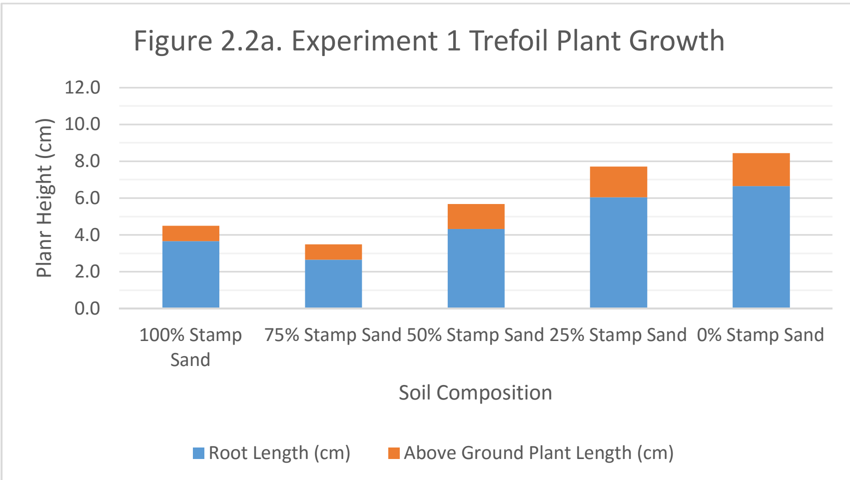


Figure 2.2a. Experiment 1 Trefoil Plant Growth
Planr Height (cm)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
100% Stamp Sand
75% Stamp Sand
50% Stamp Sand
25% Stamp Sand
0% Stamp Sand
Soil Composition
Root Length (cm)
Above Ground Plant Length (cm)

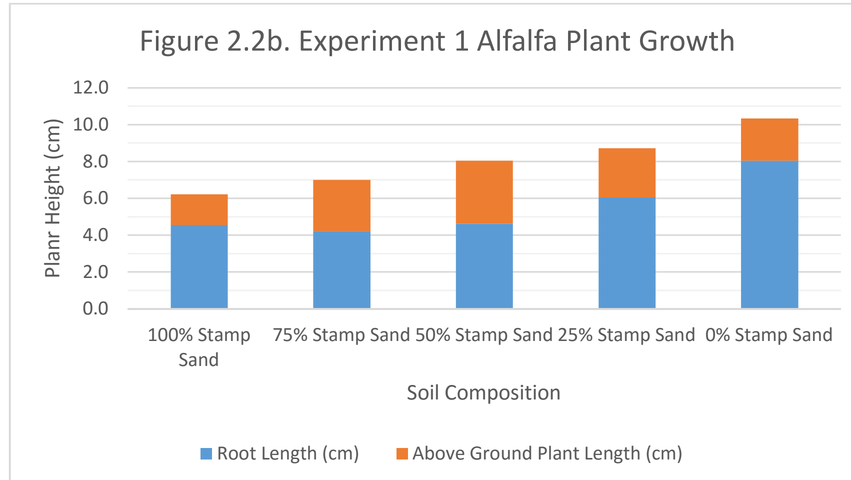


Figure 2.2b. Experiment 1 Alfalfa Plant Growth
Planr Height (cm)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
100% Stamp Sand
75% Stamp Sand
50% Stamp Sand
25% Stamp Sand
0% Stamp Sand
Soil Composition
Root Length (cm)
Above Ground Plant Length (cm)

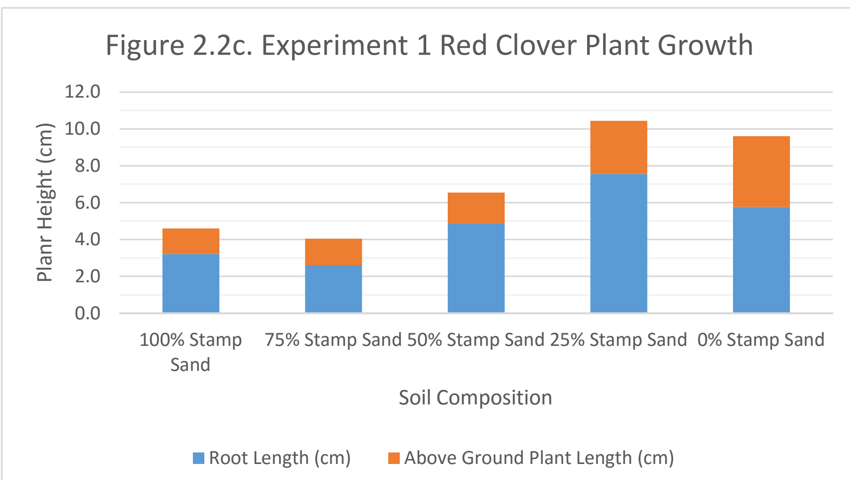


Figure 2.2c. Experiment 1 Red Clover Plant Growth
Planr Height (cm)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
100% Stamp Sand
75% Stamp Sand
50% Stamp Sand
25% Stamp Sand
0% Stamp Sand
Soil Composition
Root Length (cm)
Above Ground Plant Length (cm)

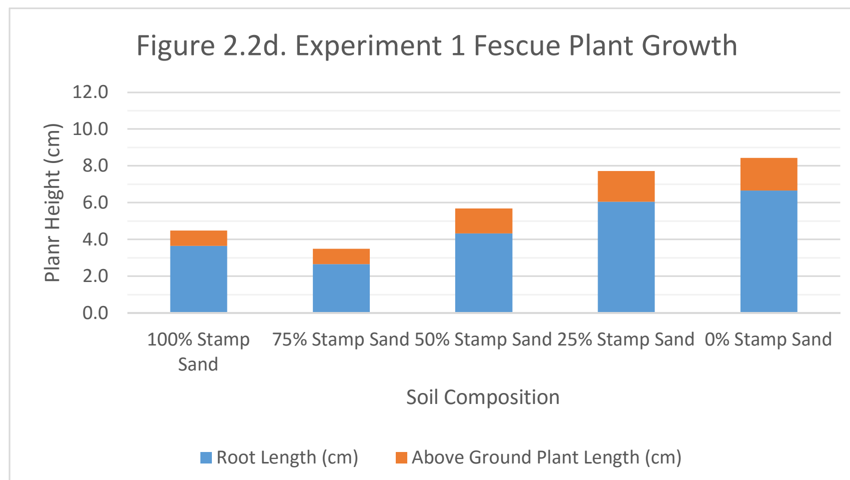


Figure 2.2d. Experiment 1 Fescue Plant Growth
Planr Height (cm)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
100% Stamp Sand
75% Stamp Sand
50% Stamp Sand
25% Stamp Sand
0% Stamp Sand
Soil Composition
Root Length (cm)
Above Ground Plant Length (cm)

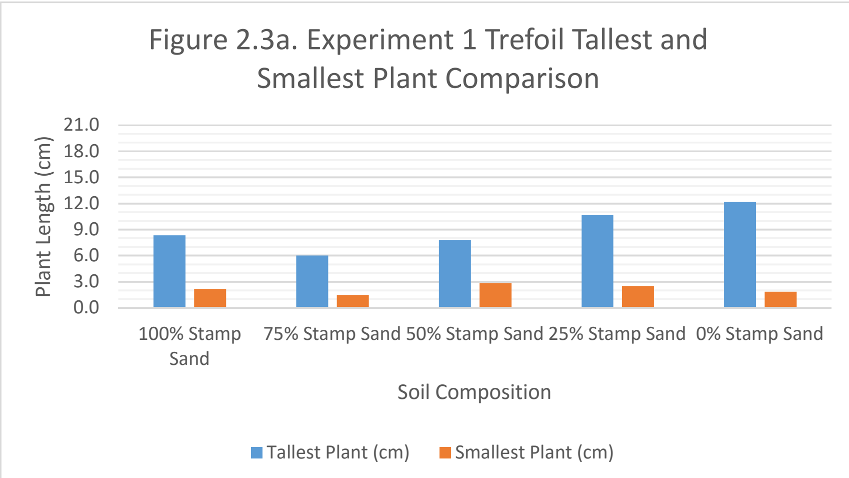


Figure 2.3a. Experiment 1 Trefoil Tallest and Smallest Plant Comparison
Plant Length (cm)
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
100% Stamp Sand
75% Stamp Sand
50% Stamp Sand
25% Stamp Sand
0% Stamp Sand
Soil Composition
Tallest Plant (cm)
Smallest Plant (cm)

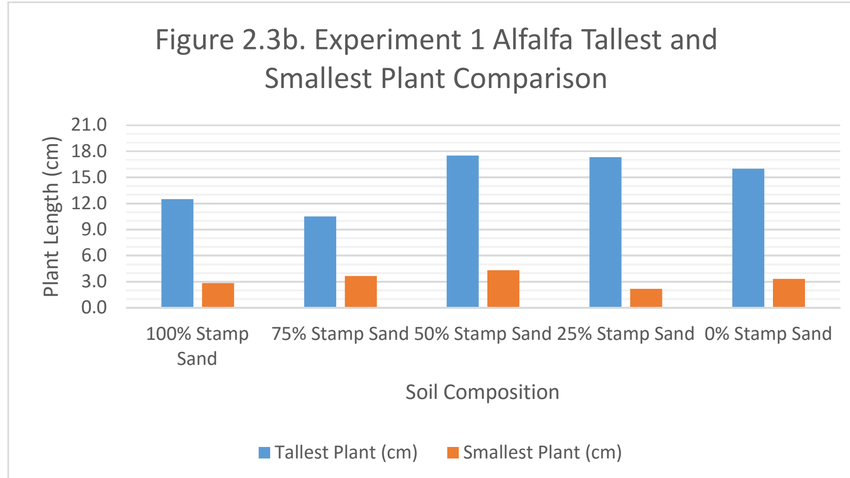



Figure 2.3b. Experiment 1 Alfalfa Tallest and Smallest Plant Comparison
Plant Length (cm)
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
100% Stamp Sand
75% Stamp Sand
50% Stamp Sand
25% Stamp Sand
0% Stamp Sand
Soil Composition
Tallest Plant (cm)
Smallest Plant (cm)

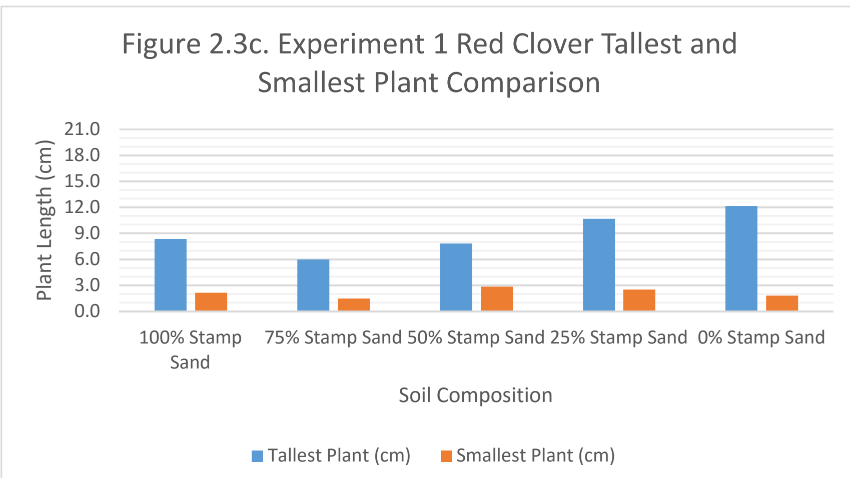



Figure 2.3c. Experiment 1 Red Clover Tallest and Smallest Plant Comparison
Plant Length (cm)
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
100% Stamp Sand
75% Stamp Sand
50% Stamp Sand
25% Stamp Sand
0% Stamp Sand
Soil Composition
Tallest Plant (cm)
Smallest Plant (cm)

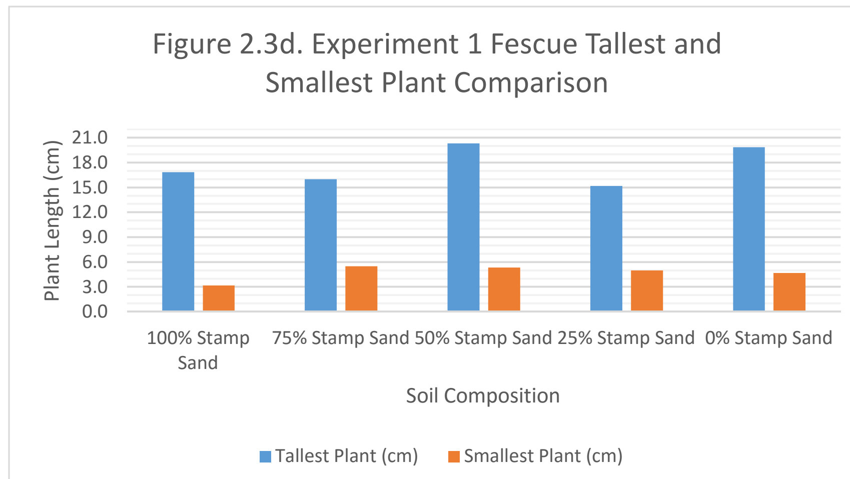



Figure 2.3d. Experiment 1 Fescue Tallest and Smallest Plant Comparison
Plant Length (cm)
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
100% Stamp Sand
75% Stamp Sand
50% Stamp Sand
25% Stamp Sand
0% Stamp Sand
Soil Composition
Tallest Plant (cm)
Smallest Plant (cm)

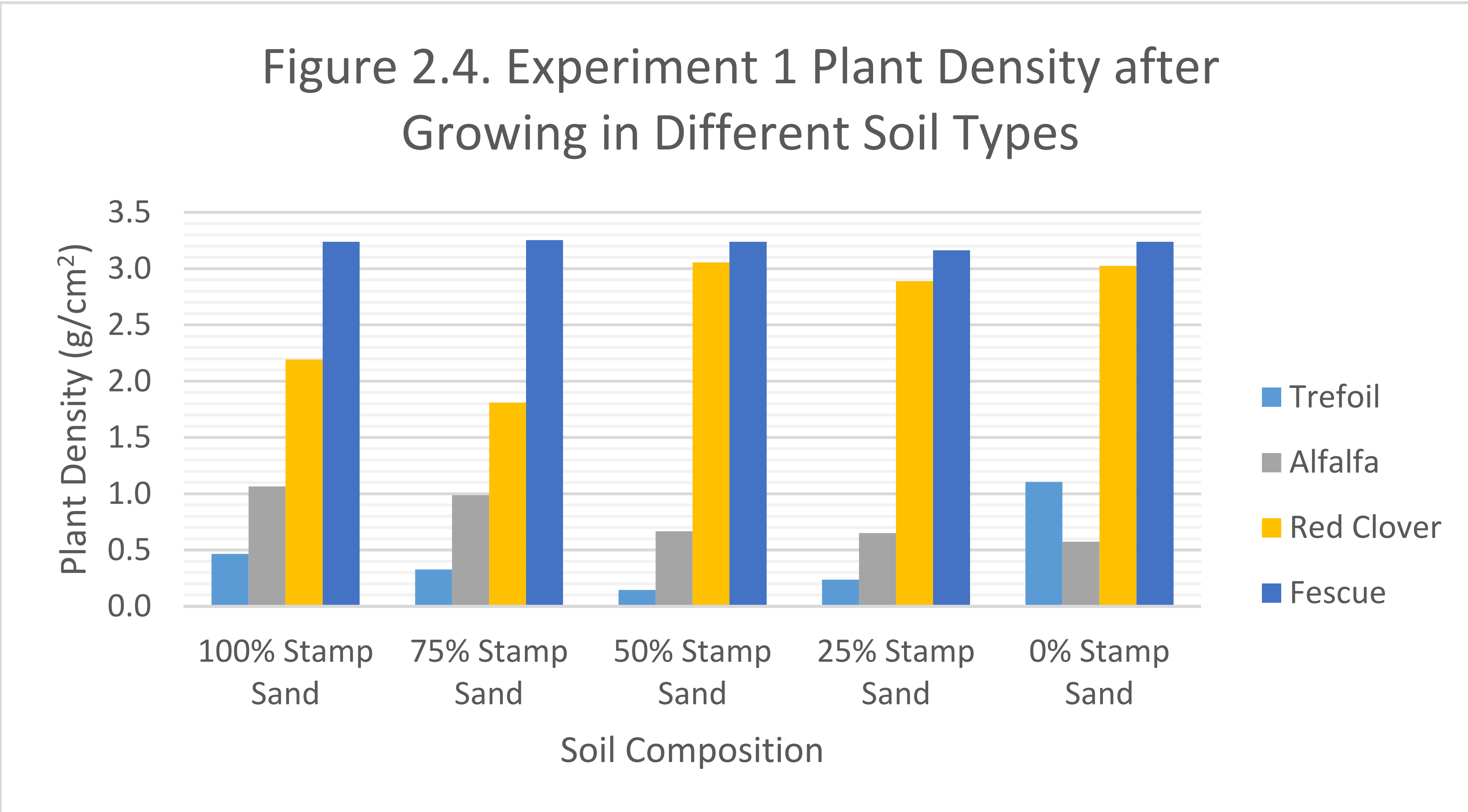


Figure 2.4. Experiment 1 Plant Density after Growing in Different Soil Types
Plant Density (g/cm²)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
100% Stamp Sand
75% Stamp Sand
50% Stamp Sand
25% Stamp Sand
0% Stamp Sand
Soil Composition
Trefoil
Alfalfa
Red Clover
Fescue

**Table 2.10. Experiment 2: Mass of Each Seed Type Planted**

| Plant Type | Mass of Seeds Planted (g) | | | |
|---|---|---|---|---|
| | Control | High Water Table | Wind | Tire Erosion |
| Alfalfa | 10 | 10 | 10 | 10 |
| Red Fescue | 10 | 10 | 10 | 10 |

**Table 2.11. Experiment 2 Data and Observations**
**Plant Type: Alfalfa**

| Day | Date | Temp (°C) | Plant Height (cm) | | | | Amount of Water (mL) | Observations | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Control | Water Table | Tire Erosion | Wind | | Water Table | Tire Erosion | Wind |
| 1 | 01-10-2017 | - | - | - | - | - | 75 | | | |
| 2 | 01-11-2017 | - | - | - | - | - | 75 | | | |
| 3 | 01-12-2017 | 21.4 | 0 | 0 | 0 | 0 | 100 | | | |
| 4 | 01-13-2017 | 23.6 | 1 | 1 | 1 | 1 | 75 | | | |
| 5 | 01-14-2017 | - | - | - | - | - | Sat. | | | |
| 6 | 01-15-2017 | - | - | - | - | - | Sun. | | | |
| 7 | 01-16-2017 | 25.4 | 1 | 1 | 1 | 1 | 125 | | | |
| 8 | 01-17-2017 | 26 | 1 | 1 | 1 | 1 | 100 | | | |
| 9 | 01-18-2017 | 25.1 | 1.5 | 1.5 | 1.5 | 1.5 | 100 | | | |
| 10 | 01-19-2017 | 23.9 | 1.5 | 1.5 | 1.5 | 1.5 | - | | | |
| 11 | 01-20-2017 | 24.2 | 1.5 | 1.5 | 1.5 | 1.5 | - | | | |
| 12 | 01-21-2017 | - | - | - | - | - | Sat. | | | |
| 13 | 01-22-2017 | - | - | - | - | - | Sun. | | | |
| 14 | 01-23-2017 | 23.3 | 1.5 | 1.5 | 1.5 | 1.5 | 100 | | | |
| 15 | 01-24-2017 | 24 | 3 | 3 | 3 | 3 | 100 | | | |
| 16 | 01-25-2017 | 22.9 | 4 | 4 | 4 | 4 | 100 | | | |
| 17 | 01-26-2017 | 22.2 | 5 | 5 | 5 | 5 | 100 | Water level decreased as water filled the soil | Hard to push wheel through plants, plants at the front are pushed down | The wind stressor will start tomorrow. It will operate form 6-10AM |
| 18 | 01-27-2017 | 23.6 | 5 | 5 | 5 | 5 | 100 | | | |
| 19 | 01-28-2017 | - | - | - | - | - | Sat. | | | |
| 20 | 01-29-2017 | - | - | - | - | - | Sun. | | | |
| 21 | 01-30-2017 | 23.6 | 5 | 5 | 5 | 5 | 100 | | | |
| 22 | 01-31-2017 | 22.5 | 5 | 5 | 5 | 5 | 100 | | | |
| 23 | 02-01-2017 | 22.5 | 5 | 5 | 5 | 5 | 100 | Some of the plants are yellow | The plants are bent where the wheels are driving over them | The plants are blown down in the direction of the wind |
| 24 | 02-02-2017 | 24.5 | 6 | 6 | 6 | 5 | 100 | | | |
| 25 | 02-03-2017 | 23.3 | 7 | 7 | 6 | 5 | 100 | | | |
| 26 | 02-04-2017 | - | - | - | - | - | Sat. | | | |
| 27 | 02-05-2017 | - | - | - | - | - | Sun. | | | |
| 28 | 02-06-2017 | 24.7 | 6 | 7 | 6 | 5 | 100 | | | |
| 29 | 02-07-2017 | 24.5 | 6 | 7 | 6 | 5 | 100 | | | |
| 30 | 02-08-2017 | 24.6 | 6 | 7 | 6 | 5 | 100 | | | |

**Plant Type: Fescue**

| Day | Date | Temp (°C) | Plant Height (cm) | | | | Amount of Water (mL) | Observations | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Control | Water Table | Tire Erosion | Wind | | Water Table | Tire Erosion | Wind |
| 1 | 01-10-2017 | - | - | - | - | - | - | | | |
| 2 | 01-11-2017 | - | - | - | - | - | 75 | | | |
| 3 | 01-12-2017 | 21.4 | 3 | 3 | 3 | 3 | 100 | | | |
| 4 | 01-13-2017 | 32.6 | 3 | 3 | 3 | 3 | 75 | | | |
| 5 | 01-14-2017 | - | - | - | - | - | Sat. | | | |
| 6 | 01-15-2017 | - | - | - | - | - | Sun. | | | |
| 7 | 01-16-2017 | 25.9 | 3 | 3 | 3 | 3 | 125 | | | |
| 8 | 01-17-2017 | 26 | 3 | 3 | 3 | 3 | 100 | | | |
| 9 | 01-18-2017 | 25.1 | 4 | 4 | 4 | 4 | 100 | | | |
| 10 | 01-19-2017 | 23.9 | 4 | 4 | 4 | 4 | - | | | |
| 11 | 01-20-2017 | 24.2 | 4 | 4 | 4 | 4 | - | | | |
| 12 | 01-21-2017 | - | - | - | - | - | Sat. | | | |
| 13 | 01-22-2017 | - | - | - | - | - | Sun. | | | |
| 14 | 01-23-2017 | 23.3 | 4 | 4 | 4 | 4 | 100 | | | |
| 15 | 01-24-2017 | 24 | 6 | 6 | 6 | 6 | 100 | | | |
| 16 | 01-25-2017 | 22.9 | 6 | 6 | 6 | 6 | 100 | | | |
| 17 | 01-26-2017 | 22.2 | 7 | 7 | 7 | 7 | 100 | Water level decreased as water filled the soil | Hard to push wheel through plants, plants at the front are pushed down | The wind stressor will start tomorrow. It will operate form 6-10AM |
| 18 | 01-27-2017 | 23.6 | 7 | 7 | 7 | 7 | 100 | | | |
| 19 | 01-28-2017 | - | - | - | - | - | Sat. | | | |
| 20 | 01-29-2017 | - | - | - | - | - | Sun. | | | |
| 21 | 01-30-2017 | 23.6 | 7 | 7 | 7 | 7 | 100 | | | |
| 22 | 01-31-2017 | 22.5 | 7 | 7 | 7 | 7 | 100 | | | |
| 23 | 02-01-2017 | 22.5 | 7 | 7 | 7 | 7 | 100 | Some of the plants are yellow | The plants are bent where the wheels are driving over them | The plants are blown down in the direction of the wind |
| 24 | 02-02-2017 | 24.5 | 8 | 8 | 7 | 6 | 100 | | | |
| 25 | 02-03-2017 | 23.3 | 9 | 9 | 6 | 6 | 100 | Fescue seems more resistant, than alfalfa does, to all of the stressors | | |
| 26 | 02-04-2017 | - | - | - | - | - | Sat. | | | |
| 27 | 02-05-2017 | - | - | - | - | - | Sun. | | | |
| 28 | 02-06-2017 | 24.7 | 9 | 9 | 6 | 6 | 100 | | | |
| 29 | 02-07-2017 | 24.5 | 9 | 9 | 6 | 6 | 100 | | | |
| 30 | 02-08-2017 | 24.6 | 9 | 9 | 6 | 6 | 100 | | | |

**Table 2.11 Experiment 2 Plant Measurements after the growing period ended**

| Plant: Alfalfa | | Control | | | | Water Table | | | | Wind | | | | Tire Erosion | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Growing Time (days) | 30 | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average |
| Total Mass in Container (g) | | 2723.5 | | | | 2952.4 | | | | 2341.0 | | | | 2885.1 | | | |
| Container Mass (g) | | 82.0 | | | | 131.2 | | | | 78.6 | | | | 116.1 | | | |
| Weighing Dish Mass (g) | | 208.7 | 288.6 | 341.3 | 279.5 | 208.7 | 288.6 | 341.3 | 279.5 | 208.7 | 288.6 | 341.3 | 279.5 | 208.7 | 288.6 | 341.3 | 279.5 |
| Soil and Dish Mass (g) | | 975.3 | 950.1 | 1,314.8 | 1,080.1 | 1,045.7 | 701.2 | 1,410.3 | 1,052.4 | 825.2 | 828.5 | 1,303.6 | 985.8 | 887.6 | 1,189.9 | 1,253.0 | 1,110.2 |
| Soil Mass (g) | | 766.6 | 661.5 | 973.5 | 800.5 | 837.0 | 412.6 | 1,069.0 | 772.9 | 616.5 | 539.9 | 962.3 | 706.2 | 678.9 | 901.3 | 911.7 | 830.6 |
| Plant Mass (g) | | 80.9 | 86.3 | 62.9 | 62.9 | 151.9 | 187.8 | 173.3 | 173.3 | 80.1 | 53.3 | 54.2 | 54.2 | 72.9 | 98.6 | 95.7 | 95.7 |
| Overall Plant Length (cm) | | 9.8 | 8.8 | 7.2 | 8.6 | 10.6 | 9.3 | 10.5 | 10.1 | 10.7 | 11.7 | 9.5 | 10.6 | 10.3 | 9.5 | 6.6 | 8.8 |
| Above Ground Plant Length (cm) | | 4.3 | 6.2 | 5.3 | 5.3 | 6.6 | 6.3 | 7.2 | 6.7 | 6.0 | 5.8 | 5.3 | 5.3 | 5.5 | 5.3 | 4.3 | 5.1 |
| Root Length (cm) | | 5.5 | 2.7 | 1.8 | 3.3 | 4.0 | 3.0 | 3.3 | 3.4 | 4.7 | 5.8 | 4.2 | 4.2 | 4.8 | 4.1 | 2.2 | 3.7 |
| Longest Plant (cm) | | 13.0 | 14.5 | 13.0 | 13.5 | 8.0 | 13.0 | 11.0 | 10.7 | 11.5 | 12.5 | 13.0 | 13.0 | 13.0 | 11.5 | 12.5 | 12.3 |
| Shortest Plant (cm) | | 7.0 | 5.5 | 6.0 | 6.2 | 7.0 | 8.5 | 7.0 | 7.5 | 7.0 | 6.5 | 6.0 | 6.0 | 6.0 | 4.5 | 5.0 | 5.2 |
| Number of Plants | | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 |
| Soil Area (cm2) | | 64.9 | 67.0 | 65.9 | 65.9 | 67.8 | 67.8 | 71.0 | 68.9 | 68.3 | 68.3 | 68.3 | 68.3 | 68.3 | 66.2 | 72.5 | 69.0 |
| Plant Density (# plants/cm2) | | 3.1 | 3.0 | 3.0 | 3.0 | 2.9 | 2.9 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 2.8 | 2.9 |

| Plant: Fescue | | Control | | | | Water Table | | | | Wind | | | | Tire Erosion | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Growing Time (days) | 30 | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average | 1 | 2 | 3 | Average |
| Total Mass in Container (g) | | 2414.0 | | | | 3034.5 | | | | 2379.4 | | | | 2536.2 | | | |
| Container Mass (g) | | 82.2 | | | | 95.0 | | | | 79.3 | | | | 92.3 | | | |
| Weighing Dish Mass (g) | | 304.8 | 299.2 | 305.8 | 303.3 | 304.8 | 299.2 | 305.8 | 303.3 | 304.8 | 299.2 | 305.8 | 303.3 | 304.8 | 299.2 | 305.8 | 303.3 |
| Soil and Dish Mass (g) | | 1011.2 | 963.0 | 997.3 | 990.5 | 1126.3 | 864.5 | 1196.6 | 1062.5 | 892.6 | 1058.6 | 1068.1 | 1006.4 | 952.2 | 952.8 | 1154.8 | 1019.9 |
| Soil Mass (g) | | 706.4 | 663.8 | 691.5 | 687.2 | 821.5 | 565.3 | 890.8 | 759.2 | 587.8 | 759.4 | 762.3 | 703.2 | 647.4 | 653.6 | 849.0 | 716.7 |
| Plant Mass (g) | | 111.9 | 88.8 | 111.1 | 111.1 | 221.3 | 138.0 | 252.7 | 252.7 | 58.9 | 85.5 | 92.8 | 92.8 | 103.8 | 155.4 | 82.5 | 82.5 |
| Overall Plant Length (cm) | | 11.8 | 11.5 | 12.2 | 11.8 | 12.0 | 11.5 | 8.7 | 10.7 | 12.5 | 13.7 | 12.5 | 12.9 | 11.8 | 13.8 | 16.0 | 13.9 |
| Above Ground Plant Length (cm) | | 7.2 | 8.3 | 7.7 | 7.7 | 9.3 | 8.5 | 6.3 | 8.1 | 7.0 | 8.5 | 7.2 | 7.2 | 7.5 | 9.2 | 10.7 | 9.1 |
| Root Length (cm) | | 4.7 | 3.2 | 4.5 | 4.1 | 2.7 | 3.0 | 2.3 | 2.7 | 5.5 | 5.2 | 5.3 | 5.3 | 4.3 | 4.7 | 5.3 | 4.8 |
| Longest Plant (cm) | | 16.0 | 18.5 | 18.5 | 17.7 | 15.0 | 14.0 | 17.0 | 15.3 | 17.5 | 15.5 | 13.5 | 13.5 | 19.5 | 18.0 | 19.5 | 19.0 |
| Smallest Plant (cm) | | 8.0 | 7.5 | 6.0 | 7.2 | 7.0 | 6.5 | 4.5 | 6.0 | 8.0 | 8.0 | 10.0 | 10.0 | 6.0 | 5.0 | 5.5 | 5.5 |
| Soil Area (cm2) | | 61.8 | 61.8 | 61.8 | 61.8 | 66.5 | 57.0 | 61.8 | 61.8 | 52.3 | 66.5 | 66.5 | 66.5 | 61.8 | 71.3 | 57.0 | 63.3 |
| Number of Plants | | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 | 200.0 |
| Plant Density (# plants/cm2) | | 3.2 | 3.2 | 3.2 | 3.2 | 3.0 | 3.5 | 3.2 | 3.2 | 3.8 | 3.0 | 3.0 | 3.0 | 3.2 | 2.8 | 3.5 | 3.2 |

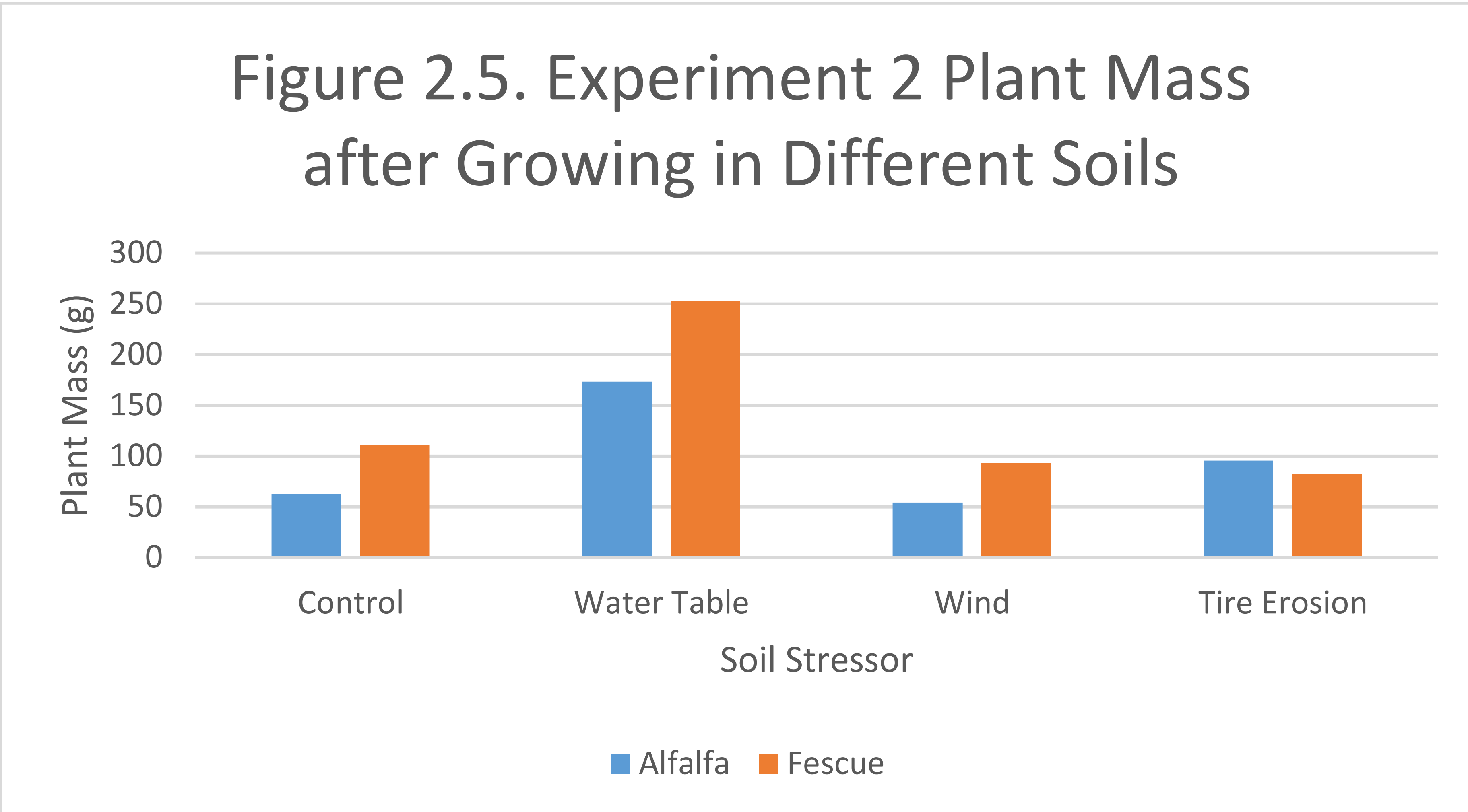


Figure 2.5. Experiment 2 Plant Mass after Growing in Different Soils
Plant Mass (g)
300
250
200
150
100
50
0
Control
Water Table
Wind
Tire Erosion
Soil Stressor
Alfalfa
Fescue

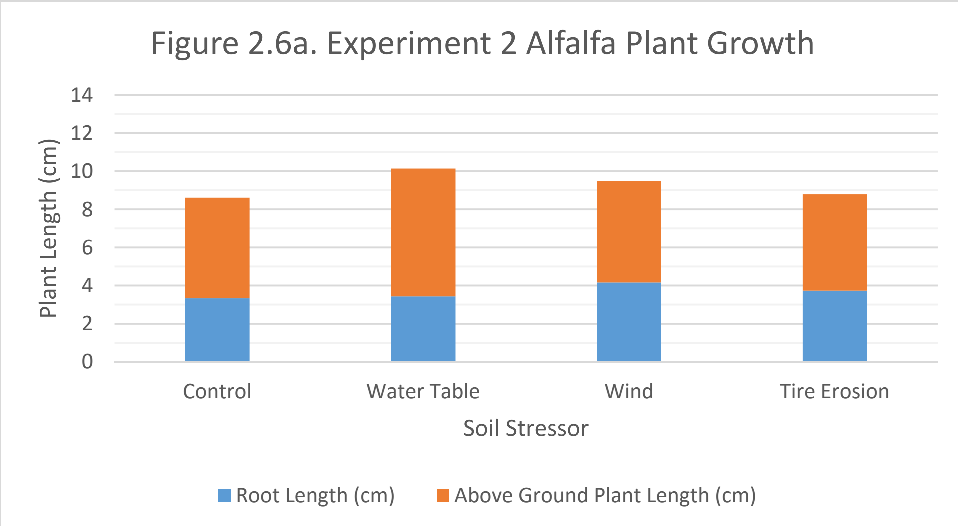


Figure 2.6a. Experiment 2 Alfalfa Plant Growth
14
12
10
8
6
4
2
0
Plant Length (cm)
Control
Water Table
Wind
Tire Erosion
Soil Stressor
Root Length (cm)
Above Ground Plant Length (cm)

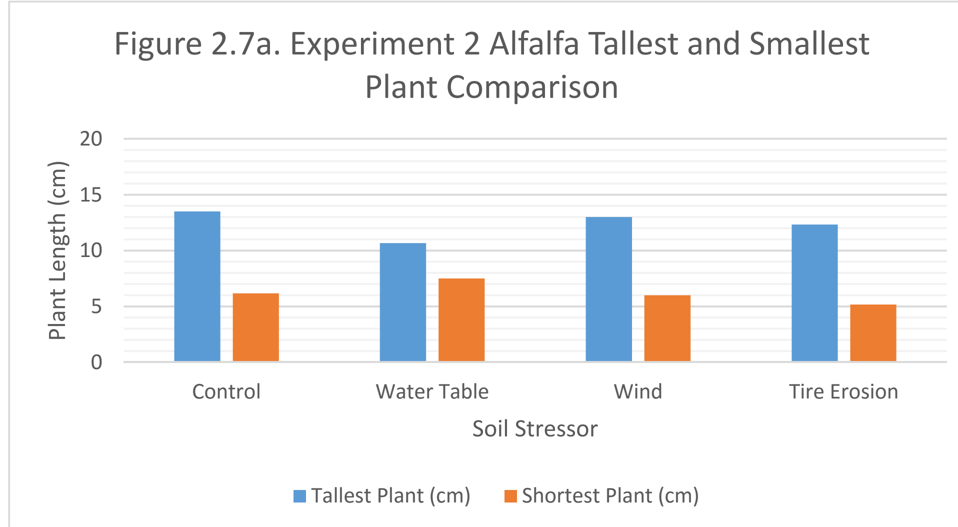


Figure 2.7a. Experiment 2 Alfalfa Tallest and Smallest Plant Comparison
20
15
10
5
0
Plant Length (cm)
Control
Water Table
Wind
Tire Erosion
Soil Stressor
Tallest Plant (cm)
Shortest Plant (cm)

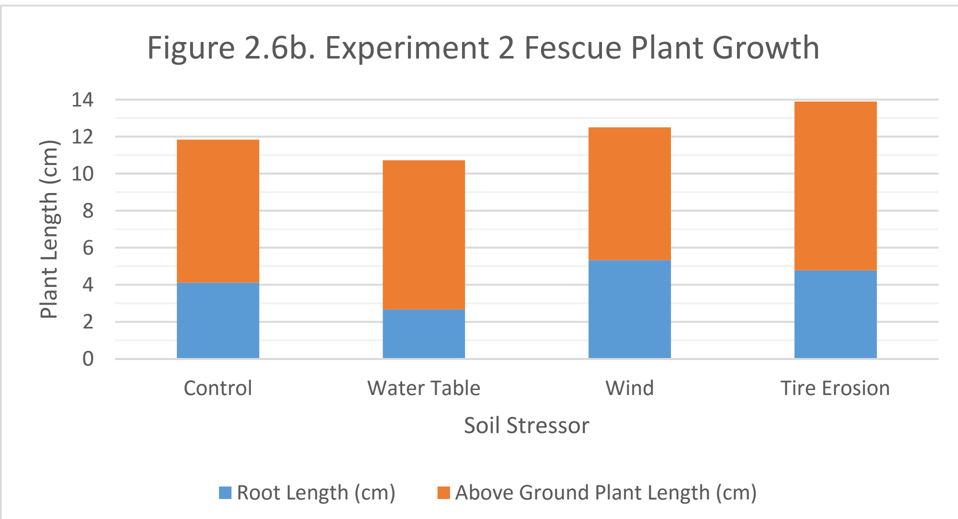


Figure 2.6b. Experiment 2 Fescue Plant Growth
14
12
10
8
6
4
2
0
Plant Length (cm)
Control
Water Table
Wind
Tire Erosion
Soil Stressor
Root Length (cm)
Above Ground Plant Length (cm)

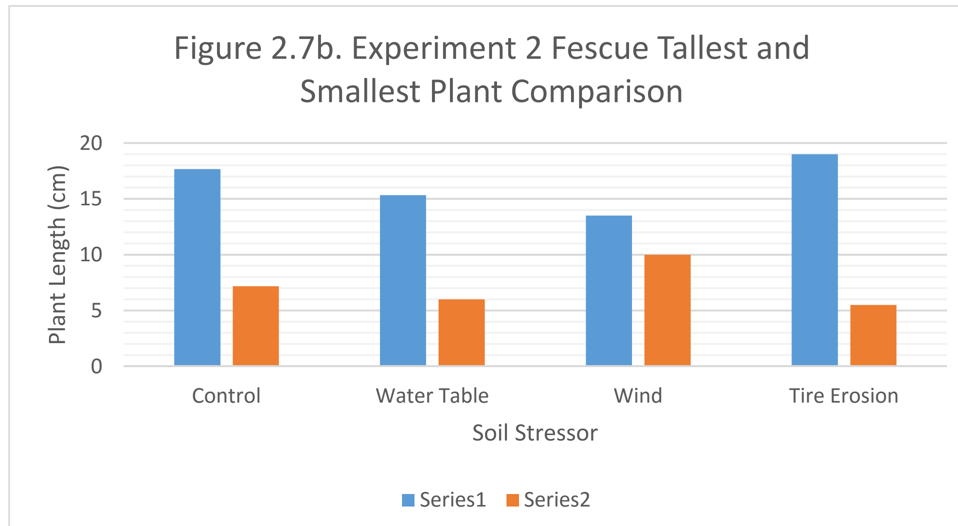


Figure 2.7b. Experiment 2 Fescue Tallest and Smallest Plant Comparison
20
15
10
5
0
Plant Length (cm)
Control
Water Table
Wind
Tire Erosion
Soil Stressor
Series1
Series2

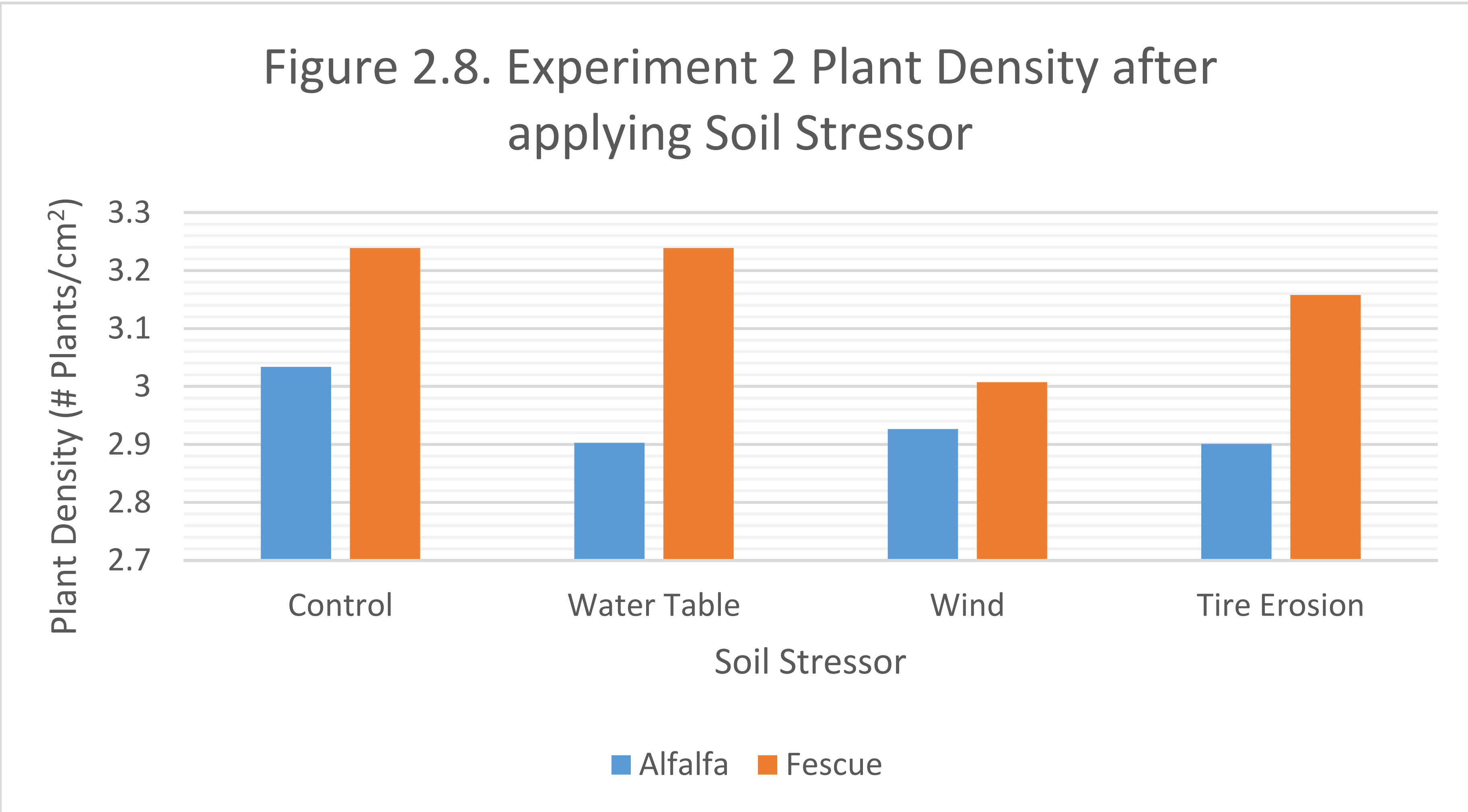


Figure 2.8. Experiment 2 Plant Density after applying Soil Stressor
Plant Density (# Plants/cm2)
3.3
3.2
3.1
3
2.9
2.8
2.7
Control
Water Table
Wind
Tire Erosion
Soil Stressor
Alfalfa
Fescue

**Table 2.5. Soil Poperties and Chemical Analysis**

| | Chemical Concentration (lbs/acre) | | | | |
|---|---|---|---|---|---|
| **Stamp Sand** | **0%** | **25%** | **50%** | **75%** | **100%** |
| **pH** | 5.5 | 5.5 | 6 | 6 | 6.5 |
| **Potassium (lbs/acre)** | | 110 | 80 | | |
| **Nitrogen (lbs/acre)** | 100 | 60 | 60 | 100 | 10 |
| **Phosphorus (lbs/acre)** | 200 | 200 | 150 | 200 | 150 |
| **Porosity (%)** | 16% | 20% | 18% | 18% | 16% |
| **Initial Moisture Content (%)** | 19% | 1% | 3% | 2% | 11% |
| **Final Moisture Content (%)** | 21% | 11% | 7% | 5% | 3% |

**Table 2.5a. Soil Porosity Calculations**

| **Stamp Sand** | **0%** | **25%** | **50%** | **75%** | **100%** |
|---|---|---|---|---|---|
| **Initial Volume (mL)** | 100 | 100 | 100 | 100 | 100 |
| **Volume Remaining (mL)** | 84 | 80 | 82 | 82 | 84 |
| **Pore Space (mL)** | 16 | 20 | 18 | 18 | 16 |
| **Porosity (%)** | 16% | 20% | 18% | 18% | 16% |

**Table 2.5b. Soil Moisture Content**

| Initial Soil Conditions (Control) | | | | | | Final Soil Conditions (Control) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Stamp Sand** | **0%** | **25%** | **50%** | **75%** | **100%** | **Stamp Sand** | **0%** | **25%** | **50%** | **75%** | **100%** |
| **Wet soil (g)** | 53.6 | 65.3 | 64.3 | 76.4 | 87.7 | **Wet soil (g)** | 50.3 | 68.7 | 69.8 | 73.6 | 79.1 |
| **Dry soil (g)** | 48.3 | 64.7 | 63.2 | 75.1 | 81.2 | **Dry soil (g)** | 45.2 | 64.1 | 66.7 | 71.0 | 77.3 |
| **Canister mass (g)** | 20.4 | 20.8 | 20.9 | 20.9 | 20.9 | **Canister mass (g)** | 20.8 | 20.9 | 20.4 | 20.9 | 20.9 |
| **Canister #** | 3 | 1 | 4 | 5 | 2 | **Canister #** | 1 | 2 | 3 | 4 | 5 |
| **Initial Moisture Content (%)** | 19.0% | 1.3% | 2.5% | 2.4% | 10.9% | **Final Moisture Content (%)** | 20.9% | 10.6% | 6.8% | 5.2% | 3.2% |

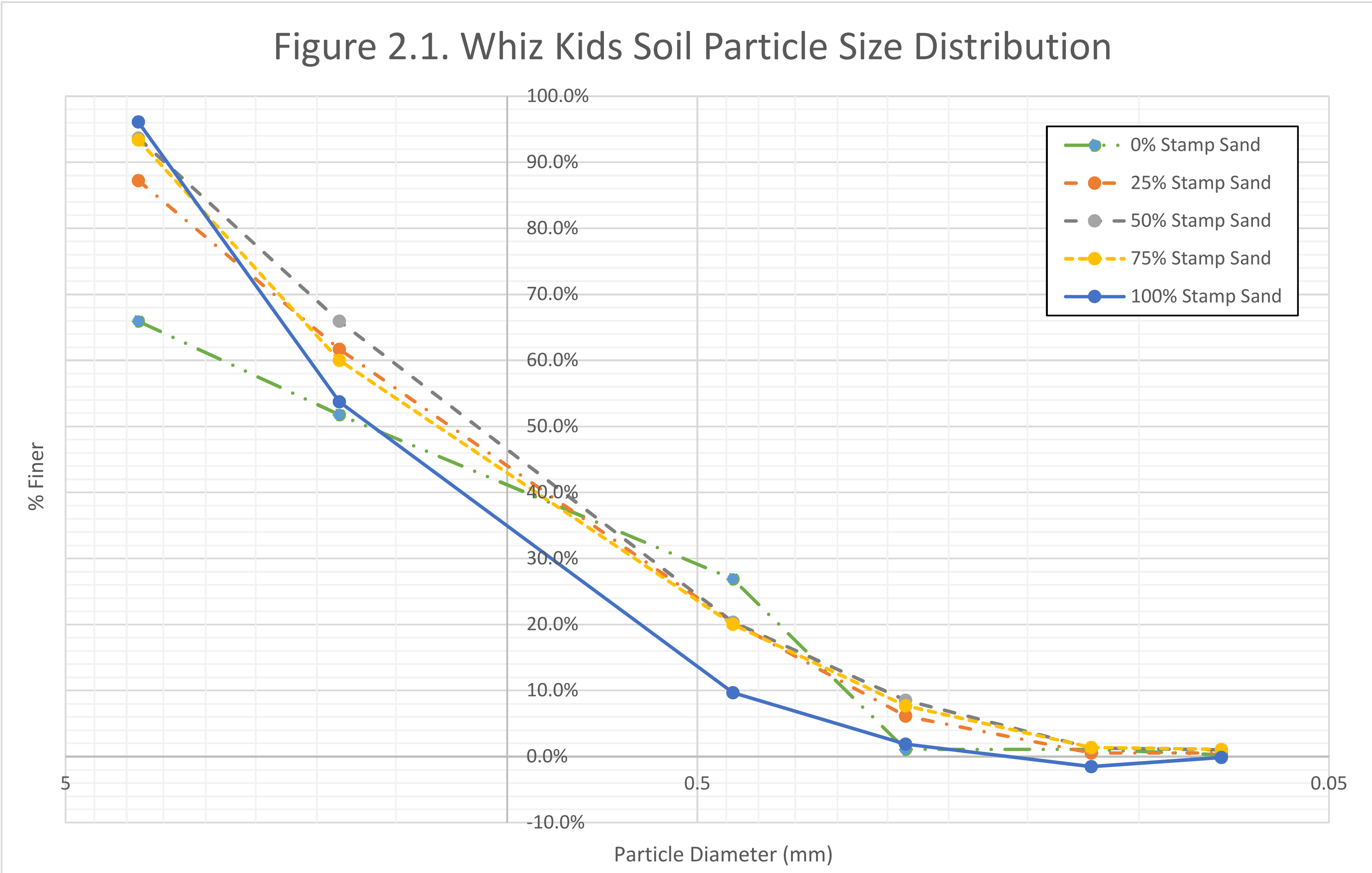
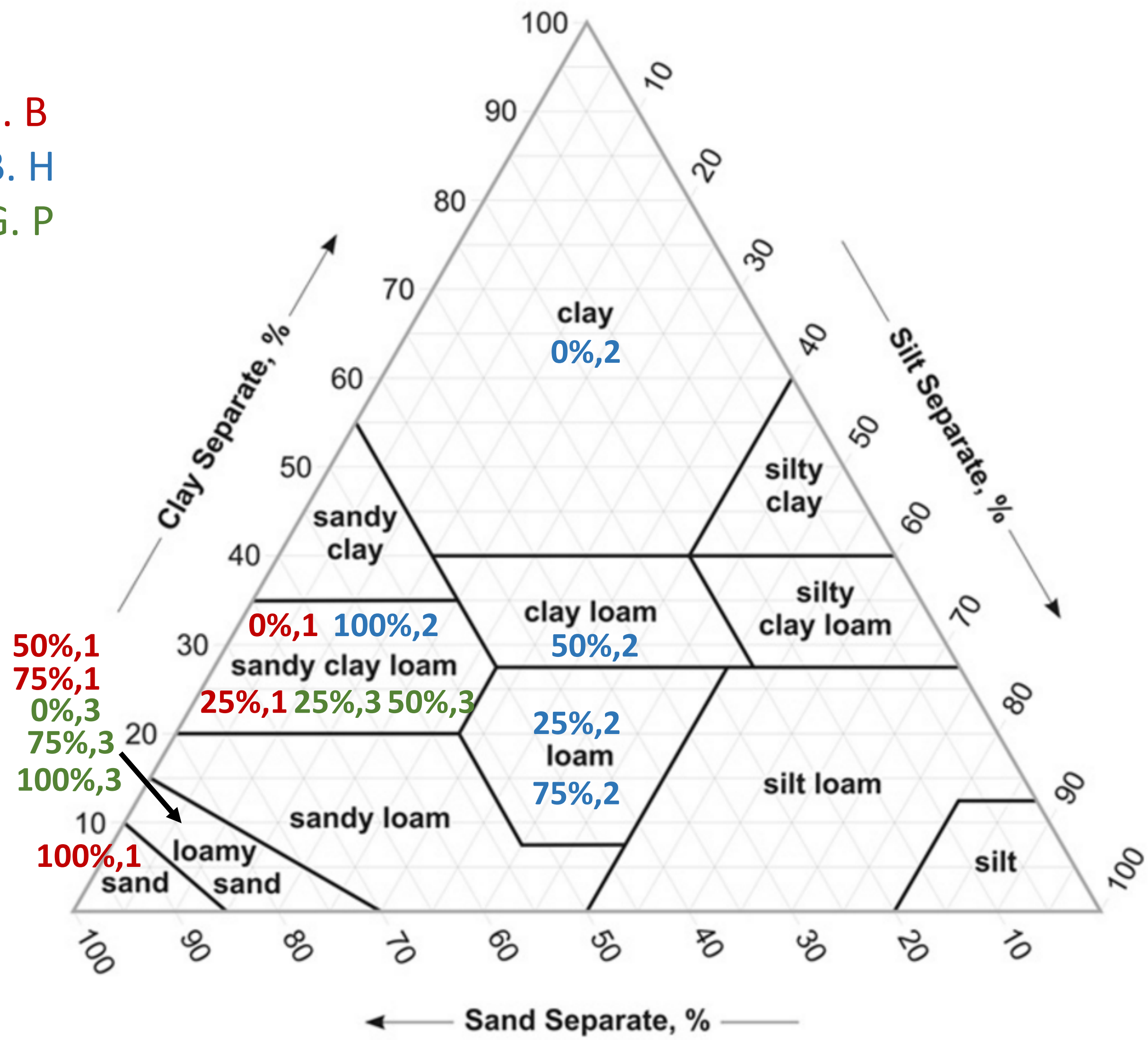


Figure 2.1. Whiz Kids Soil Particle Size Distribution
% Finer
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
-10.0%
5
0.5
0.05
Particle Diameter (mm)
0% Stamp Sand
25% Stamp Sand
50% Stamp Sand
75% Stamp Sand
100% Stamp Sand

# Figure 2.2. Whiz Kids Soil Texture Triangle based on 0%, 25%, 50%, 75%, 100% Stamp Sand with remaining fraction as top soil (Soil Science Lab Manual)

1. S. B
2. B. H
3. G. P



**What problem in your community did your team investigate? Why is this problem important to your community?**

Stamp sand is an abundant material in our community due to the mining that took place many years ago. There are some areas along Lake Superior and Torch Lake that are covered in stamp sand. Though the EPA (Environmental Protection Agency) has cleaned up some of the areas, by spreading topsoil over the stamp sand and making a disc golf course or nature trails (LSSI), there are some areas that need remediation. The traditional method of remediating the stamp sands is to place topsoil on the sands (6 in was done for the initial remediation of the Torch Lake Stamp Sands, but now it is 12 in) followed by planting hardy plants (trefoil, fescue, red clover and alfalfa) (Meingast and Kafcznski). This process is very expensive. If less topsoil is used, the cost is reduced. This could mean that more stamp sand could be remediated for either the same cost or for a decreased cost. If the stamp sand and topsoil are mixed via a plowing/cultivating process, there is less stratification of the stamp sand/topsoil mixture.

Our team wanted to find out if there was a way to reduce the amount of topsoil, but still achieve good plant growth. The stamp sands are deposited along the lake shore. This means that the water table is relatively high. The Keweenaw Peninsula juts out into Lake Superior which frequently results in high winds. Many people like to ride bikes and four-wheelers along the stamp sands. We think this would result in erosion and poor plant growth. Therefore, we wanted to know if soil stressors (wind, a high water table or cycling/four-wheeling) affected plant growth on the stamp sands. We developed two experiments to test these impacts:

1. Plant trefoil, fescue, red clover and alfalfa in soils with different ratios of stamp sand to topsoil (100% stamp sand, 75% stamp sand, 50% stamp sand, 25% stamp sand and 0% stamp sand with the remaining fraction being topsoil). We would observe which plant type grew the best in which soil mixture.
2. To determine the effect of wind, high water table and cycling/four-wheeling, we used two of the plants that grew well in a given soil mixture to test the effect. We placed soil containers with the plant already growing in a container of water to simulate a high water table. We exposed a second set of plants to a daily four hour wind event. In a third set, we "drove" a wheel over the center of the container to simulate a bike or four-wheeler travelling across the soil. For each of these, we monitored plant growth.

We plan on discussing our results with the Lake Superior Stewardship Initiative and the Lake Linden Village Council to determine if we could test our results in a 10 ft x 10 ft plot during the summer of 2017.

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## Research Summary

Stamp Sand Description/Composition: Stamp sand is an abundant material in our area, the Keweenaw Peninsula, due to the mining that took place many years ago. Our school is located on Torch Lake which is on the Keweenaw Peninsula in Michigan's Upper Peninsula. Stamp sand is a by-product of the copper mining. It was produced when the mines would take the rock containing copper and bring it to a stamp mill where they pounded the copper out of the rock until the rock was broken to little pieces. They then dumped the remaining rock into giant piles along the lakeshore, selling the copper to make copper wire and copper pennies. (The Stamp Sands at Gay)

Some of these sands are made up of water holding slags. These slags are from the cooling of igneous materials with water after the smelting process. Other sands were produced from stamping the copper out of rock. In addition to copper being in the rock, there are other metals (copper, arsenic, cadmium, silver and lead) within the rock. (Baker)

When these metals are within the rock, they do not pose much risk to plants or animals. For the most part, stamp sand does not impose much danger, but only limited plant life can live on it. Plants have a difficult time growing in the sands because there are limited amounts of organic matter and other nutrients that plants need. (Forgrave)

When the sands were deposited in the lake, water eroded some of the rock and exposed the heavy metals. This has caused a great deal of pollution in Torch Lake and this region is an EPA area of concern. One effect of this pollution was the presence of tumors on fish caught in the lake. This occurred more often years ago when the lake and the surrounding area had not yet been remediated. (Forgrave, Meingast and Kafcznski)

Parts of Torch Lake, especially at the bottom, have collected heavy metals from these materials. Some stamp sand can cause human health issues. Health concerns were tested by various organizations, and they proved that more problems with stamp sand could occur in the future if they were not remediated. Some of the problems included runoff of the stamp sand into the groundwater and seepage into shallow drilled residential wells. Remediation of the area occurred in the 1990's and was completed by the EPA and other government agencies. The Houghton County Health Department regulates the drilling of drinking water wells around these sites. (Baker)

There are some ecological problems also. The continuous release of slag and stamp sand through wind, surface water runoff, and water/wave erosion pose environmental risks. Stamp sand has decreased the plant life along the lakeshore of some lakes in both Keweenaw and Houghton Counties due to their inability to inhibit much plant life. Also, some lakes, like Torch Lake and Boston Pond, have been contaminated due to the presence of the stamp sand. (Baker)

Soil Characteristics/Tests:
Soils are characterized in two ways:

- Structure (porosity, moisture content, grain size distribution, soil classification (for engineering and agriculture))
- Chemical composition (pH, and nitrogen, phosphorus and potassium concentration)

In the following section, we will describe the factors we measured and researched with respect to these two categories. We completed each of these tests on every soil mixture.

The structural characteristics of soil described either how they will support a structure or what occurs when the soil is excavated. These are civil and geological aspects of soil. They also describe how moisture is held and travels in the soil which is an overlap of engineering and agricultural aspects. Since we were interested in how different plants grow in various amounts of stamp sand and soil, we looked at the agricultural classification of soils. (American Geosciences Institute)

Soil porosity is how much void (or pore) space is left between soil particles.  These spaces might be formed from the movement of rock, worms, and/or insects.  The texture of the soil might also affect the empty space.  There are three main soil textures, which are sand, silt, and clay.  Sand particles have a diameter of between 0.5 mm and 2 mm, which would be visible to the naked eye. Silt is between 0.002 mm and 0.5 mm, which feels smooth and slippery. Clay is less than 0.002 mm and is slippery when wet.  The size and shape of these influence the way that the soil particles fit together, and this impacts porosity. (American Geosciences Institute)

One indication of soil structure is porosity which is a measure how much open space there is. Open pores in the soil is needed to transport water and nutrients to the root and to allow the roots to grow in the soil. The porosity test consisted of taking a 40 mL sample of soil in a beaker. Using a graduated cylinder containing a known volume of water, we poured water into the soil until the water was just at the top of the soil. Using the volume poured into the soil and the amount of soil in the beaker, we could calculate the porosity. (American Geosciences Institute,Integrated Teaching and Learning Program)

The amount of water in the soil impacts how well plants grow. We wanted to determine the soil moisture content in the soils both at the beginning and end of experiment 1. We took a 50 g sample of soil and placed it in a metal canister. Our adviser took it home and dried soil in her oven. We weighed the soil before and after drying. The weight loss was due to the water evaporating from the soil. Using the volume of soil and the masses before and after drying, we calculated the moisture content. (Department of Sustainable Natural Resources)

Grain size distribution determines how the soil will transport water and other nutrients, along with allowing paths for roots to grow. If the soil has many rocks in it, plants will find it hard to grow. Plants will also have a difficult time growing if the soil has too many fine particles because the soil pores will be filled with those fine particles leaving not much space for the roots or water. We used a standard sieve analysis procedure. In this test, we used a stack of seven sieves with the largest openings on the top and the smallest on the bottom. We put a measured mass of soil in the top sieve and then shook the stack of sieves for two minutes. Afterwards, we measured the amount of soil on each sieve. These results were plotted to show the particle size distribution. (University of Texas, Arlington)

In the test that determines the amount of sand, silt, or clay that is in the soil was the soil texture test. In this test there are a set of instructions or steps needed to tell what type of soil it is. Some of the steps included if the soil makes a ribbon, how strong the ribbon is, what the texture of the soil is like, and then what type of soil it is.

To complete the soil texture test, we placed roughly 25 g of soil in our hands and added water to the soil. If the soil did not stay in a ball then it was SAND. Next we placed water in our hand and tried to form a ribbon. If it did not form a ribbon, it was LOAMY SAND. If it did, we wetted the soil more and rubbed it between our fingers to determine the texture of the soil (ie: silty loam, clay loam or clay loam). (Soil Science Lab Manual)

Soils are also characterized by their chemical composition which influences how the plants will grow. Soils with too high or too low amounts of these chemicals will not have “good” plant growth. Some plants need different nutrients to grow well than other plants. We specifically looked at the amount of potassium, phosphorus and nitrogen, along with soil pH. Potassium, Nitrogen and Phosphorus are particularly important for plant growth. We knew this because many plant fertilizers are described by the percentages of P-K-N which are Potassium, Nitrogen and Phosphorus. pH is important because some plants grow better in acidic or basic soils. To determine their concentrations, we used soil test kits supplied to our school by the Lake Superior Stewardship Initiative (a K-12 outreach program that has student investigate and measure different items that affect or impact the Lake Superior watershed). The test kits contained the procedures (listed in our references) and all the chemicals and materials needed to analyze the soils.

Potassium (K) is a macronutrient and is important nutrient for plants and humans. Large amounts of potassium are absorbed in the roots of many plants. To test the level of potassium, we used universal extracting solution and 2 grams of soil to collect the soil extract. We then used potassium reagent tablets to remove the potassium from the extract. The potassium can then be measured in pounds per acre potassium. (Lake Linden-Hubbell High School, Potassium)

Nitrogen (N) makes up 80% of the Earth's atmosphere with the remaining 20% being oxygen. Nitrogen can be absent in acidic soil, which causes less growth and germination in plants. To measure the nitrogen levels in soil, we once again used universal extracting solution to remove liquids and chemicals from the soil. We then used filtration paper and nitrate reagent to get the liquid sample to match the sample colors on the chart. (Lake Linden-Hubbell High School, Nitrogen)

All plants need phosphorus (P), therefore we wanted to determine the amount of phosphorus in the soil. We followed the procedure our school uses when testing soil for the LSSI program. First, we filled a test tube with Universal Extracting Solution and added one measure of soil to the test tube. We capped the tube and shook it for one minute. Next, we filtered the liquid to remove the soil. This liquid was mixed with a phosphorus reagent. We added a phosphorus reagent tablet to the solution and mixed it until the tablet dissolved. The resulting liquid color corresponded to a certain phosphorus concentration on the Phosphorus Color Chart. (Lake Linden-Hubbell High School, Phosphorus)

Acidity in soil can be determined with pH, which can be either acidic, alkaline, or neutral. Acidic soil can be hard to grow plants because they cannot get enough nutrients. We mixed Tricon Flocculating Solution with the soil into a test tube. Tricon Soil pH Indicator was then added to the tube, which was then inverted. The test tube was then placed in the Tricon pH Comparator and then was held up to the light where we could tell what pH it was based on a color chart provided with the test kit. (Lake Linden-Hubbell High School, pH)

<u>Plants That Grow Well in Stamp Sand (a Poor Soil)</u>:
To determine which plants we wanted to test, we researched what others had already tried to grow in stamp sands. This ranged from corn to grasses and legumes.

Researchers at Michigan Technological University (Michigan Tech) wanted to see if inoculating corn with a bacteria would cause it to grow better than corn that was not inoculated when both were planted in stamp sand. After day 45 of growth, the plants were uprooted and their lengths were measured. Both types of corn grew in the stamp sand, but the corn that was inoculated grew better. Ramakrishna Wusirika also measured the amount of copper absorbed by the corn. The bacteria increased the enzyme activity and increased the soil fertility which increased the plant growth. The bacteria converted the copper into a substance that the plant was able to take up. (Goodrich)

Torch Lake and portions of the Lake Superior shoreline are Environmental Protection Agency (EPA) Areas of Concern. Our school is located on Torch Lake and our football field lies on top of stamp sand. The region is an area of concern because the stamp sands contain high concentrations of different metals that are toxic to fish and other wildlife (not people directly). The clean-up of the area began when drums containing toxic materials were removed from the area. In 1992 they started adding the topsoil onto the stamp sand. The Natural Resources Conservation Service planted about 35,000 plants on Gull Island, which is located in the middle of Torch Lake and takes up about seven acres. Gull Island was not originally part of the Superfund site, but was added because of complaints from locals because the stamp sand was being blown towards/on main land. For other areas, the EPA had an objective to place six inches of soil on top of the stamp sand and then grow vegetation on top. The EPA proceeded to grow legumes and grasses. Most of the plants that they grew were not native to Michigan, such as Red Clover, Alfalfa, Trefoil, Ryegrass, and Fescue. (Public Sector Consultants, Inc, Baker)

The Environmental Protection Agency (EPA) had an objective to place six inches of soil on top of the stamp sand and then grow vegetation on top. The EPA proceeded to grow legumes and grasses. Most of the plants that they grew were not native to Michigan, such as Red Clover, Alfalfa, Trefoil, Ryegrass, and Fescue. They started to clean up by removing the toxic drums from the stamp sand. In 1992, they started adding the topsoil onto the stamp sand. The Natural Resources Conservation Service planted about 35,000 plants on Gull Island, which is located in the middle of Torch Lake and takes up about seven acres. Gull Island was not originally part of the Superfund site, but was added because of complaints from locals because the stamp sand was being blown towards/on main land. (Baker)

When the sands were remediated, four of the plants planted in the area were Birdsfoot trefoil, red clover, alfalfa and red fescue. These were the plants we decided to research.

- Birdsfoot Trefoil is a long lived perennial plant. It requires 20 cm of rainfall per year. It has 20% more growth after July than most dryland grasses. The bloom is a bright yellow color arranged in a spiral pattern around the center of the plant. It generally has 5 smooth leaflets. The seeds should be planted ¼ in deep. Although trefoil has poor germination rate, it does germinate within 5-10 days. To improve germination the seed should be inoculated with Rhizobium lupini bacteria. This helps establish root growth which in turn improves plant growth. Trefoil seedlings are not very vigorous. Trefoil grows best in soils with a pH range of 6-6.5. Because trefoil is a nitrogen fixing plant (where it draws its nitrogen from the atmosphere (Flynn and Idowu), no nitrogen needs to be added to the soil. Most of the information on potassium and phosphorus needs for this plant were based upon using it as an animal feed and the effects on animals if the levels were too high. (Undersander et al, Hall, GrowOrganic.com, BestGrass.com)

- Red clover is a nitrogen-fixing short lived perennial, which usually produces around 3 hay crops per year. When planted, most of the seeds germinate and the seedlings are vigorous. Red clover has taproots that are very thick and can grow between 24 and 36 inches. Lateral roots also rise up from the taproots, growing small, ovoid nodules that change atmospheric nitrogen into protein nitrogen, which the plant uses as energy for photosynthesis. This plant has a large resistance to diseases and can survive in soil with a pH of 6 or higher. Red clover requires nitrogen (N) to live and produce oxygen. Soil that red clover is planted in with a pH lower than 5.5 will require more nitrogen than it normally would need. The required amount of phosphorus (P) and potassium (K) needed for red clover are similar to the amounts of these elements needed in alfalfa.

- Alfalfa is another nitrogen fixing plant. The elements required for the growth of alfalfa include: nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, iron, boron, manganese, zinc copper, molybdenum. Alfalfa needs a great deal of phosphorus and potassium to grow well. Alfalfa plants take in these nutrients and water through their roots and leaves. Alfalfa seeds are generally kidney-shaped. Sometimes alfalfa seeds will have an impermeable seed coating also known as a “hard seed”. Some hard seeds will not germinate for weeks, months or even years lying dormant in the soil. Alfalfa seeds will begin to germinate after absorbing about 125% of their weight in water. The germinating seed begins with the young root going through the seed coat. Alfalfa seedlings have a medium vigor. Temperatures ranging from 65 to 85 deg F are crucial for maximum growth. After four weeks of germination, the root hairs on the radicle are infected with bacteria that is a nitrogen fixing. During the vegetative stage, alfalfa produces enough leaf growth to get enough food purely through the process of photosynthesis. The decrease in temperatures and shorter days of winter can also change the growth patterns of alfalfa. Alfalfa likes to grow in soils with a pH greater than 6.5. (Undersander et al)

- Tall Fescue is a deep-rooted, long-lived, sod forming grass which is well suited as hay or silage. Fescue is very drought-resistant and the seedlings are very vigorous. This plant is especially adapted to acidic soils (pH of 5.5 or lower). However, fescue will not grow as well if planted with other grasses such as bluegrass. This plant is often found near waterways, ditches, and roadsides. This is because fescue also has a high tolerance to animal and vehicle activity. Tall fescue can reach its maximum fertility in soils with a pH between 6.0 and 7.0. In the winter months, fescue can take in as much as 150 pounds of nitrogen (N). It does require some phosphorus and potassium for good growth. (Penn State Extension, Hall)

<u>Soil Stressors</u>:
Our second experiment involved investigating the effects of different environmental and man-made stressors on plant growth. We wanted to ensure that the plant we recommended for planting on the stamp sands would still grow even when stressed. We chose a high water table, wind and bike/4-wheeler tracks as the items to test.

<u>Wind</u>: Wind is caused by differences in pressure. Wind wants to flow from an area of high pressure to an area of low pressure to balance it out. The Coriolis effect is when the air veers a certain direction or the air does not flow directly from high to low pressure, it tends to swirl.

Torch Lake is not big enough for a micro-wind system, but Lake Superior is. In the summer, Lake Superior causes the air to cool, especially when there is little wind. In our area the air comes from the higher altitudes and fills the lower altitudes or valleys. The direction from which the wind comes affects the speed because it is based on how many objects there are to block it. The more objects there are to block it the greater the resistance and the slower the winds will become. The wind speeds can prove to be greater especially on the sands where there is barriers or land forms to block the wind. On Torch Lake, this is especially true because the wind just travels up Portage Lake to Torch Lake to where the sands are located.

There are dominant wind directions during different seasons. In our area due to the latitude, the wind mainly comes from the northwest in the winter and southwest in the summer. Most of our strongest storms come from the west/northwest.

Air tends to be warmer over land than water. Because we are on a peninsula surrounded by water on three sides, the air tends to swirl due to this effect. The stronger the differences in pressure are the stronger the winds will be. The average wind speed on the stamp sands tends to be around 5-15 miles per hour. There are very few days where there is no wind, though sometimes at night there will be no wind.

Wind does affect plant growth. The most effect wind has on plants is when they are very small and some of the soil is exposed to the wind. The wind will whip the plants down, but can also remove some of the topsoil that is exposed. When plants die they leave behind organic matter, strong winds erode that organic matter and soil. Once the plants are fully grown the wind does not hit the soil and the wind does greatly affect the plants. Since plants need carbon dioxide to grow, if they respire in a region of no wind, the oxygen cannot be removed and the plants suffer. Wind can cool plants down via evapotranspiration.

<u>High winds</u> (30-35 mph) can cause the soil particles to be drawn up into the air. Since silt particles are very small, they will become airborne first. Our soils do not have much silt. Therefore, higher winds would be required for the soil particles to enter the air. (Dee)

<u>Water Table</u>: The water table in some areas is constantly changing. An example would be the Lower Arkansas River Valley (LARV) (Located in southeastern Colorado), This area has been really heavily irrigated because of the agricultural region. This has increased the water table in this area. In other areas the water tables can be raised by excessive rainfall or flooding. Some effects of this event can cause crop reduction in some areas. There are some methods that are being investigated to lower the raising water tables. This would be done to mitigate the salinity , selenium , also waterlogging conditions. (Lehmann, et al.)

<u>Wheeled Tracks</u>:
Michigan has over 1,300 of biking and off-road vehicle (ORV) trails (Michigan DNR); many of which are in the  Keweenaw Peninsula.  Many people ride on the stamp sands and many trails run through the stamp sands. Therefore, we wanted to see the effect of these activities on plant growth.

Common environmental impacts of recreational trail use include, vegetation loss and compositional challenges, soil compaction, erosion or worn away soil, muddiness, and disruption of wildlife. On a formal trail most vegetation loss is typically caused by maintenance, visitors, or construction. Doubling the trail width can cause double erosion and double trampling shrubs and trees can be lost due to construction. There is a certain acceptable and unavoidable soil loss on trails. Construction work can compact organic material or soil. Also treads of tires can erode or remove soil from the trails. Soil harm can be caused by erosion by exposing rocks and roots. Here are some soil degradation forms include, compaction, muddiness, displacement, and erosion. The weight of the trail users can also cause soil compaction. (Marion and Wimpey)

COMPACTION: The compaction of soil is due to weight of the users and their equipment. Trail compactors include; feet, hooves, or treaded tires. Compacted soils tend to be more compacted and less permeable to water runoff. Compacted soils supported traffic and are less subjected to erosion. On a new trail soil compaction can prove to be a hard process due to new and loose soil. Less permeable soil can have water pool up and make a dry trail muddy and wet.

DISPLACEMENT: Trail users can also push soil off the trail causing displacement and ruts. Soil displacement happens when soils are damp and loose or when users are traveling at high speeds or other movements that cause horizontal movement. Soil can be caught in treads or shoes or hooves. Soil is displaced from the center of the trail to the edge causing hills or slopes. This will cause drainage problems.

MUDDINESS: Trails located in areas with poor drainage will prove to be muddy. Muddiness can also occur when flowing water flows across the trail staying in a low lying trail areas. Displacement compaction, and erosion can cause muddiness. Trail use can also cause muddiness by causing cupped treads that collect water or snowmelt.

EROSION: Soil erosion can prove to be an unavoidable and indirect cause of trail use. Though soil erosion can also be caused by flowing water. (Marion and Wimpey)Trails can be made in a slope shape, but trail use can cause displacement. An concave trail surface can direct flowing water and cause erosion. Loose uncompacted soil particles are most prone to erosion.

## Hypothesis

**Hypothesis**

For our experiment, we grew multiple types of plants in different quantities of stamp sand and topsoil. In order to develop our hypothesis, we needed to research which plants grew best in poor soils (ones with few nutrients). From the plant types chosen (alfalfa, red clover, fescue and trefoil), we learned that alfalfa and red clover have the shortest germination times of 2-3 days (BestGrassSeed.com), while trefoil and fescue have germination times of 5 -10 and 5-15 days, respectively (GrowOrganic.com, BestGrassSeed.com). Although we saw a great deal of trefoil on the stamp sands that had been remediated, it is the most difficult of the plants we selected to germinate.

We want to find which plant types will grow in stamp sand with minimal amount of additional topsoil. The addition of topsoil is costly because the topsoil not only has to be purchased, but it has to be spread and/or tilled into the stamp sand which is also costly. In our experiment we will be planting in 100%, 75%, 50%, 25%, and 0% stamp sand with the remaining soil being topsoil. We believe that at 75% stamp sand there will be adequate plant growth. We think that the 25% topsoil will add enough nutrients for the plants to grow while still using minimal amount of topsoil.

The second part of our hypothesis is which plant types would grow the best in this soil. Alfalfa and red clover will grow the most effectively in 75% stamp sand for three reasons:

- They have the shortest germination time.
- When we went to the dredge in Osceola Township, there was a great deal of Red Clover.
- Both Alfalfa and Red Clover are Nitrogen fixers and are used a green manures. They have a large root structure and are able to convert nitrogen to ammonia (NH3) which is a plant nutrient. This allows the plant to draw the nitrogen needed from plant growth from the air instead of it being natural in the soil. (Flynn, 2015)

The second experiment we completed investigated the impact of soil stressors (high water table, wheels on trails and wind) on plant growth using the soil type and plant that had adequate growth. We selected our stressors because:

- Many of the stamp sands were deposited on lakeshores which have a high water table
- The Keweenaw Peninsula juts out into Lake Superior and this results in high wind events
- Many people hike, ride bicycles and 4-Wheelers on the stamp sands which will cause soil erosion

<u>Wheel Stressor</u>: We believe that the plants will go back to how they initially were after stress has been applied by wheels. An example on why we think this is if someone steps on grass, it return to its original position. But if the stress continues over a long period of time, the plant dies. This is proven when people continually go over the same spot and eventually create a trail.

<u>Wind Stressor</u>: When a plant is exposed to wind over a short period of time, it bends in the direction of the wind. We think that the plants will grow, but the plant will grow at a slant in the direction that the wind hits it. This is evident along the lakeshore where trees are bent in the direction the wind has hit them. But if there is no wind for awhile , the plant will grow normally (straight up and down) again.

<u>High Water Table Stresso</u>r: In the spring when the snow melts, the water table in our area rises. We can see that when areas flood, plant growth stops or is drastically slowed down. As the water table drops below the top of the soil, plant growth starts. If the water table is high for a long period of time, the the soil would be too wet for plants to grow well. Therefore, we do not believe plants will grow well because the root growth will be stunted.

**Independent Variables and Dependent Variables:**

| Table 2.1. Whiz Kids Experimental Independent and Dependent Variables | | |
|---|---|---|
| | **Experiment 1** | **Experiment 2** |
| **Description** | Investigated the effect of stamp sand on plant growth | Studied the impact of soil stressors on plant growth |
| **Independent Variables** | Types of seeds and percents of stamp sand with remainder as topsoil.(0%, 25%, 50%, 75%, 100%) | The soil stressors(wind, high water table, tire erosion), types of seeds, and percents of stamp sand with remainder as topsoil.(0%, 25%, 50%, 75%, 100%) |
| **Dependent Variables** | Plant height, root depth, plant density | Plant height, root depth, plant density |

## Experimental Design

**List the materials you used in your experiment.**

The materials for the experiments are also listed as the first step in each procedure. We included references to the different methods in our procedures.

| Table 2.2 Materials for Experiment 1 and 2 | |
|---|---|
| **Experiment 1: Which plant grows adequately in a mixture of Stamp Sand and Topsoil?** | **Experimental 2: How will a plant grow in a mixture of Stamp Sand and Topsoil when the plant is stressed?** |
| 5 gal Stamp sand | Box Fan |
| 5 gal Topsoil from local farms | Water |
| Grow lights (Grow Crew, 120V, 60 Hz, Max 8A, 4 - 54 W lamps) | 8 ½ gal Juice cartons (modified as described in Experiment 1) |
| Metric Ruler | ¼ lb Fescue and Alfalfa seeds |
| Balance (150 g +/- 0.01 g, 5,500 g +/- 0.1 g) | 12 L of Topsoil |
| Multiple beaker volumes for measuring the soil | 12 L Stamp sand |
| 25 - ½ gallon juice cartons | Balance (150 g +/- 0.01 g, 5,500 g +/- 0.1 g) |
| ¼ lb Seeds (Alfalfa, Trefoil, Red Clover, Fescue) | 100 mL Graduated cylinder |
| Plastic mixing container | 1,000 mL Beaker |
| Gardening spade | Garden spade |
| Graduated cylinder for measuring the water for the plants | 200 g mass |
| Electronic timer for grow lights | Lego Wheel (diameter = 2.5 cm) |
| Electronic room thermometer | Lego parts |
| | Grow Light (Grow Crew, 120V, 60 Hz, Max 8A, 4 - 54 W lamps) |
| | 2 electronic timers (1 for fan and 1 for grow lights) |
| | Anemometer to measure the wind velocity |
| | Electronic room thermometer |
| | Container for the water table experiment (must hold two soil containers) |

**Controls and Constants:**
Table 2.3 lists the control and constants for our two experiments.

| Table 2.3. Whiz Kids Control Groups and Experimental Constants | | |
|---|---|---|
| | **Experiment 1** | **Experiment 2** |
| **Description** | Investigated the effect of stamp sand on plant growth | Studied the impact of soil stressors on plant growth |
| **Control** | The soil mixes with with no seeds planted in them were the primary control. The secondary controls were the 100% stamp sand and 0% stamp sand (or 100% topsoil) soil mixes. | The plant in the soil mixture with no stressor was the control |
| **Constants** | ● Volume of soil in each container (and composition of soil for each soil mixture)<br>● Mass of seeds added to each container (except control)<br>● Volume of water added on a given day<br>● Amount of light provided (12 hours per day)<br>● Room temperature (measured daily) | ● Volume of soil in each container<br>● Soil composition<br>● Mass of seeds added by plant type (Alfalfa and fescue)<br>● Volume of water added on a given day<br>● Amount of light provided (12 hours per day)<br>● Room temperature (measured daily)<br>● The type of stressor |

**Experimental Process:**
The experimental procedures are listed in the Uploaded files. The safety precautions are listed at the beginning of each procedure.

<u>Safety Precautions</u>:

- We used safety goggles and latex gloves when completing the soil chemical analysis tests.
- When drying the soils in the oven, we used insulated gloves when putting them in or removing them from the oven.
- We used several standard experimental procedures. We followed these methods explicitly. These are listed in our references and cited within our procedures.
- We completed our experiments after school in Mr. Squires' Science Classroom. This room has laboratory style tables along with various glassware, scales and equipment that we used for our experiments.
- Our adviser was present whenever we were working on the experiments to ensure we completed the experiment safely.

## Data Collection and Analysis

**Data Collected:** See the Tables and Figures in the Uploaded files.

**Data Analysis:**
Since we completed two experiments and soil analyses, we divided this section into Soil Analysis, Experiment 1 and Experiment 2.

Soil Analysis:
Prior to completing either of our experiments, we analyzed the soil using the tests described in the research section.

Chemical Analysis:
In our research, we described the chemical soil tests we completed. We measured pH, potassium, nitrogen and phosphorus for each soil mixture (0%, 25%, 50%, 75% and 100% stamp sand with the remainder being topsoil). Table 2.5 contains the data. The pH was approximately 6 for all soil types. For potassium, there were not enough potassium reagent tablets and we were unable to obtain more. Consequently, we were only able to do 2 soil tests, which were 25% and 50% stamp sand; 110 and 80 lbs/acre of phosphorus, respectively. For nitrogen, the lowest concentration was 10 lbs/acre in 100% stamp sand which contrasted with 100 lbs/acre for 75% and 0% stamp sand. For phosphorus, the results showed that the soils had either 150 or 200 lbs/acre.

Physical Analysis:
We determined both the particle distribution and the soil texture type, along with soil porosity and moisture content. These tests indicate how well the roots and grow and how the water and nutrients can flow through the soil.

To get a better idea of the soil particle size, we completed a sieve analysis. For all of the soil types, the lines are similar. This indicates that even with topsoil, the particle size distribution was similar for all soil mixtures. On Figure 2.1, the 25%, 50%, and 75% (stamp sand) are approximately the same spot for most of the points. The 0% and 100% vary more than the rest of the points. This is because we might have used the sieves in the incorrect order for the 0% stamp sand. At the right end of the graph, where the particle size is the smallest, all of the soil types are at the approximate same fineness. As the percent top soil increased, the fineness of the particles increased.

We wanted to determine the soil type for each of our soil mixtures (0,25,50,75,100%). The overall process was:

1. In the soil characterization test we first placed roughly 25 g of soil in our hand and added water to it.
2. We then decided if the soil would stay in a ball.
3. After that we decided if the soil would stay in a ribbon.
4. We then determined how strong the ribbon was.
5. After that we determined the texture of the soil to determine what type of soil it is.

Each team member completed this procedure for each soil type. Our results are shown in Figure 2.2. For the most part, our results were located in the sandy clay to sandy loam area of the soil triangle. This means that regardless of the amount of stamp sand in the mixture, the soil was still sandy.

We determined the soil porosity for each of the soil types. Table 2.5a shows the data collected, while Table 2.5 contains a summary of the values. Porosity is how much of a rock or soil is open space.  We did this test because we wanted to see if soil, stamp sand, or a mixture of the two had the most and least amount of pore space.  We also tested to find the initial moisture content and the final moisture content.  The soil porosity ranged from 16% (0%  and 100% stamp sand) to 20% (25% stamp sand). This range was small and the differences could have been due to our experimental process and not soil differences.

To determine the soil moisture content before and after Experiment 1, we used the oven drying method described in the research section. The data collected are in Table 2.5b and the summary values are in Table 2.5. The initial moisture for 25%, 50% and 75% stamp sand was 1%, 3%, and 2%, respectively.  For 0% and 100% stamp sand stamp sand, the results were higher at 19% and 11%, respectively.  This resulted in quite a large range. We are not sure why this occurred because the 0% and 100% stamp sand had the least amount of water. It could have been due to the moisture in the soil settling to the bottom of the buckets of topsoil and stamp sand, but it is unclear to us. The final moisture content was 21%, 11%, 7%, 5%, and 3% for 0%, 25%, 50%, 75%, and 100% stamp sand, respectively.  This trend seems reasonable because topsoil would tend to retain water and stamp sand would tend to let water drain out. We noticed the following changes between the initial and final soil moisture contents:

- 0% stamp sand stayed about the same, only increasing by 2%
- 25% stamp sand drastically increased, going up by 10%
- 100% stamp sand decreased by 8%
- 50% and 75% approximately doubled from the beginning moisture content to the final moisture content, but still remained low

<u>Observations</u>:
For both experiments, we recorded data and observations daily. We did not collect data in general on snow days or weekends because school was closed.

<u>Experiment 1</u>:
In Experiment 1, we grew four different plants(alfalfa, red clover, fescue, trefoil) in five different quantities of stamp sand and topsoil (0%, 25%, 50%, 75%, and 100% stamp sand).  We began our experiment on November 15, 2016, and ended it on December 16, 2016.  We ended this experiment when we were able to see which two plant types and grew best and in what soil type the plants grew adequately.  Our end results showed that alfalfa and fescue grew adequately in 100% stamp sand.

The room temperature ranged from approximately 17.4 - 28.5 deg C. Most days that we recorded the data, we also watered the plants. On the days we had snow days we were not able to water the plants and since we did not have school were also unable to water the plants on weekends. The following are the dates in which we got our first plants. In Alfalfa, on November 17, we got our first plant in 0% stamp sand. On November 18, we got plants in all of the soil types in Alfalfa. For Red Clover, we got our first plants in all soil types on November 18. Based on the results that we got, the plant types that we are going to stress will be fescue and alfalfa in 100% stamp sand.

To grow our plants, we needed to plant seeds of alfalfa, trefoil, fescue, and red clover, in the mixtures of 0%, 25%, 50%, 75%, and 100% stamp sand. For each mixture and each plant type, we used approximately 5 grams of seed (See Table 2.7). This was to ensure equal masses of seed for each container. If we had not done this, we would not know if one plant grew better than another due to a higher seed mass or if the growth was due to the plant and the soil type.

In Experiment 1, our plant growth, temperature, amount of water, and observations were recorded in Table 2.8. We watered the plants almost every day except for weekends (Saturday and Sunday). Most of the plants sprouted between the 4th and 6th days of growth. Unlike we originally thought, there were a few plants in the control. We believe this was because we may have accidentally dropped some seeds from the other plant types into the control container or there might have been seeds in the topsoil or stamp sand.

For the control there were no plants in 100% stamp sand, 75% stamp sand, 50% stamp sand, and 0% stamp sand. We think this was because the higher amounts of stamp sand or the least amount of organic matter. We did not think there would be any plants in the control at all though. There were plants in the 25% stamp sand, there was 0.1 g. We were surprised that any plants grew, but there was only a few plants in the 25% stamp sand. We think that the reason there were plants in the 25% stamp sand was maybe one of the seeds from the other containers fell in the control.

We determined the average plant density (number of plants/cm$^2$). To determine the plant density, we divided our test container into three sections. We removed the soil and plants from each section. We weighed the mass of plants and counted the number of plants. This number did include wilted plants. If the number of plants in a given section exceeded 200, we stopped counting. We then divided the number of plants by the cross-sectional area that we measured. Additionally, we randomly selected three plants and measured their overall, plant and root lengths. We looked through the plants and selected the three tallest and smallest plants and measured their overall length. These measurements were then averaged. The data are shown in Table 2.9 and Figure 2.4. Fescue reached the maximum number of plants for each soil type. Red clover also had the maximum number for 50%, 25% and 0% stamp sand. Trefoil did not grow well in any soil type. Alfalfa did well in low amounts of topsoil, but not when there was a great deal of topsoil. Figure 2.4 shows the plant density results. Overall, fescue had the highest plant density, and as expected, the control (no seeds planted) had the lowest. A summary of each plant is following:

- Control: When we started the experiment, we did not expect to have any plants, but we ended up having a few. For the control, very few plants grew in any of the soils. There were no plants in 0% and 75% stamp sand. The plant density for 25% stamp sand, 50% stamp sand, and 100% stamp sand were was 0.05 plants/cm2, 0.02 plants/$cm^2$.and 0.03 plants/$cm^2$, respectively. Any plants present could be due to accidentally dropping seeds into them or seeds may have been in the soil that we collected.
- Trefoil: Trefoil had the highest plant density in 0% stamp sand and the lowest in 50% stamp sand. The densities were relatively the same in 25%, 75%, and 100% stamp sand.
- Fescue: In fescue, all of the soil types had 3.2 plants/$cm^2$ except in 75% stamp sand, which had 3.3 plants/$cm^2$.
- Alfalfa: For Alfalfa, the amount of plants/$cm^2$ decreased as the percent of stamp sand decreased. This is unusual because the plants grew worse as the amount of better soil (the soil with more organic matter) increased. The results were 1.1plants/$cm^2$ , 1 plants/$cm^2$, 0.7plants/$cm^2$ , 0.7 plants/$cm^2$, and 0.8 plants/$cm^2$ for 100%, 75%, 50%, 25%, and 0% stamp sand, respectively.
- Red Clover: Red clovers plant densities were the highest in 0%, 25%, and 50% stamp sand, while 75% had the lowest. 100% stamp sand was about in the middle of 50% and 75% stamp sand.
- Overall: Fescue had the highest plant density regardless of soil type; and trefoil, no matter what soil type, had the lowest overall densities. Red clover had the second highest plant densities overall. The reason we picked alfalfa over red clover for Experiment 2 is because the red clover plants started to wilt and die towards the end of the experiment.

The mass of plants grown in each soil type is related to plant density. Figure 2.1 and Table 2.9 show the plant mass. A summary of the results for each plant type is below.

- Trefoil: For trefoil there were plants in all of the amounts of stamp sand. As the percent of topsoil increased the mass of plants also increased. In 100% stamp sand the mass was 0.2g and in 0% stamp sand the mass was 4.2g. We thought that this happened because the more topsoil and organic matter there was in each container the easier it would be for the plants to grow.
- Alfalfa: For alfalfa there was a trend. The plant mass decreased with the decrease of stamp sand. The plant mass for 100% stamp sand was 11.1g and the mass for 0% stamp sand was 4.8g, and at lowest amount was 2.4g. We think this may have happened because the seeds did not germinate evenly or the watering was not even. For the plants in between 100 and 0% stamp sand there was no noticeable trend.
- Red clover: For red clover there was a noticeable trend. The mass went up and then it went down. It increased until it hit 50% stamp sand, and then it decreased until 0% stamp sand.
- Fescue: For fescue there was a similar trend to red clover. The plant mass increased up to 50% stamp sand and decreased down to 0% stamp sand.

We wanted to know how the plants grew with respect to how much of the overall plant was in the roots versus how much was aboveground (See Figures 2.2a-d). To make these measurements we took three plants that were randomly selected and averaged the measurements. Figure 2.3a-d shows the tallest and shortest lengths for trefoil, alfalfa, red clover, and fescue in 0%, 25%, 50%, 75%,and 100% stamp sand. For trefoil, the tallest plant height increased as the amount of stamp sand decreased, although the length slightly decreased for 75% stamp sand. This trend may have been caused by the increase of the organic matter as the fraction of stamp sand decreased. The shortest plant length (1.5 cm) in alfalfa occurred in 25% stamp sand, but was essentially constant for all soil mixtures. Also, there was a trend for the shortest plants in alfalfa, the plant length stayed relatively the same but shortest length was 1.5 cm. The tallest alfalfa plant measurements had no trend for the different soil mixtures, but the greatest length was about 17.5 cm. In fescue, the tallest plant lengths did not vary greatly and did not exhibit any trends. The shortest plants length measurements for fescue also did not exhibit a trend. In the red clover measurements, the tallest plant length from 75% stamp sand to 0% stamp sand. For the shortest red clover plants, the plant length decreased from 50% stamp sand to 0% stamp sand. In 100% topsoil, trefoil and red clover grew the best. On the other hand, alfalfa, red clover and fescue had adequate or good growth in 100% stamp sand. These data correlate well with the plant masses and densities. Trefoil had the least growth, followed by fescue. Alfalfa and red clover had similar growth.

Figures 2.2a - 2.2d show the average plant length of the plants we tested (trefoil, alfalfa, red clover, and fescue). In general, the root length was much longer than the plant length for all plant types. We believe this is because the plants need to grow long roots so that they can get enough nutrients to supply them to grow the plant aboveground.

- Trefoil: For trefoil, Figure 2.2a shows that the plant length increased as the amount of stamp sand decreased for 100% stamp sand to 0% stamp sand, although 100% and 75% stamp had similar plant lengths. This trend occurred for the all the lengths we measured.
- Alfalfa: The aboveground length increased with 100% stamp sand being the shortest and 0% stamp sand being the longest (See Figure 2.2b). Gradually, the root length increased from 75% stamp sand to 0% stamp sand, but the 100% stamp sand root length was greater than both 75% and 50% stamp sand. The aboveground plant length for the different soil types showed increased slightly as the amount of stamp sand decreased.
- Red Clover: In Figure 2.2c, red clover's aboveground plant length steadily increased from 100% (the least) to 0% (the greatest) stamp sand. The overall plant length varied between the plants, but 75% stamp sand had the shortest and 25% stamp sand had the tallest. Like the aboveground length, there was no trend, and 75% had the lowest and 25% had the greatest.
- Fescue: For the aboveground length, the root length, and the below ground length, the fescue plants all increased from 75% to 0% stamp sand. The plant length for 100% stamp sand was slightly larger than 75% stamp sand. (See Figure 2.2d)
- Overall Comparison: All of the plants had more root growth than aboveground plant growth. This shows that for our growing period, much of the plant's energy went into establishing a good root structure. Alfalfa had the most aboveground plant growth. Trefoil and fescue had the overall least amount of plant growth.

For all plants, we noticed that the plant height and amount increased as the amount of stamp sand decreased. Trefoil plants began to die about halfway through the experiment. We also observed that a white mold began to grow on the trefoil plants. This could have killed the plants. Red clover showed some plant wilting towards the end. This seemed to indicate that it needed more water. The fescue and the alfalfa seemed to have the best plant growth based on visual inspection. Therefore, these were selected as the plants for Experiment 2.

Our data refutes the hypothesis because parts of our hypothesis was incorrect. We thought that 75% stamp sand would allow the plants to grow the best without using much topsoil. However, 100% had the highest plant growth of the two plants we used for Experiment 2. We also thought that red clover and alfalfa would have the most plant growth. Red clover and alfalfa grew had the second and third best plant growths, respectively. Towards the end of the experiment, the red clover plants began to wilt and die. Fescue grew the best overall. Consequently, we decided to use fescue and alfalfa in 100% stamp send to test the effect of soil stressors (wind, high water table, and wheels) on plant growth.

Experiment 2:

In Experiment 2, we stressed fescue and alfalfa in 100% stamp sand. This was decided since in Experiment 1, when we found out that while some plants grew better than alfalfa in a higher percentage of top soil, alfalfa was the best (besides fescue) in 100% stamp sand. We started this experiment on January 10, 2017 and ended it on February 8, 2017. We started using the stressors on January 26, 2016, which was 17 days after we started growing our plants. During this experiment, we noticed that the wind and wheel stressors were making the plants bend. During the increased water table stressor, we noticed that the plants were starting to get yellow and die.

We tried to start our second experiment before Christmas break (December 23 - January 3). We planted the fescue and alfalfa seeds, but had poor germination. This could have been due to many factors. During breaks, the heat is turned down in the building. Additionally, one of our team members was watering the plants but had a family emergency and was unable to water the plants from December 31 - January 3. When we returned to school, there were very few plants and many of them were wilted or dead. Consequently we had to restart our second experiment.

The data for Experiment 2 are shown in Table 2.11 and 2.12 and Figures 2.5 - 2.8. Over the duration of the test, the temperature ranged from 21.4°C to 26°C; so the temperature stayed pretty consistent. As shown in Table 2.11, fescue was the first plant to emerge was fescue on January 12, 2017, followed by alfalfa one day later. The tire and water table stressors began to be applied on January 26, 2017, and the wind stressor on January 27, 2017. The wind began a day later because the timer was set to run from 6:00AM - 10:00 AM. We were either not at school or are in class during that time.

To simulate a high water table, we placed the soil containers in a pan with 2 in of water. When we started the water table stressor, the water level in the container went down as the water entered the soil pores. We observed on this first day, that the tire was hard to push through the plants and that plants at the front of the container were being pushed down. As the test progressed, “tracks” showed up in the plants.

Throughout Experiment 2, fescue was slightly taller than alfalfa regardless for all of the stressors. The exception was for the tire stressor where the two plants were essentially the same in height. On February 1, 2017, in the water table test, we noticed that some of the plants were turning yellow. On the same day in the tire tests, we noticed that where the tire contraption drove, the plants were bent; there were two indentations in both plant containers where the Lego wheels were driven. It was at this time that we observed that the alfalfa plants were blown down in the direction of the wind in the wind experiment, but the fescue plants were only bent. Based off of these observations, we were able to tell that fescue was able to resist the stressors more.

The plant mass of alfalfa and fescue are in Figure 2.5. Since the roots contained some dirt, the plant masses are contain both the plant mass and the dirt. The highest plant mass occurred in the water table container for both fescue (250 g) and alfalfa (160 g). The low water table enabled the plants to get a great deal of water. At about two weeks into the stressor portion of the experiment, the alfalfa plants began to turn yellow. This seemed to indicate that the alfalfa plants were getting more water than they needed. The plant masses for fescue and alfalfa were slightly higher in the container with the wheel stressor than the wind.

In general, fescue is a taller plant, which could cause it have a greater mass. Fescue grew faster than alfalfa, so it was able to attain a greater mass in a shorter amount of time. The height of the fescue was lower in the wind and tire erosion containers, making it have a smaller mass, whereas alfalfa had a smaller range of plant growth. Alfalfa is a slower growing plant than fescue. We believe that over a long period of time, alfalfa would end up having a plant height similar to fescue.

For alfalfa, the water table, and tire erosion had a greater plant mass than the control, with the water table drastically mass drastically larger. The wind stressor was only slightly lower than the control. For Fescue, the control had a greater mass than the wind and tire stressors. The water table stressor was still drastically larger than the other stressors. This trend was the same for the plant growth and tallest and smallest plant comparisons (Figure 2.6 and 2.7, respectively).

We measured and averaged three randomly selected plants from each of three sections of soil in each container. Figure 2.6 shows plant growth in Alfalfa and Fescue with the different soil stressors. Alfalfa had the highest aboveground growth in the water table experiment at 7.2 cm. The lowest aboveground height was at 5.4 in the tire erosion container with alfalfa. The greatest alfalfa root length was in wind at 4.1 cm. Alfalfa’s shortest root length was in control at 2.6 cm. Fescue had the highest aboveground length in tire erosion, with a height of 9.8 cm. Fescue’s shortest aboveground length was 6.4 in wind. The root length for fescue was at its longest in wind with a length of 4.6. Fescue’s shortest root length was in water table at 2.3 cm.

To determine how well plants grew in each container, we found the tallest and shortest plant from each of the three sections (See Figure 2.7). For all stressors when evaluating the tallest plant length, the fescue plant length was longer than for alfalfa. The fescue was taller alfalfa for all stressors except the water table container.

Alfalfa plant lengths for the tallest and shortest plants are shown in Figure 2.7a. In general, for all stressors, the tallest plants were shorter or essentially the same as in the control. For the shortest plant, the wind and wheel containers had plant lengths similar to the control, while the plants in the water table container were slightly taller.

In Figure 2.7b, the tallest plant in the control was greater than the tallest plant in the water table and wind containers. The tallest fescue plant in tire erosion was higher than the control. For these data, the “tallest” and “shortest” plants were selected, and this was not necessarily in the region where the tires travelled. The shortest plant length showed a different trend; the control was higher than the water table and tire erosion containers. The shortest plant in the wind container was taller than the control.

Figure 2.8 shows Alfalfa and Fescues plant densities for the different soil stressors. The plant densities stayed relatively similar for fescue in water table and control, which had the highest plant density of 3.23 plants/$cm^2$.  Wind had the lowest plant density for fescue, which was 3. Tire erosion fescue plants had a density of 3.15 plants/$cm^2$. Alfalfa’s highest density was also in control at 3.04 plants/$cm^2$. Alfalfa had the lowest density of plants in tire erosion and water table, which were both at 2.9 plants/$cm^2$. The wind plants had a plant density of 2.92 plants/$cm^2$.

For the wheel and water table containers there were visible effects from the stressors. In the wheel container there was a path that was visible from where the wheel had passed during our experiment. A reason that the plant length might have been the greatest in the wheel container because we may have not taken the plants we measured where the wheel passed. The plants where the wheel passed would have been shorter or more compacted. For the wind container the plants were the shortest because the wind may have dried out the plants and some may have died. Also the plants may not have grown as fully because of the stress of the wind. Now for the water table the plant height was around the same height or medium height compared to the other stressors. We think this may have happened because the high water table over watered them or flooded them so some of the plants died due to the excessive water.

For Experiment 2, our data refutes the hypothesis because it was incorrect. We said that under the tire stressor, the plants would go back to how they were before the stressor. This was correct at the beginning of the experiment, but after we had been applying the stressors for several days, the plants were not going straight up again.  In fact, for the alfalfa, the plants began to be compressed into a green mat of plants. This means that if these plants were being driven over for a short period, they would be fine. If the stress continued, the effects of the stress would be that plant growth would be slowed down.

We hypothesized a similar outcome for the wind stressor. We stated that the plants would only be bent when there was wind and then they would return to how they were prior to the wind. This was incorrect be the wind ended up killing off a lot of the plants and made it so that the plants that lived were always bent. We believe that it he plants had enough time with no stressors and adequate water, the plants would grow back and the ones that did not die would go straight again.

We stated that the plants would not grow with a high water table. For the period of time that we did our experiment, this was incorrect. The alfalfa plants around the edge of the container were starting to turn yellow and die, but the plants in the middle were still mostly green and healthy. We believe that if we continued this experiment for a longer period of time, all or most of the alfalfa plants would have died. Fescue, on the other hand, grew well in the high water table experiment.

**Potential Errors:**
Completing any experiment will cause errors to occur. Although we tried to minimize mistakes, they could have impacted our results. The major ones are listed in the table below.

| **Table 2.4. Whiz Kids Possible Experimental Errors** | |
|---|---|
| **Error** | **Impact** |
| <u>Grow Light Timer Malfunctions</u>:<br>1. Interval incorrect<br>2. Other students reset the timer<br>3. Power outage in the room<br>4. Timer was unplugged | ● Most of the malfunctions caused the amount of time that the grow light was on to be shorter. This would cause the plants to grow slower and make the experiment longer.<br>● If the interval when the light was on was too long, the light would be on too long which would simulate more daylight. This would cause the plants to grow more. (We wanted 12 hours of light. If the interval was off, it was off by about ½ hour. This should not have impacted our experiment greatly.)<br>● At the beginning of our experiment, students who had class in the room where our experiment was were resetting the timer. We moved the timer and our science teacher let the other teachers know about issue and it stopped. |
| Missing days to water plants (weekends, snow days, family emergencies (as discussed in Team Collaboration) | This would have slowed down plant growth. |
| Low seed germination | Fewer plants would be growing in a given |

| | |
|---|---|
| | container. This was an element we were looking for in the first experiment. In the second experiment (plant growth stressors), it might have impacted the overall conclusion of what the stressor did to the plants. This is discussed in the Scientific Inquiry, Analysis section. |
| Some seeds might have ended up in a container with a different plant. | If a plant was not the type that should have been in a given container, we included it in our observations and it was discussed in the the Scientific Inquiry, Analysis section. |
| Inconsistent temperature in the room. | When school is not in session, the heat is turned down. This would have slowed down plant growth. |
| Not calibrating (or zeroing) the mass balance prior to weighing the soil or plants. | This would have caused errors in the masses measured. |
| **Plant measurements:**<br>● <u>Plant density</u>: We counted each individual plant. However, we stopped counting plants when we reached 200 plants.<br>● <u>Plant mass</u>: We measured plant mass by placing all the plants onto a scale. We were unable to remove all of the soil particles.<br>● <u>Plant length</u>: Plant length was measured in our experiment by randomly taking 3 plants from each container. | **Resulting Error:**<br>● The plant density values were higher than what the data table shows.<br>● The plant mass was higher than if we had been able to remove all of the soil.<br>● In Experiment 2 for the tire container, this may have resulted in a higher plant length. For that container, we should have taken plant samples from where the tire tracks were. |

## Drawing Conclusions

**Interpretation/Evaluation of Results:**

<u>Physical and Chemical Soil Analyses Interpretation</u>:

We determined both the particle distribution and the soil texture type, along with soil porosity and moisture content. These tests indicate how well the roots and grow and how the water and nutrients can flow through the soil.

The 100% stamp sand moisture content was drastically lower than the topsoil (0% stamp sand) moisture content.  This may be because the topsoil has more organic matter and could retain more water. The pH was essentially constant between 0% and 100% stamp sand, with the topsoil pH being lower by 1 than the 100% stamp sand (pH = 6.5). It could be because the topsoil we used had a lower pH than the stamp sand. The potassium results were inconclusive since we were only able to do two of the tests. The nitrogen results were also inconclusive because there was no trend in the data. The phosphorus content stayed about the same for all of the tests. This may be because the amount of phosphorus is not dependent on the amount of organic matter. The porosity stayed about the same, varying only between 16% and 20%. This would mean that the region for root growth and water was about the same for all soil mixtures.

When we compared the porosity of our soils (16% - 20%) to typical values of sand porosity (25% - 50%) (Soil Science Lab Manaul), our measured values were slightly lower. We used a porosity procedure developed for middle and high school science classes, which was different from the ones used in a scientific laboratory. From discussions with a local farmer, we learned that our soils are sandy. Therefore, when we mixed our topsoil with stamp sand, that would have resulted in a sandy soil. This was verified when we completed the soil texture analysis (Figure 2.1) where most of the soils are in or near the sand regime regardless of who analyzed them. The sieve analysis (Figure 2.1) shows that all of the soil mixtures were similar (i.e. the lines for the different soil mixtures lie close together). This verifies the tight range we found in our porosity measurements.

Data Interpretation:
Experiment 1:
The purpose of Experiment 1 was to determine the least amount of topsoil that could be added to stamp sand and achieve successful plant growth. Therefore, this section will focus on the growth of fescue, red clover, alfalfa and trefoil over our experimental period.

We noticed that fescue and red clover had the highest plant densities out of the four plants (See Figure 2.4 and Table 2.9). The pH of our soils ranged from 5.5 to 6.5. Red clover and fescue will grow well in soils with that pH range. Trefoil and alfalfa grow well in soils at the end of our soils' pH range. Trefoil and alfalfa had much lower plant densities than the others. This could have happened because these plants' seedlings are not very vigorous when compared to the seedlings of fescue and red clover. The plant mass did include wilted and dead plants. Red clover had many wilted or dead plants. This caused the plant density to be much higher than it would have been if we had only included live plants in the plant density.

There was growth in all containers that seeds were planted in. Figure 2.1 summarizes the results for the five soil mixtures with respect to plant mass. The trend for the four plant types was that the plant mass increased for all soil types.

Trefoil was the plant with the least amount of growth. The mass of trefoil in each soil type increased as the amount of stamp sand decreased. Trefoil seeds must be inoculated for good plant growth and germination. We do not know if our seeds were inoculated. As a plant, trefoil seeds do not germinate well, nor are the seedlings vigorous. These factors would also have affected plant growth and the plant mass.

For alfalfa, the plant mass was highest in 100% stamp sand. There was a sharp decrease in growth at 75% stamp sand and then the mass increased for 50% and 25% stamp sand. There was a slight mass decrease from 25% to 0% stamp sand. This inconsistent pattern may have happened because the containers were watered differently or the seeds may have germinated differently. The topsoil used may not have contained uniform amounts of organic matter which would also affect plant growth. Some alfalfa seeds have impermeable seed coats that do not let water in. These seeds do not germinate for months or years; so some may not have grown.

For red clover, mass of the plants increased from 100% stamp sand to 25% stamp sand; 0% stamp sand had a lower mass than 25% stamp sand. This may have been due to uneven watering or inconsistent seed germination.

Fescue was the only grass grown. The plant mass increased from 100% stamp sand to 50% stamp sand and then decreased for 25% and 0% stamp sand. Like the other plants, this may have happened because of the watering and the seed germination. The reason for the limited plant mass is that fescue needs nitrogen in the soil. The other three plants were nitrogen fixers and were not as sensitive to nitrogen in the soil. plants need nitrogen to grow so there may have not been much nitrogen in the soil. Fescue is a grass. Grasses tend to grow very rapidly at the beginning and then slow down when they reach their optimum height. This could have caused the plant mass for fescue to be much higher than for the other plants.

Figure 2.2 a-d shows the aboveground and root lengths of trefoil, alfalfa, red clover and fescue in 0%, 25%, 50%, 75%, and 100% stamp sand. Trefoil had the greatest root length and aboveground length in 0% stamp sand at 6.5 cm and 1.9 cm, respectively. Trefoil also had the shortest root and aboveground lengths at 2.4 cm and 0.9 cm in 75% stamp sand. The root length in alfalfa ranged from 4.1 cm (75% stamp sand) to 8.1 cm (0% stamp sand). The aboveground length had a range of 1.4 cm (100% stamp sand) to 3.1 cm (50% stamp sand). Red clover's aboveground length had a range from 4.1 cm to 1.3 cm. The root length had a range from 6.6 cm to 2.4 cm. The range of aboveground lengths in fescue was 2.1 cm to .4 cm. Fescue's root lengths ranged from 6.3 cm to 2.4 cm.(Move to analysis)

In Figure 2.2 a-d, aboveground and root lengths of trefoil, alfalfa, red clover and fescue in 0%, 25%, 50%, 75%, and 100% stamp sand are shown. Alfalfa had the greatest root length overall in 0% stamp sand. We believe this is because alfalfa is a nitrogen fixer. Red cover is also a nitrogen fixer, but we noticed that red clover started to wilt near the end of the experiment. The greatest aboveground length was in 0% stamp sand in red clover. This may be because red clover has the shortest germination time out of the four plants.

The trends for the longest and shortest plants lengths could be due to the amount organic matter in the soil. In 100% stamp sand, there was little to no organic matter, while 0% stamp sand would have the highest fraction of organic matter. For trefoil and red clover, the trend was that the plant length increased from 75% to 0% stamp sand. The plant lengths of red clover and trefoil increased as more topsoil was added to the containers. This was probably due to a higher percentage of topsoil. Fescue grew well in all soil types. This may have been due to because fescue can grow in acidic soils. Alfalfa plants in 100% stamp sand grew adequately. Alfalfa is a nitrogen fixer and extracts its nitrogen from the air instead of the soil.

<u>Experiment 2</u>:
For Experiment 2, we tested how alfalfa and fescue would grow when stressed by wheels, high water table and wind. We decided to use alfalfa and fescue since they grew adequately in 100% stamp sand, as shown in Experiment 1. We preferred to complete Experiment 2 in 100% stamp sand because that is what is at the Gay stamp sands. When we planted the plants, we used 10 g of seeds (See Table 2.10), unlike in Experiment 1, in which we used 5 g. We started the plants prior to our holiday break with 5 g of seeds. Unfortunately, there was poor germination and we had to start over in January. Since we knew from Experiment 1, that the plants required several days to germinate and grow, we knew we were under a time constraint. We had to complete the test, make measurements, record and analyze the data, interpret the data and finish the documentation of both experiments before the February 22 deadline. The additional seed mass ensured plant germination.

Regardless of the soil stressor, fescue seemed to grow better. This could have been due to fescue being a grass and alfalfa being a leafy plant. For the wind stressor, a fescue had plant stalks. Therefore, when the wind caught the plants, they bent. Alfalfa also bent with wind, but had leaves. The leaves were dead in some areas or dried up. They were dried maybe because of the wind that was blowing on them because of the stressor. The wind may have resulted in the decrease of the plant growth.

The differences between fescue and alfalfa plant growth when exposed to a high water table could also be due to the fact that one was a grass and the other nitrogen fixer. A grass has stringy, roots, while a nitrogen fixer typically has roots with nodules. The leaves were a yellow color because the roots were drawing up excessive amounts of water. Fescue, on the other hand, did not appear to be affected by the high water table because the roots were more thin and stringy than alfalfa. This may have slowed down the rate at which water was drawn into the plant, resulting in less plant stress.

For both fescue and alfalfa, there were visible effects from the tire erosion. For alfalfa, the plants and leaves were pushed down or compacted on the soil. This is because the broad leaves of alfalfa caught the wheel and were compacted. For fescue, the plants were not as affected by the tire, but there were still some visible effects. The fescue plants are thin stringy plants that did not catch the wheel but were pushed down in the direction of tire travel.

The following section focuses on the overall interpretation of Experiments 1 and 2.. For Experiment 1, we determined which plant type will grow the best in the least amount of stamp sand (0%, 25%, 50%, 75%,100%). To do this, we measured plant density, plant mass, and plant length. We found that the plant length measurement was the best way to represent the plant growth because there was the least variability between the measurements. We measured the plant lengths (aboveground and root length, along with the tallest and shortest plants) of 3 plants in each container of soil. We found, regardless of plant type, these three measurements were similar. All of these tests had factors that would introduce error (also in Table 2.4):

- Plant density: We counted each individual plant. However, we stopped counting plants when we reached 200 plants.
- Plant mass: We measured plant mass by placing all the plants onto a scale. This may have been inaccurate because we did not clean all of the soil out of the plant roots, which may have increased the plant mass.
- Plant length: Plant length was measured in our experiment by randomly taking 3 plants from each container. In Experiment 2 for the tire container, this may have resulted in a higher plant length. For that container, we should have taken plant samples from where the tire tracks were.

In Experiment 2, we tested different stressors on alfalfa and fescue. In this experiment, we also determined the plant growth by testing the plant density, mass, and length. Like in Experiment 1, we believe that the overall plant length measurement was the best indication of plant growth. The tallest/shortest plant measurements would also be a good indication of plant growth, but did not differ much from the overall plant length results. If we complete additional tests, we would ensure that we completed plant length measurements in the stressed regions. The other tests may not have been as good because:

- In the density test we stopped counting at 200 plants, but the stressors may have decreased the plant amount.
- The plant mass measurement was inaccurate because some soil was left in the roots.

Overall Results versus Hypothesis:
Our data refutes the hypothesis because for both experiments we were either partially or completely incorrect. Our hypothesis said that alfalfa and red clover would have adequate growth in 75% stamp sand. We ended up having the adequate growth of these plants in alfalfa and red fescue in 100% stamp sand. Therefore, our hypothesis was partially correct since alfalfa was one of the best plants, and 100% stamp sand was close to 75% stamp sand. Although the plants grew well in 100% top soil, we did not choose to do this since we were trying to figure out what plants we could grow in stamp sand with the least amount of topsoil. For the Experiment 2, we thought that over a short period of time, the plants would not be drastically affected by wheels driving over the plants. Comparing the results to the hypothesis, the plants did grow, but they were compressed where the wheels travelled. For the wind stressor, we hypothesized that the plants would grow, but would be slanted in the direction of the wind. This was incorrect since, although fescue did bend with the wind, alfalfa was bent and began to wilt and die. For the water table test, we thought that the plants would die due to high moisture. This was incorrect for both plants. Fescue did not show any stress, while the alfalfa plants began to turn yellow. This was an indication of stress. We think that if our test went for a longer period, the alfalfa plants would have

started to die. Overall, our experiments were successful because we were able to evaluate the growth of four different plants in various stamp sand/topsoil mixtures. We were also able to judge the effects of stressing two of the plants under conditions that are similar to what occurs naturally to stamp sand deposits in our area.

Re-Test/Further Test Hypothesis:
Since we found in Experiment 1 that fescue and alfalfa grew in 100% stamp sand, our team wants to test this experiment on a larger scale. We would ask the LSSI and Lake Linden Village Council if we could have two test plots in the Lake Linden sands. In one plot, we would grow fescue and the other would have alfalfa. Each plot would be 10 ft x 10 ft. The existing plants would be removed and then we would till the plots prior to planting the seeds. Over time, the plants would grow and we would observe them every other day until fully germinated. After germination, the plots would be monitored weekly. We would monitor plant growth for approximately one month, along with weather conditions (temperature and rain). After the monitoring period, we would compare the test plot results to our indoor experimental results. We would compare trends in the data tables and graphs to see if what happened at the lab scale was duplicated outside. We would report our results to the LSSI and the Lake Linden Village Council. If the outdoor test was successful,we would discuss our results with the Michigan Department of Environmental Quality because this process would be an improvement over the current remediation process on the sands (placing a 12 in layer of topsoil on the sands and then planting seeds).

Improvements to Experiments:
The potential errors were summarized in Table 2.4. Most of these errors would not change our experimental procedures. On the other hand, if we were to re-do our tests, we would do the following:

- Plant Watering: We “poured” water in the soil using a graduated cylinder. Instead, we could “sprinkle” the water on the soil using a small garden sprinkler This would ensure even plant growth.
- Removing all the soil from the plant roots was very difficult and we could not get all of the dirt off. We would find a way to wash them or blow the soil out of the roots.
- Counting the number of plants was a time consuming process. We would research how others have done this to see if there is a better method.
- We would try to find a better time to water the plants. We did the watering at lunch because the team did not have class then. We also had to have a teacher or staff member open the door. We needed to have a consistent time each day and lunch seemed to be the best. We could have watered after school on the days we had eCybermission meetings, but we could not water after school on the other days because we had to get on the bus.
- For Experiment 2, we started the high water table and wheel stressors on one day after school. The next day, we started the wind experiment because the fan was on a timer from 6am - 10am. We could have started the water table and wheel stressor tests during lunch, but were worried about having enough time. This would have meant that the tests would have been started 2 hours apart instead of 12 hours apart.

- We would try to find a better solution for the containers. The containers we used were recycled juice containers that when they were excessively wet they would leak. Maybe we could find a better solution for finding water tight containers, like plastic ones.
- We could assign jobs earlier when we were watering and recording. This would make it so the watering was consistent and also the recording.
- We also could have started the experiment earlier so would we would have time for potential errors. This would give us extra time especially since we were growing plants.
- When we were measuring the plant length we may not have taken the plants from where the plants were driven over with the wheel.

Conclusion:
The Whiz Kids completed two experiments on the growth of plants in stamp sand. Experiment 1 was used to determine which plant(s) (alfalfa, fescue, red clover and trefoil) would grow sufficiently well in the least amount of topsoil. Using the plants that grew best (alfalfa and fescue) in Experiment 2, we tested how well those plants would grow when exposed to three different stressors (wind, wheels and high water table).

In Experiment 1, we found that fescue and alfalfa grew well in 100% stamp sand. This was concluded by measuring and comparing the plant mass, density, and height. We found that the plant length was the best indicator of successful plant growth.

In Experiment 2, using the two plant types (fescue and alfalfa) that proved to grow the best in the least amount of topsoil, we measured the impact of soil stressors on plant growth. Out of the three stressors, the wind had the most effect on the plant height whereas the wheel stressor had the most effect on plant growth.

After our tests, we realized fescue grew the best with short term stressors (2 weeks). However, if the tests were completed over a longer period, like what we proposed in the Re-test section, we think alfalfa would have more growth. We believe this would happen because alfalfa takes longer than fescue to fully grow.

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