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Soil Moisture and Porosity Affects the Abundance and Distribution of Ageratum houstonianum

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Soil Moisture and Porosity Affects the Abundance and Distribution of *Ageratum houstonianum*

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Abstract

Introduction: *Ageratum houstonianum* is an herbaceous, drought-tolerant plant also known as Blue billygoat weed. It grows well in drained soil and shaded areas. Soil moisture and porosity are two abiotic factors that affect the abundance and distribution of *A. houstonianum*. An ideal condition for plants to grow includes a greater amount of soil moisture and porosity. Higher porosity would mean that there is a greater number of pores, which would result in more significant plant nutrients because of its ability to retain more water. The purpose of this research was to see how soil moisture and porosity based on the gradient with regards to distance from the tree impact the abundance and distribution of *A. houstonianum*.

Materials and Methods: The belt transect method was used to test the soil moisture and porosity, and three belts with four quadrants in each were formed. For each of the belts, the first two quadrants closer to the tree were called zone 1, and the last two quadrants were labeled as zone 2. We hypothesized that there was an increase in abundance and distribution further away from the tree. Abundance was calculated by finding the density of the total number of species over each quadrant area. Soil samples were collected to test the soil moisture and porosity. Paired two-sample t-tests and ANOVA single factor tests were performed.

Results and Conclusion: The t-tests showed a difference between the relationship of abundance/moisture, abundance/porosity, and moisture/porosity. The ANOVA test compared the means of density/moisture/porosity between zone 1 and 2 to see if they were statistically different from each other. Based on the results, there was a decrease in the density as the distance from the tree increased. Soil moisture and porosity also decreased as the distance from the tree increased, which rejected the hypothesis. Closer to the tree, there was an increase in moisture, density, and porosity, which led to the abundance of *A. houstonianum* species because the ideal conditions were met.

Key Words: soil moisture, soil porosity, *A. houstonianum,* Blue Billygoat weed, belt transect

Introduction

Many factors ranging from abiotic to biotic, including interspecific and intraspecific, affect plant population density. The two abiotic factors are soil moisture and porosity. Soil consists of four essential components: mineral materials, organic matter, water and solutes, and air (Kramer, 1944). Soil also consists of living organisms such as bacteria, fungi, and insects that may affect plants' growth.

Soil porosity determines the amount of water that can be held. The greater the number of pores, the higher the water holding capacity of the soil. Soil moisture is classified into four ways as gravitational, capillary, and hygroscopic water and water vapor (Kramer, 1944). The water that is needed for plant growth lies between the field capacity and the permanent wilting percentage. Field capacity is a "moisture content that has been exposed to a centrifugal force of 1000 times gravity," and the permanent wilting rate is the "moisture content of a soil at which permanent wilting of plants growing therein first becomes apparent" (Kramer, 1944). The higher the range between the field capacity and wilting percentage, the higher the amount of water available for plant growth. Plants grow well in a wide range of soil moisture (Veihmeyer and Hendrickson, 1950).

Soil porosity is the amount of open space between soil particles. The texture of the soil, the size, and compaction significantly affect the porosity of the soil. There are three main types of soil- sand, clay, and silt. Sand consists of larger particles, and silt contains medium particles while clay has small particles. A fine soil has smaller particles, but it has innumerable pores than coarse soil (Ball, 2001). Fine soils can hold more water because water is held tighter in smaller pores. Thus, this is why clay soil is rich in plant nutrients. Porosity is measured as a percentage of the soil volume. A high percent of porosity would mean that there is a greater number of pores, so more water can be retained, which would result in greater plant nutrients and better growth for the plants.

Ageratum houstonianum (the Blue billygoat) is the most abundant weed on Prairie View A&M University (PVAMU) campus. Therefore, we sought to better understand the factors affecting plant density and distribution around campus. Therefore, in this research, we studied how the soil moisture and porosity impact the abundance and distribution of A. houstonianum species at various distances from a tree.

A. houstonianum is a drought-tolerant herbaceous succulent plant (Gagliardi and Van Auken, 2010). Dr. William Houston sent the original seed of A. houstonianum species from Veracruz (Mexico), where he first collected them. The seeds were cultivated and then introduced to India in the early nineteenth century and reported as occupying upland herbaceous species' niches (Gavilán, 2016). The species was then reported escaping from gardens and spreading in places like Florida, Cuba, Jamaica, and Hawaii. Typically, it has been known to escape from cultivation and spread elsewhere. It does not tolerate frost, but in some articles, it has been stated that it can survive at low temperatures. It is propagated through the production of flowers and seeds. It has been observed that the plant thrives best in fertile and moist soils. It grows particularly well where soil fertility is high, with dense populations developing when fertilizer is used (Gagliardi and Van Auken, 2010).

Because A. houstonianum is a drought-tolerant invasive species, we hypothesized that there would be an increase in species distribution the further away the plant was from the a trunk. We predicted that the soil moisture and porosity level would be higher when the plant it is further away from the tree. We can seek to understand the habitat by testing the soil using the belt transect method, which enables the analysis of abiotic factors affecting the growth of A. houstonianum. This research will clarify if the soil composition has a significant impact on the abundance and distribution of plant species.

Methods

Two belt transects were constructed to measure the soil moisture and porosity level in two distinct areas on PVAMU's campus. The two areas chosen were located on opposite sides of the campus (Locations A and B). Soil moisture and porosity based on a gradient of distance from a tree were measured to see how it impacted the abundance and distribution of A. houstonianum.

Stakes were placed 1 meter away from the tree at each site to complete the belt transect. Using ropes, the belt was divided into four quadrants having equal sides of 50 centimeters. To determine the distribution and abundance, the width of each cluster of the blue billygoat weed species in each quadrant was measured. Two more belts were made beside the first one to ensure that the belts were 1 meter away from the tree and 50 centimeters apart. The blue billygoat in the first two quadrants, approximately 1-2 meters, was closer to the tree and considered zone 1. The last two quadrants were considered zone 2. The total number of plant species found in each quadrant, and each belt, was used to find the density per quadrant. Data were collected twice a week for three weeks.

To determine the soil moisture, a total of 12 soil samples were collected from three belts in each of the four quadrants. From each sample, 10 grams of soil were placed in an oven at 100°C overnight. The weight of the dried soils was measured. The moisture content of the soil was calculated as weight loss after drying the soil. The data were collected twice a week for a total of three weeks.

Soil porosity is how much open space or how much pore is in between the soil particles. Porosity is often expressed as a percentage concerning the total volume. To test for soil porosity from each of the four quadrants of each of the three belts, a total of 12 soil samples were collected. Each sample of 50 millimeters (sample volume) was added to the beaker. Then 50 millimeters of water from the graduated was gradually added to the beaker to cover the surface of the soil. The final volume of water used was measured. The difference between the final and initial water in the graduated cylinder was calculated to find the pore volume.

$$P = \frac{\text{Pore Volume}}{\text{Sample Volume} + \text{Pore Volume}} * 100$$

The data were collected twice a week for a total of three weeks.

Results

Based on Figure 1, the total average density of zone 1 is 356.89 m2, and the total average density for zone 2 is 346.67 m2. One can observe that the closer the distance is to the tree, the higher the density. Thus, the more abundant the blue billygoat species are.

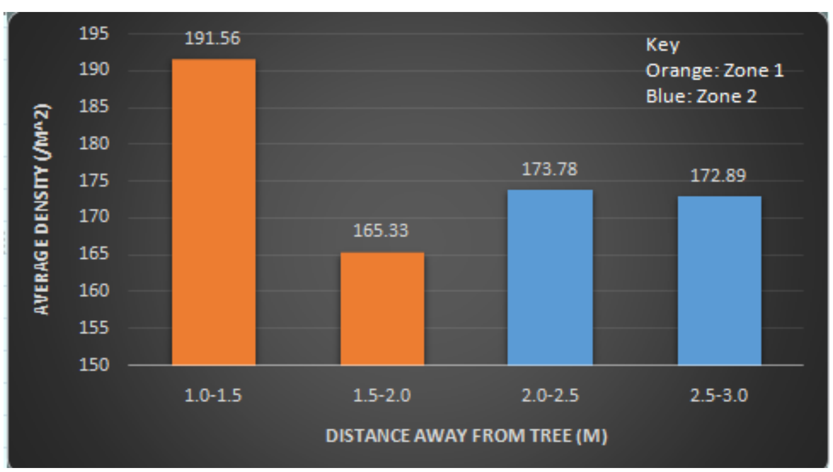

Figure 1 The density is impacted in relation to the distance from the tree. It shows the average density of plants in each quadrant but divided into Zone 1 (orange), closer to the tree trunk, and Zone 2 (blue) further away from the trunk. Zone 1 has a higher density compared to Zone 2.

To test the abundance difference between the means of zone 1 and zone 2, ANOVA was used. The null hypothesis was that there is no difference between the two zones. Based on Table 1, the p-value of 0.79 is bigger than the alpha p-value of 0.05. However, the F-value of 0.79 is smaller than the F-critical value of 4.13. Thus, the null hypothesis is rejected. ***There is a difference in density between the two zones.***

Similarly, the amount of water loss is more significant in zone 1 than in zone 2. Based on Figure 2, the total average amount of water loss in zone 1 is 2.07 mL, and the total average amount of water loss in zone 2 is 2.05 mL. Zone 1 has about 0.02 mL greater amount of water loss than zone 2. The moisture of the soil decreases as the distance from the tree is increased.

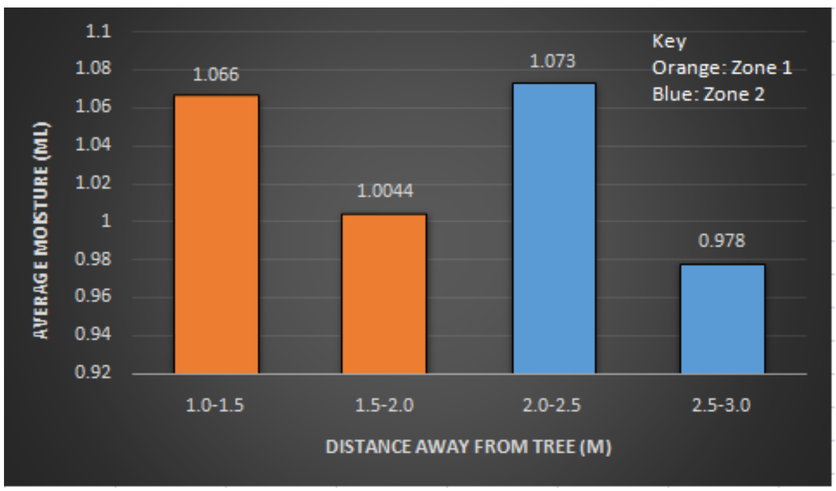

Figure 2 Moisture is impacted in relation to the distance from the tree. It shows the average moisture of soil in each quadrant but divided into Zone 1 (orange), closer to the tree trunk, and Zone 2 (blue) further away from the trunk. Soil moisture is greater in Zone 1 compared to Zone 2.

When ANOVA was completed on this data set, once again the p-value (0.826) was bigger than the alpha p-value of 0.05, and the F-value (0.0489) is smaller than the F-critical value of 4.13. Therefore, the null hypothesis was rejected, and ***there is a significant difference in water loss between zone 1 and zone 2.***

Like moisture, porosity decreases as the distance from the tree is increased. As observed in Figure 3, the total average porosity in zone 1 is 55.73%, while the total average porosity in zone 2 is 48.68%. There was about a 7% decrease in porosity from zone 1 to zone 2.

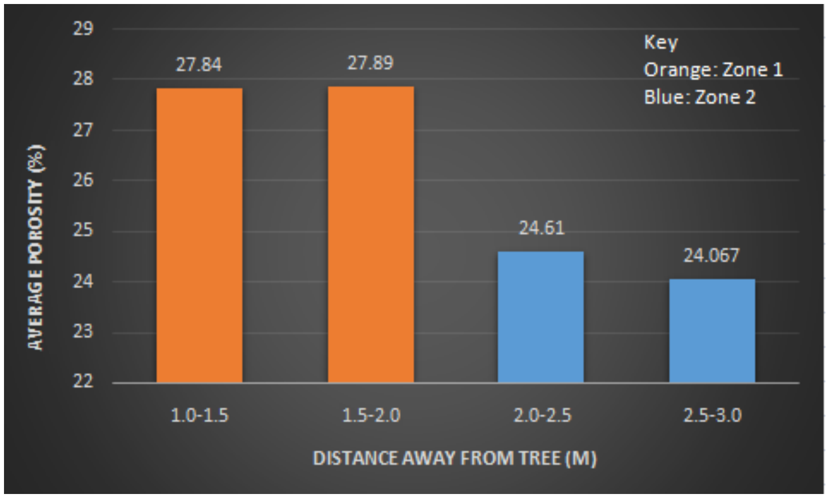

Figure 3 Porosity is impacted in relation to the distance from the tree. It shows the soil's average porosity in each quadrant but divided into Zone 1 (orange), closer to the tree trunk, and Zone 2 (blue) further away from the trunk. Soil porosity is greater in Zone 1 compared to Zone 2.

The p-value of the ANOVA was 0.06, which is bigger than the alpha p-value of 0.05, and the F-value of 3.81 was smaller than the F-critical value of 4.3. Therefore, the null hypothesis was rejected, and ***there was a difference between in porosity between the two zones.***

There is not much significant difference between the average moisture versus distance away from the tree. However, there is a decrease in density as distance increases. The relationship between density and moisture is hard to conclude in Figure 4. The slopes showed that both density and moisture tend to decrease as distance increases. Both the density and moisture also have a weak coefficient of determination of R2 = 0.31 and R2 = 0.29, respectively.

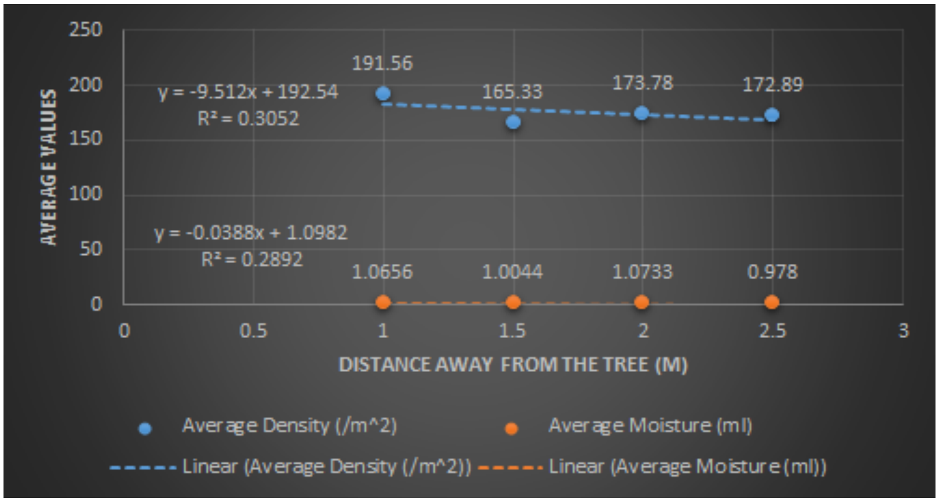

Figure 4 The relationship between density and moisture. It compares the average density of plants and average soil moisture in each of the four quadrants of the belt transect. Both of their linear regression is weak and similar. Therefore, the relationship between density and moisture is hard to conclude.

The t-test for the density and moisture was performed. Based on Table 1, there is a vast interval between the variance of density and moisture. The null hypothesis was that there is no difference between the means of density and moisture. The t-critical two-tail value is 3.18, which is smaller than the t-statistical value of 31.54. Therefore, the null hypothesis was rejected, which means that ***there is a relationship between the abundance of the Blue billygoat species and the soil's moisture.***

Table 1 The means of **density and soil moisture** were compared. The t-critical two-tail value is smaller than the t-statistical value, confirming a relationship between the abundance and soil moisture.

t-Test: Paired Two Sample for Means		
	Average Density	*Average Moisture*
Mean	175.890	1.030
Variance	123.505	0.002
Observations	4.000	4.000
Pearson Correlation	0.575	
Hypothesized Mean Difference	0.000	
df	3.000	
t Stat	31.544	
P(T<=t) two-tail	0.000	
t Critical two-tail	3.182	

However, In Figure 5, the average density and average porosity are both decreased as further away from the tree. There is a direct relationship between the two variables. The coefficient of determination of porosity, R2 = 0.85, is much greater than the coefficient of porosity determination, R2 = 0.31.

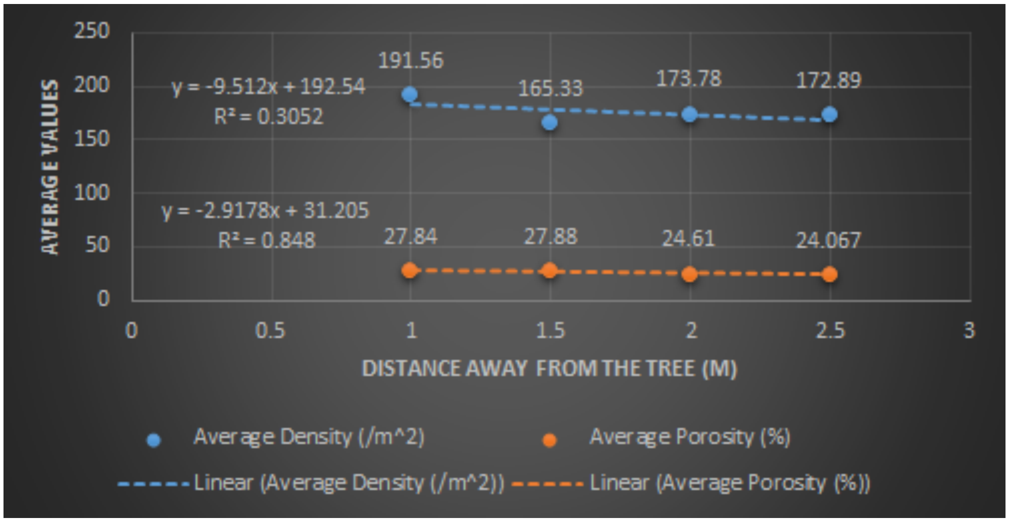

Figure 5 The connection between density and porosity. It compares the average density of plants and average soil porosity in each of the four quadrants of the belt transect. Average density's linear regression is stronger compared to the average soil porosity's linear regression.

The t-test for the density and porosity was performed and is shown in Table 2. The null hypothesis was that there is no difference between the means of density and porosity. However, the t-critical two-tail value of 3.18 is smaller than the t-stat value of 27.83; thus, we rejected the null hypothesis. There is a significant difference between density and porosity.

Table 2 The means of density and soil **porosity** were compared. The t-critical two-tail value is smaller than the t-statistical value, confirming a relationship between the abundance and soil porosity.

t-Test: Paired Two Sample for Means		
	Average Density	*Average Porosity*
Mean	175.890	26.099
Variance	123.505	4.183
Observations	4.000	4.000
Pearson Correlation	0.260	
Hypothesized Mean Difference	0.000	
df	3.000	
t Stat	27.830	
P(T<=t) two-tail	0.000	
t Critical two-tail	3.182	

There is a relationship between moisture and porosity, as shown in Figure 6. The higher the porosity, the more water it holds. Thus, the higher the moisture content of the soil. The slope of the average porosity is -1.46, and the slope for the average moisture is -0.019. Based on the two equations' negative slope in Figure 6, both the moisture and porosity decreased as the tree's distance increased. However, porosity has a stronger coefficient of determination of R2 = 0.848, while moisture has a weaker coefficient of determination of R2 = 0.289.

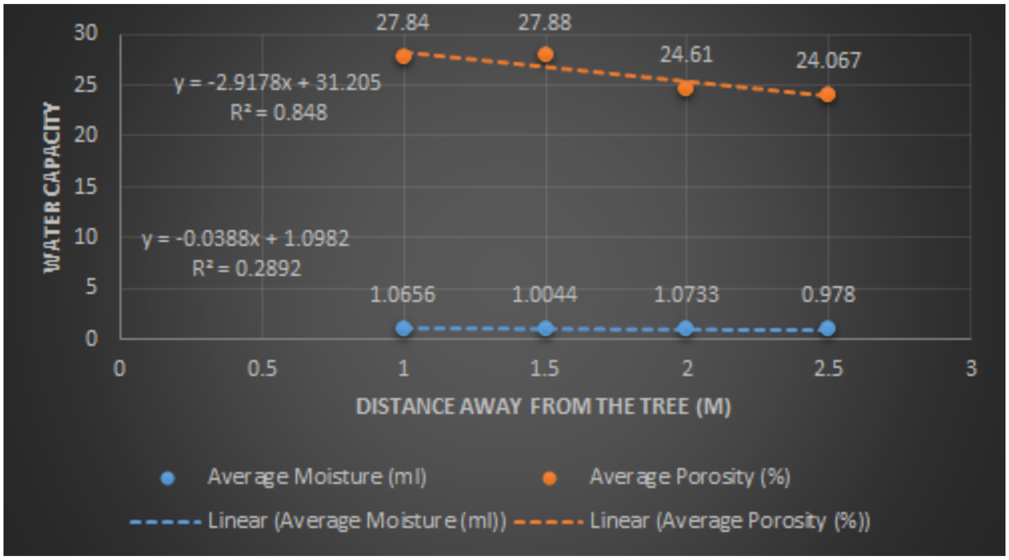

Figure 6 The relationship between moisture and porosity. It compares the average soil moisture and porosity in each of the four quadrants of the belt transect. Average soil porosity's linear regression is stronger compared to the average soil moisture's linear regression.

The t-test was performed to test the relationship between density and moisture. The mean average density was 175.89, and the average moisture was 1.03032. The null hypothesis was that there is no difference between the mean of density and moisture. Therefore, this t-test in Table 3 focused on the t-critical two-tail value. Its value of 3.18 is less than the t-stat value of 24.62, rejecting the null hypothesis.

Table 3 t- The means of **soil moisture and porosity** were compared. The t-critical two-tail value is smaller than the t-statistical value, confirming a relationship between the soil moisture and soil porosity.

t-Test: Paired Two Sample for Means		
	Average Moisture	*Average Porosity*
Mean	26.099	1.030
Variance	4.183	0.002
Observations	4.000	4.000
Pearson Correlation	0.202	
Hypothesized Mean Difference	0.000	
df	3.000	
t Stat	24.621	
P(T<=t) two-tail	0.000	
t Critical two-tail	3.182	

Discussion

Different types of plants grow best in various kinds of soil. The best soil is considered to be sandy loam because it contains a balance of sand, silt, and clay. A higher level of pH and calcium levels ensures that soil can retain water and a sufficient amount of organic matter and pore space. This is supported by the research performed by Lamsal et al. (2019) and his team on the seed germination ecology of *A. houstonianum*. It was found that the drought-tolerant species are photoblastic, and they germinated best in a neutral to an acidic environment not too deep into the soil.

Based on the results in Figure 1, the closer the distance from the tree, the higher the density. Thus, the more abundant the *A. houstonianum* species are. When testing for soil moisture, zone 1 (1.0-2.0 m from the tree) had about 0.02 ml greater amount of water loss than zone 2 (2.0-3.0 m from the tree). Moisture decreased as the distance from the tree increased. Like moisture, there was nearly a 7% decrease in porosity from zone 1 to zone 2. The porosity decreased as the distance from the tree increased. ANOVA test was performed and revealed a relationship between the variables changes as the distance increases. The results rejected our hypothesis by showing an inverse correlation between the distance and variables.

The soil moisture and porosity increased in areas closer to the tree. Thus, the abundance of *A. houstonianum* increased as it grew closer to the tree because the condition was more favorable for the growth of the plants. This is supported by the results obtained from Location B. The paired two-sample t-test showed a relationship between density/moisture, density/porosity, and moisture/porosity. Greater moisture and porosity were found closer to the tree, leading to more abundance in the *Ageratum houstonianum* species, thus rejecting the hypothesis.

A. houstonianum thrives at a minimum of 8°C, grows best in partial shade to full sunlight, and prefers free drained soil with a sufficient moisture level (Gavilán, 2016). Our results are like the research conducted by others. It was noted that a particular species named *A. conyzoides* shared identical characteristics with *A. houstonianum*. But it was found that *A. houstonianum* is a highly invasive species and mostly around highly moist conditions (Singh et al., 2011). This is also supported in the Zhang et al. (2021) study, where they found that *A. houstonianum* had decreased the microbial community diversity. This proves that *A. houstonianum* is a highly invasive species, taking over other plants and becoming more abundant in the area they are in.

To further this study, researchers conducted an ANOVA test that studied the effect of plant species on various morphological, and it showed that there was a significant difference in water use efficiency and specific leaf area, which means that this species prefers to be in areas where the soil had free draining to water and has plenty of nutrients. The experimental data we collected supports that this species uptakes a vast amount of water from our data experiment moisture and porosity. The on-campus location we chose had similar physical characteristics to what Singh et al. (2011) studied in their research. Our ANOVA test studied the relationship between density, moisture, and porosity. The amount of water loss from zone 1 was 0.02 ml greater than zone 2.

Research has previously compared the relative abundance percent of dominant species in soil seed banks at different phases on three quarries (Zhang and Chu, 2013). When we compared the ANOVA test done by (Zhang and Chu, 2013) to our results, we were able to support that there is a significant difference between the two zones. Zhang and Chu's research showed that species richness increased at three quarries along with ecological development; the soil seed banks were dominated by a few annual species, such as *A. conyzoides, A houstonianum, Cynodon dactylon, Digitaria longiflora, and Kyllinga brevifolia* (2013). They also characterized each site's seed bank as a whole, the mean species richness, the mean seed density, and the mean diversity from all quadrants within one location (Zhang and Chu, 2013). This experiment labeled different species based on where they are found. TH94 is a pioneer woody species represented at older phases, which is where *A. houstonianum* had the highest numbers from 0-5 cm. But from 5-10 cm, it decreased in several viable seeds in the soil. When we compared our results to Zhang and Chu's (2013) research, we found out that there is a similarity between the density of *A. houstonianum* concerning the distance from the tree. The research on viable seeds can support that the growth of *A. houstonianum* species is dependent on the environment and its resources. These findings can support our study that soil moisture and porosity impact the abundance and distribution of *A. houstonianum* species regarding the distance.

Bhatta, Joshi, and Shrestha (2020) studied the invasive alien plant species in Bardia National Park using roadside surveys and grid sampling. Their methods of studying the plants were very similar to ours. They found that *A. houstonianum* species had the highest frequency along the roadside and was the second most frequent grid sampling species. They also examined the distribution of the twelve invasive plant species, and it was found that they were more abundant when they were closer to roads, settlements, and rivers. It supported their hypothesis that the invasive species are spreading into protected areas. Their findings can also support our study in that soil moisture and porosity impact the abundance and distribution of *A. houstonianum* species. Our study found that the soil was greater in moisture and porosity when closer to the tree trunk, and therefore the *Ageratum houstonianum* species were more abundant. This is supported by the Bhatta, Joshi, and Shrestha (2020) study in that the species were more abundant in the floodplain region. Also, in their study, *A. houstonianum* was more abundant when they were closer to roads. In nature, trees are located closer to roads, and at PVAMU, trees are spaced out closer by the sidewalk, which is closer to roads. Therefore, it supports our experiment in that the soil was greater in moisture and porosity when closer to the tree trunk; therefore, the *A. houstonianum species* were more abundant.

Although we experimented with two different locations, not all of our data was conclusive. The density of the belts located by Location A could not be compared because we noticed that the number of plants counted on each day was very different; thus, we discontinued the experiment in that location. However, while comparing the moisture and porosity levels from Location A and Location B, we saw that they were similar. Even though we did not use all our data from Location A, we could compare the two locations because both had similar moisture and porosity results. Our results showed higher moisture and porosity levels in Zone 1, whether in Location A or Location B

For future studies, our research team plans to analyze other abiotic and biotic factors affecting the abundance and distribution of plant species, such as testing for soil pH levels. We can also test different locations and measure the light intensity to see if it affects the distribution and abundance. In conducting this research, we noticed a huge amount of clay upon collecting different soil samples. Therefore, doing further research on the percent soil composition of clay, silt, and soil in the soil would provide a positive impact to interpret the results.

Conclusion

To conclude, the discovery has been made that there was a relationship between the distance of the tree and the distribution of *A. houstonianum*. We discovered that there was a decrease in the distribution of *A. houstonianum* when it was furthest away from the trunk. The soil was greater in moisture and porosity when closer to the tree trunk; therefore, the *A. houstonianum species* were more abundant. Away from the tree, the soil was lower in moisture and porosity, so the *A. houstonianum* was less abundant. Based on the results, most plants grow best in the ideal conditions when there is an increase in soil moisture and porosity.

Acknowledgment

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