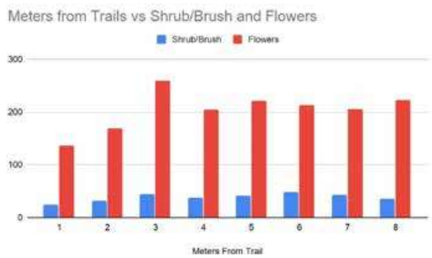

Figure 2: The total number of shrubs and brush varies less with distance than the number of flowers.

within those five, the biodiversity increased with distance from the trail. This seems reasonable as the amount of foot traffic on each meter outside the trail should decrease with distance. The diversity index used (Simpsons) penalizes areas with a low total number of species, but also areas with high variability in the counts of species present. Therefore the average biodiversity isn't the only measure used. The counts of plants are shown in a split bar graph (Figure 2). However, each type of data provides a different warning. The loss of biodiversity has a huge consequence on an ecosystem's inability to withstand natural disasters (4). These can include earthquakes and volcanic eruptions, something Yellowstone is known for, but now can also include climate change, which the ecosystem needs diversity to be able to handle and recover from. The decrease in absolute count of plants, especially flowers, (Figure 2) can also show the start of a chain reaction, harming first pollinators, then their predators, and working its way across the ecosystem, as discussed in the introduction. The idea that the reduction in one species can have effects across the ecosystem is powerful and makes it important to investigate every impact humans can have, no matter how small they might seem. The difference between the flowers and shrubs in Figure 2 can be explained by a variety of reasons, the most obvious being their ability to withstand trampling. This can be for one of two reasons, either the plant itself is made of a woodier stem, making it more resilient to damage and less desirable to trample over, or the plant's infrastructure is less dependent on the parts above ground. Both of these are true in the case of the most prevalent of these, the sagebrush. The hard stem and large area covered make it both difficult to bend and impossible to go through or over, especially compared to a flower.

These findings show that currently, even official trails are not completely successful in keeping visitors off of vegetation. To mitigate this issue, the simplest response would be education. When entering a park, signage defining rules for trail use and how to mitigate plant damage when straying off the trail could have a large impact on this loss of biodiversity seen. Another simple, yet likely extremely effective response could be to install railings on parts that receive a lot of foot traffic to reduce its impact (5). A physical barrier is something impossible for a visitor to forget and could decrease in the severity of the issue (5).

In future experiments, this study could be further improved by having a larger team to identify and count plants and species. This would allow for better accuracy while counting, and more locations in general. It would also allow for the accounting of grass species which could not be done in the interest of time and equipment in this experiment. I'd also want to have a larger dataset with more varied locations to ensure the results aren't specific to an area, and instead speak on trails as a whole.

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The Effect of Different Fertilizer Treatments on the Sprouting Time and Growth of *Cosmos* seeds, seeds of the genus *Myosotis* Forget-Me-Not seeds, and Cruciferae *Brassica nigra* Mustard seeds

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ABSTRACT

During the past decade, climate change has become an important topic. A few ramifications include an excess amount of carbon dioxide and rising temperatures. It is predicted that ecosystems may change due to climate change and its effects on soil communities, resulting in a decrease in plant biodiversity. Soil communities contain tons of components with minerals being one. For this study, different treatments were formed, each containing varying levels of nitrogen, phosphorus, sulfur, and lime and altering the pH. I sowed three different species: *Cosmos* seeds, *Myosotis* Forget-Me-Not seeds, and Cruciferae *Brassica nigra* Mustard seeds. I hypothesize that as the treatment levels decrease in pH the sprouting time and plant growth will increase. Additionally, I predict that as the treatments increase pH, sprouting time and plant growth will increase as well. The results did not support my hypothesis. Only two pots have sprouts. The ANOVA results for the sprouting time in response to the treatment types was 0.042, a rejection of the null hypothesis. Moreover, the ANOVA p-value for the treatment type effect on plant height was 0.000024. The final ANOVA test conducted, which examined the difference in mean plant height between the three species, was 0.00441. All of these ANOVA results are significant, demonstrating that climate change may have a great impact on plant biodiversity.

INTRODUCTION

Over the past decade, climate change has become an increasingly pertinent global issue. Although significant data has been recorded in the last century, this phenomenon began thousands of years prior. Since the 1880s, the global temperature has risen 1.8°F (Callery, S. et al. Accessed 30 Jul 2020). Additionally, carbon dioxide levels are drastically increasing: "reaching its highest amount in the last 650,000 years" (Callery, S. et al. Accessed 30 Jul 2020). Both are ramifications of climate change, an issue that greatly affects the climate in many regions and subsequently the composition of soil (Classen, A. T. et al. 2015).

There are numerous components that constitute soil composition including, water, microorganisms, and minerals (Classen, A. T. et al. 2015). Water plays an important role in both chemical and biological decomposition (DeGomez, Tom, et al. 16 May 2019). The decomposition of materials releases nutrients and carbon for plants (Kleinman, S. 16 May 2019). With only a little water, soil biota struggles to decompose material and get nutrients (Kleinman, S. 16 May 2019). On the other hand, an excess amount of water results in a loss of oxygen for microorganisms and an increase in soil methane production (Kleinman, S. 16 May 2019). Microorganisms decompose raw organic matter (DeGomez, Tom, et al. 16 May 2019). Nitrogen-fixing bacteria, a specialized microorganism, facilitates the extracting of the necessary nutrient (DeGomez, Tom, et al. 16 May 2019). Plant growth and health can be restricted without microbes (DeGomez, Tom, et al. 16 May 2019). Lastly, minerals release ions that are essential for nutrient retainment (DeGomez, Tom, et al. 16 May 2019). Each plays a vital role in the composition of soil. Previous evidence suggests that community compositions will transform, and the productivity of various ecosystems will decrease due to an altercation in rainfall (Porporato, A. et al. Nov 2004). It is hypothesized that ecosystems may react differently based on the relationship between soil components and plants provided that

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climate change has a significant impact on microbial communities in soil, ultimately affecting plant biodiversity and development (Classen, A. T. et al. 2015). Altercations to any of these vital components of soil, may cause a decrease in plant biodiversity (Classen, A. T. et al. 2015).

Narrowing the focus to minerals, it is evident that an increased level of nitrogen greatly minimized the growth period of plant growth (Ingestad, T. 1977). Additionally, the utilization of NPK-fertilizers [fertilizers containing Nitrogen, Phosphorous, and Potassium] at its most potent level proved to produce the highest plant growth compared to areas that only received a fraction of the recommended dose of fertilizer (El-Bassiony, A.M., et al. 2010). Another mineral, Sulfur, that is said to increase Nitrogen uptake, does not have an effect on plant growth as being the sole soil fertilizer applied (Salvagiott, Fernando, et al. 2 Aug 2009, Saskatchewan Inst. of Pedology. Jan. 1984). However, another study stated that Sulfur fertilization had a significant effect on the yield of crops, increasing the mean range 60 percent (Aulakh M.S. 2003). Another study illustrates that all characteristics of plants, including, plant height, growth rate, and number of branches increased as a result of greater levels of sulfur (Piri, Issa, et al. Oct. 2011). Agricultural limestone, a fertilizer that increases pH, drastically enhanced yield more than 200% in comparison to locations that were not limed (Buerkert, A., et al. 21 Mar. 1907). Lastly, the addition of phosphorus fertilizer considerably increased plant height (Nkaa, F.A., et al. Sept. 2014).

Along with plant height, sprouting time is another important factor to examine. According to one study, the soil type with the most Nitrogen available had the fourth highest percentage of germination compared to the soil type with the least Nitrogen available, having the greatest average percent (Sladonja, Barbara, et al. 2014). The amount of Phosphorus in each soil was tested as well in the same study. The soil type with the most Phosphorus had the second greatest percentage of germination (Sladonja, Barbara, et al. 2014). Conversely, the second to lowest average percent of germination occurred in the soil type that had the least amount of Phosphorus available (Sladonja, Barbara, et al. 2014). Lastly, the pH of the soils was also measured. The soil type that was the most alkaline had the greatest percent of average germination, while the most acidic soil had the fourth highest average.

From learning and reading about other studies, I hypothesize that as the treatment types decrease the soil pH, the percentage of germination will increase as well. As the treatment types increase in pH, I predict that the germination percentage will increase. Additionally, I hypothesize that the plant height and growth will increase as the treatment types increase pH and as the pH of the soil decreases, plant height will as well.

METHODS

I gathered 12 small clay pots. Next, I researched the materials needed to increase or decrease the pH of soil. I researched plants with short germination times as well. The types I chose include blood meal, rose and flower mix, limestone, and sulfur. Each of these had varying levels of nitrogen and phosphorus: both are minerals that alter the pH of a soil. I bought *Cosmos* seeds, seeds of the genus *Myosotis* Forget-Me-Not seeds, and Cruciferae *Brassica nigra* Mustard seeds and then I prepared 6 different soil types. The first soil treatment consisted of 50% agricultural lime and 50% potting soil. 100% potting soil was then measured to create the second soil. The third soil treatment was formed with 67% potting soil and 33% blood meal. Then, 33% rose mix and 67% potting soil was utilized for the fourth soil treatment. The fifth treatment consists of 17% and 83% rose mix. Finally, 50% sulfur and 50% potting soil was utilized to make the sixth soil treatment. After making the treatments, I tested the pH of the soils. The levels of pH are 7.5, 7.0, 6.0, 5.5, 4.5, and 4.0, respectively. Each of these 6 unique soil types were created twice to fill the 12 pots. After placing the soil in the pots, I then moved all the pots to a location that receives good sunlight throughout the day. I then planted the seeds. For one group of six pots, I placed 2 groups of four *Cosmos* seeds in each pot. The other group of six pots contained 2 groups of four Forget-Me-Not seeds and 2 groups of four Mustard seeds. Next, I watered each pot until the soil was saturated. Data was then collected, using a centimeter ruler to measure height and water was given to the plants each day. After two and a half weeks of data had been collected, an ANOVA test was performed to test the difference among the mean responses in sprouting time for each treatment type. Since the results of the ANOVA test were significant, I then proceeded to complete a Tukey Post Hoc test to compare the difference between all of the means.

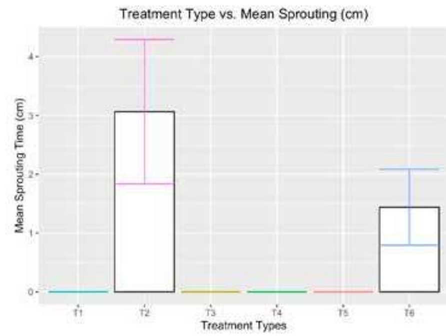

Figure 1: The mean sprouting time of the *Coreopsideae Cosmos* seeds, *Myosotis* Forget-Me-Not seeds, and *Brassica Nigra* Mustard seeds in the 6 different treatment types.

For plant height, an ANOVA test was done to examine the difference between the mean height for all sprouts. Because the p-value of ANOVA test was significant, the Tukey Post Hoc test was performed. Lastly, I completed an ANOVA test for plant height of the three different species all in Treatment two. Again, since the results were significant, a Tukey Post Hoc test was executed.

Sample No.	1	2	3	4	5	6
Treatment Types	Agricultural Lime and Potting Soil	Potting Soil	Blood Meal and Potting Soil	Rose Mix and Potting Soil	Rose Mix and Potting Soil	Sulfur and Potting Soil
Nitrogen (%)	10	10	22	14	20	10
Phosphate (%)	12	12	12	20	32	12
Potash (%)	6	6	6	10	16	6
Magnesium (%)	10.39	0.04	0.04	2.04	5.04	0.04
Calcium (%)	26.95	7	7	7	7	7
Sulfur (%)	6	6	6	6	6	96
Calcium Carbonate (%)	49.82					
Magnesium Carbonate (%)	42. 60					
Fir Bark (%)	25	25	25	25	25	25
Perlite (%)	25	25	25	25	25	25
Mushroom Compost (%)	25	25	25	25	25	25
Earthworm Castings (%)	25	25	25	25	25	25

Table 1: Chemical composition and soil composition of all six treatment types.

RESULTS

As seen in Figure 1, treatment two (T2) and treatment six (T6) were the only soil types in which seeds germinated. The ANOVA test produced a significant p-value indicating a rejection of the null hypothesis of there being no difference between treatments and sprouting time. Treatment two had the most sprouts; however, the mean sprouting time was greater than treatment six. The average sprouting time for treatment two (T2) was 6.15 days compared to treatment six (T6), in which the mean was 1.4375 days. The standard deviation for treatment two and six was 4.918 and 2.581, respectively. For the mean sprouting time data, the p-value was 0.0042, so it is significant. In Figure 2, the mean height for treatment two (T2) is 2.762 with a standard deviation of 4.256. The p-value was 0.0000224, which is of significance. Finally, in Figure 3, species A and species B were the only groups to have sprouts. The ANOVA test resulted in a significant p-value, that being 0.00441. Additionally, the average plant height for species A and species B was 1.5125 and 8.025, respectively. The standard deviation for species A was 1.065 and for species B it was 6.056.

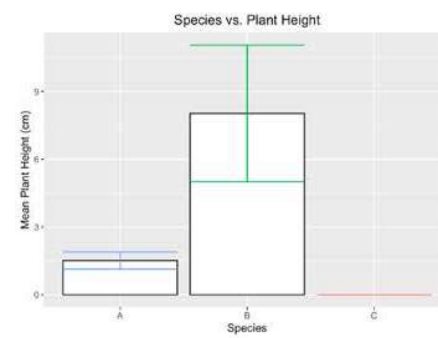

Figure 2: The mean height of the *Coreopsideae Cosmos* seeds, *Myosotis* Forget-Me-Not seeds, and *Brassica Nigra* Mustard seeds in the different treatments.

ANOVA test p-value: 0.0042	
Treatment Comparisons	P-value adj
T2-T1	0.0032596
T3-T1	1.0000000
T4-T1	1.0000000
T5-T1	1.0000000
T6-T1	0.4755294
T3-T2	0.0032596
T4-T2	0.0032596
T5-T2	0.0032596
T6-T2	0.3356747
T4-T3	1.0000000
T5-T3	1.0000000
T6-T3	0.4755294
T5-T4	1.0000000
T6-T4	0.4755294
T6-T5	0.4755294

Table 2: Tukey Post Hoc test values for all different combinations among the treatment types.

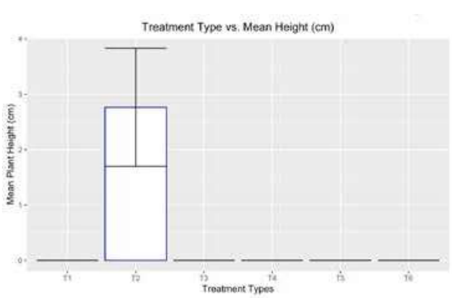

Figure 3: The mean height of each species in Treatment 2. "A" is *Myosotis* Forget-Me-Not seeds, "B" is Coreopsideae *Cosmos*, and "C" is Brassica Nigra Mustard seeds.

DISCUSSION

The results do not support my hypothesis. Before conducting the experiment, I anticipated that the seeds planted in soils that had the mineral fertilizers, which contained nitrogen and phosphorus, would have the shortest germination and greatest growth; however, only the plain potting soil and the treatment with sulfur had sprouts. While the plants in treatment six, the soil with sulfur, had a shorter germination period, the sprouts quickly died. This resulted in treatment two having the most seeds germinate and greatest mean growth.

While this study does not align with the conclusions of other researchers, the results are significant in that it demonstrates that mineral fertilizer may have harmful effects on the germination period and the growth of plants (Ingestad, T. 1977, El-Bassiony, A.M., et al, Buerkert, A., et al. 21 Mar. 1907, Aulakh M.S. 2003, Nkaa, F.A., et al. Sept. 2014). Furthermore, the data shows that treatment types with an increase in supply of nitrogen and phosphorus, decreasing the acidity, will lead to a reduction in the germination percent (Roem, W. J., et al. 11 Dec. 2002). It is evident that the different soil treatments had a great impact on the sprouting time of the different plants. It is unknown if the treatment types had any effect on the plant height, since no sprouts grew in soils with fertilizers. The results of this study suggest that the changing relationship between minerals and plants and changes to soil compositions may have more drastic effects than expected. Lastly, the results may be due to the levels of pH and other minerals in the fertilizer being too high for the plants.

The results of the experiment may not support other studies due to human error and other factors. To begin, I may not have sowed the seeds in the way that was recommended, however, I did follow the instructions for planting on each seed packet. As the study continued, I may not have been giving the plants enough water each day. Additionally, a few variables may not have been controlled. For instance, the amount of sunlight provided could not be controlled. Lastly, the temperature of the soil may have been altered during the duration of the experiment.

For future investigations, it would be interesting to study the effect of extreme levels of carbon dioxide on growing plants. This would be done to study another ramification of climate change: greenhouse gases. Investigating the sprouting time and growth of plants in soil with varying temperatures would be another intriguing future study.

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ANOVA test p-value: 0.00441	
Species Comparisons	P-value adj
B-A	0.0096293
C-A	0.6977923
C-B	0.0061873

Table 3: Tukey Post Hoc test values for each the three different species all in Treatment two.

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