Biochar Production with the Invasive Albizia Tree Species and the Impacts of Application on Nanea Plant Growth

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Abstract

The invasive species of Albizia is quickly outcompeting native plants. The state of Hawaii is currently making attempts to tackle this issue with the Albizia but no efficient or lasting solution has been found. Biochar may be the solution to face this problem. Biochar is the product that is produced when biomass (wood) is put through the process of pyrolysis. This process of pyrolysis transforms biochar into a carbon sink, enabling it to sequester carbon contained in the wood. And with carbon emissions greater than ever biochar may also be able to play a vital role in the uphill battle against climate change. The primary goals of this research were to assess the suitability of the invasive tree Albizia for biochar production, investigate optimal biochar production methods, and examine the impacts of biochar on the health and growth of indigenous plant species. A series of trials were held to test biochar kilns with different modifications and different lengths of time for each trial, all results were recorded and a TLUD/retort hybrid kiln ended up consistently producing the highest yields of biochar verse ash, as well as the most fuel efficient. The effect of biochar on plant growth was investigated by planting Nanea seeds (native plants) into different percentages of biochar. The percentages were; 10%, 20%, 30%, 40%, 50%, and the control with 0% biochar. In this study there were two separate groups of biochar, one group had biochar that was soaked in water and the other group had biochar (group with "charged" biochar) that was soaked in a compost tea prior to mixing in with soil. The plants for each group were planted separately, meaning that the soil with uncharged biochar had its own planters each with 10%, 20%, 30%, 40%, 50%, and the same for the soil with charged biochar. After conducting this study

for 40 days and looking at the research there was no data that indicated that there was any significant difference in the growth of the plants grown in soil with either charged or uncharged biochar (Figure #4). But there was a significant difference in the plant growth between the plants that grew in soil with any percentage of biochar and the control with 0% biochar (Figure #1)(Figure #4). The biochar percentage group that produced the best results for plant growth was the 20% charged biochar. Compared to the growth of the plants in the control, the plants that grew in the 20% biochar soil did a staggering 49.53% better.

Introduction

The invasive species of Albizia whose scientific name is Falcataria Moluccana, is one of the fastest-growing trees in the world and is quickly overtaking the native forests of Hawaii. The Albizia tree is also starting to become a public safety hazard for people who live around these trees. This species of Albizia grows at such a fast rate that doesn't allow itself to keep up with its growth, causing the tree to have thin, weak, and brittle branches and trunks making them more prone to breaking and falling on roads, infrastructure, property, and people *(USDA Forest Service, 2023)*. Because of the negative effects that Albizia has, the state of Hawaii has been looking for a long-term management solution to remove Albizia from our forest.

Biochar is a charcoal-like substance that is produced by burning organic material from agricultural and forestry wastes (also called biomass) in a controlled process called pyrolysis *(Spears, 2018)*. When the organic matter is converted into biochar the carbon that was present becomes stable, meaning that the carbon in the biochar will be sequestered for more than 2,000 years *(Glaser, 2009)*.

The objective of my research was to determine if the invasive tree Albizia is suitable to create biochar, what the best way to produce biochar is, and the effects biochar has on the health/growth of native plants. By using biochar as a management solution for Albizia, we are not only able to remove them from our forest but also use the biomass from the removed Albizia to create biochar. This biochar that is created will sequester up to 70% of the carbon in the biomass instead of the carbon returning to the atmosphere, helping to combat climate change *(Spears, 2018)*.

Biochar is not only known for its ability to sequester carbon but also for its effects on agriculture. To explore the effects of biochar on plant growth, Nanea seeds were planted into pots with different percentages of biochar mixed into normal soil as well as a control with just soil. The growth of the plants was monitored for each group by measuring the length of the germination period as well as the height of the plants throughout the study period. After the research was concluded, the surviving plants were turned over to the science department for planting on the Punahou campus.

Nanea, scientifically known as the Vigna species, is an indigenous plant native to the Hawaiian Islands. It belongs to the Pea family (Fabaceae) and holds ecological and cultural significance within the Hawaiian ecosystem. Nanea is one of three Vigna species found in Hawaii, alongside its close relatives, Vigna o-wahuensis and Vigna sandwicensis. This perennial plant species is characterized by its unique morphology and symbiotic relationships with native pollinators *(University of Hawaii, 2009)*.

Materials & Methods

The approach used was to collect Albizia tree wood from sites where the tree had been cut down due to its danger to nearby buildings. The Albizia logs that were collected were then dried and then cut into one-by-one square-inch chunks.

The biochar kiln that was used was built from an expired propane gas tank and a discarded metal barrel drum. The kiln was built as a Top Lit Updraft (TLUD) device. Meaning that the fire is started at the top of the biomass and burns downward while air is pulled upward. The flame stays slightly above the biomass as the heat causes the wood to off its volatile gases that are flammables upward. There was also a surrounding outer shell created by the metal drum that created an airflow chamber where the air became very hot and was delivered to the top of the flame cap. After the internal temperature reached 500 degrees Celsius a secondary fire would be started at the bottom of the kiln. The particular build and method of the biochar kiln allowed the biochar chamber to reach a maximum temperature of up to 950 degrees Celsius. The high temperature was held until no smoke was detected and the visible flame at the top of the kiln's intensity started to reduce. The chamber was then capped with the barrel lid and the bottom holes were covered to stop all combustion and not allow any air or oxygen to enter. The kiln was then left alone for several hours to allow the biochar to naturally cool to ambient air temperature.

The cooled biochar was then taken out of the chamber and ground down into smaller chunks to be used for plants. After the biochar was made into smaller pieces around ½ centimeter by ½ centimeter. The biochar was then measured and mixed in with different amounts of soil to create different percentages. The five different percentages of biochar soil (10%, 20%, 30%, 40%, 50%) and the control which had 0% biochar were put into cardboard starters.

Aside from the pyrolysis process, the biochar was placed through one additional process before creating soil-amended mixtures. It was determined that after the initial pyrolysis, the biochar was repelling water. All of the biochar is ground into uniform sizing using quarter-inch mesh wire, a bucket, and a stack of weights on an axle to apply pressure and friction. The biochar was further placed through sieves to remove all powder and retain only soil-sized granules. After the grinding and sifting were completed, the biochar was weighed and sized for volume, it was placed into mesh bags. The mesh bags of biochar were placed into either a bucket of water or into a bucket of water with a compost tea bag and molasses for 48 hours. The goal of soaking the biochar in water get rid of the hydrophobic properties that biochar has when it is straight out of the kiln. The goal of soaking the other half of the biochar in a compost tea and molasses not just water was to start microbial life in the biochar micro pours as well as to get rid of the hydrophobic properties. This process of soaking the biochar in the compost tea is called “charging”, you are essentially charging the biochar with nutrients before it enters the soil. Because biochar is made at such a high temperature any microbial life or nutrients that the biomass previously possessed is destroyed during the pyrolysis process *(Edeh, 2021)*. This can result in the biochar initially absorbing all of the nutrients in the soil that it is introduced into, causing the plants in that soil to not have any nutrients.

Then the Nanea seeds which were provided by a teacher in the science department at Punahou School were prepared for germination by filing the outer layer of each seed to enhance the speed and probability of germination. This sanding of the seed is called scarifying. After the process of scarification was finished two Nanea seeds were planted into each of the 6 cubicles of all of the starters.

The plants were placed in an area where all plants would get equal amounts of sunlight. They were also watered an equal amount once a day. The height of the plants was also measured and recorded every three to four days.

Once the plants became too large for the original starter they were all transferred to a larger pot. And the measuring and recording of the plant height were continued till day #40.

Results & Discussion

Biochar production: Many attempts and modifications were made to the biochar kiln itself and the process to make the biochar. This specific kiln build and process proved to produce the best yield and quality of biochar consistently.

The Biochar pyrolysis process was monitored for time and temperature. On average it took about 2 hours to complete a burn cycle. This number does not include the collection and process time for the Albizia tree branches and logs. This number refers to when the burn was scheduled and materials were on hand. Safety equipment and burn materials would be gathered and staged, the chunks of Albizia wood would be weighed before it was placed into the burn chamber of the kiln and the biomass would be lit from the top of the exhaust column. It would take about 15 to 20 minutes for the heat to reach the bottom of the burn chamber, and then another 10 minutes to get the internal temperature of the chamber to 950 degrees Celsius. The pyrolysis process would be monitored for another 10 to 15 minutes. Once the pyrolysis process had gone a minimum of 10 minutes the kiln would be moved and placed onto a large pot to cover the bottom holes and the metal lid of the barrel as well as weights would be placed on the top to ensure no oxygen was able to enter. Any oxygen allowed to enter at this point in the process would cause the biochar to start oxidizing into ash. After enough time had passed for everything to cool the biochar along with the ash would be weighed and recorded. This method that we used ended up creating the least amount of ash and higher amounts of biochar which is the optimal result. The biochar that was created was of high quality and had high carbon content.

Nanea plant growth: The Nanea seeds were sacrificed and then initially planted into their respective mix ratios in small cardboard starter planters. They were transferred to larger pots about two weeks after germination and the heights were tracked until 40 days had passed from initial planting. The Nanea seeds that were planted into the mixes of biochar were observed to germinate faster than the Nanea seeds that were planted into the control soil (without any biochar amounts added).

As the plant grew there was a very obvious difference in the rate of growth between the control and the plants with biochar. Although the initial hypothesis was that there would be a difference between the charged and uncharged biochar, the results of the plant growth show no significant difference in growth between the plants with charged and the uncharged biochar (Figure #4).

When comparing the plant growth between the control and both the charged and uncharged biochar there is an obvious observable difference in the plant growth. Regardless of the percentage of biochar added to the soil or whether the biochar had charged or uncharged biochar, the plants that had biochar in the soil did astronomically better (Figure #2)(Figure #3). In figures two and three you can see that the lines on the graph plotting the plant growth of 10%-50% biochar are clustered together and the control is the outlier always around two or more centimeters below (Figure #2)(Figure #3). On the last day of the plant growth study, all of the plants were taken and the results showed that out of all of the plants the plants with the soil containing 20% of charged biochar grew the most (Figure #4). The average height of the plants that grew in the 20% biochar soil was 11.21cm while the average height of the plants that grew in the control (0%) biochar soil was 6.76cm (Figure #4). The difference in growth in the plants that grew in 20% biochar and the control with 0% biochar is 49.53% (Figure#1). The results showed no definitive pattern to be able to distinguish and find a reason for the difference in the growth between the different percentages of biochar (Figure #2)(Figure #3). That being said the 20% charged biochar plants were taller by 5% - 17% compared to the growth of the other plants with different percentages of biochar (Figure #1)(Figure #4).

Conclusion

There were several different parts of the research that was conducted, but each part was tied together in the end. The state of Hawaii is currently facing a problem with the overwhelming rate that the invasive species of Albizia is taking over our forests. The tree not only drives out native plants but also creates a public safety hazard. The Hawaii state government has made attempts to try different methods of controlling and removing the Alibiza (USDA, 2023). A common problem in the methods is that after they remove the Albizia tree they have nowhere to put it and no good plan on how to use it. That is where biochar comes into play. Instead of looking at the wood from the Albizia tree as worthless and something to be discarded, by looking at it as a resource, organizations can then utilize the wood to create biochar out of it. This biochar can now be put back into our forests to help the growth of native plant species. Biochar's ability to sequester up to 70% of the present carbon for thousands of years can also be a way to assist efforts in fighting against global warming/climate change (Spears, 2018). Whereas if you were to put the discarded Albizia wood in some place to rot over time, all of the carbon that the Alibiza tree stored and accumulated over time would be released back into the atmosphere when there is such a great alternative option.

Biochar is not something that can just exclusively be used by a small group of people. Hopefully, the use of biochar will spread to more people in the near future. The results of the effects of biochar on plant growth additionally corroborate the fact that biochar can easily be used by the general public. The results stated that just 20% of biochar in the soil can increase plant growth by up to ~50% (Figure #1). And if 20% is too much then even just a mere 10% of biochar in the soil can increase plant growth by up to ~35% (Figure #1). The small amount of biochar needed to see results can hopefully make it appeal to a larger population of people.

Overall, this research addressed the research objectives and provided invaluable insight into utilization of Albizia wood as a viable material to make biochar, the best process to make biochar, and the optimum percentage of biochar for plant growth. The findings showed that the wood for Albizia can be made into high quality biochar and that plant growth can be tremendously increased by using this biochar, particularly 20% biochar (Figure #4). These findings not only help in the removal process of the invasive Albizia tree, but also demonstrate that biochar can be a practical and effective way to help native plant growth. Biochar could potentially even serve as a replacement for the chemical-filled fertilizer that is commonly used in many people's vegetable gardens. But even with the extraordinary abilities biochar possesses, the current problem is the lack of knowledge the large majority of people have on biochar.

This study has been able to further advance the understanding of biochar use in the Hawaiian Islands. However, this study had certain limitations such as sample size, time, and facilities/equipment. In future research, I hope to address the limitations faced in this study. One particular topic that needs to be explored in future research is the accurate carbon content of the biochar that was created through different methods. By gaining further knowledge on the carbon content it has the potential to unlock many avenues for even further exploration. Ultimately, the insight acquired from this research opportunity has the ability to make significant contributions throughout our community and further. And hopefully, it is able to inspire others and prompt future advances in this area.

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Tables and Figures

Figure #1

		Height (cm)										
Day #	Date	10% Charged	20% Charged	30% Charged	40% Charged	50% Charged	0% Control	10% No Charge	20% No Charge	30% No Charge	40% No Charge	50% No Charge
Day 1	3/23/23	0	0	0	0	0	0	0	0	0	0	0
Day 2	3/24/23	0	0	0	0	0	0	0	0	0	0	0
Day 3	3/25/23	0	0	0	0	0	0	0	0	0	0	0
Day 4	3/26/23	0	0	0	0	0	0	0	0	0	0	0
Day 5	3/27/23	0	0	0	0	0	0	0	0	0	0	0
Day 6	3/28/23	0	0	0	0	0	0	0	0	0	0	0
Day 7	3/29/23	0	0	0	0	0	0	0	0	0	0	0
Day 8	3/30/23	2.058	2.5	2.117	2.342	2.07	0.881	1.718	1.892	1.8	1.925	2.327
Day 9	4/1/23	2.917	3.5	2.867	3.192	3.1	1.031	2.918	2.808	2.964	2.792	3.658
Day 10	4/3/23	4.075	4.742	3.858	4.275	4.34	1.131	4.109	4.2	4.283	3.825	4.967
Day 15	4/8/23	5.393	6.083	5.025	5.367	5.53	2.256	5.173	5.025	5.192	4.858	5.9
Day 17	4/10/23	6.2	6.858	5.825	6.233	6.29	2.925	5.718	5.658	5.883	5.442	6.617
Day 20	4/13/23	6.592	7.533	6.567	7.017	6.7	3.3	6.273	6.333	6.45	5.917	7.283
Day 23	4/16/23	7.042	8.258	7.183	7.533	7.05	3.681	6.755	6.817	7.083	6.467	7.833
Day 27	4/20/23	7.675	8.833	7.883	8.367	7.66	4.338	7.573	7.7	7.842	7.208	8.375
Day 30	4/23/23	8.308	9.642	8.692	9.358	8.41	5.063	8.455	8.525	8.508	8.142	8.892
Day 33	4/26/23	8.867	10.57	9.542	10.283	9.12	5.731	9.191	9.392	9.517	9.067	9.45
Day 40	5/1/23	9.642	11.209	9.817	10.617	9.42	6.756	9.545	9.758	10.308	10.008	9.667

Figure #2

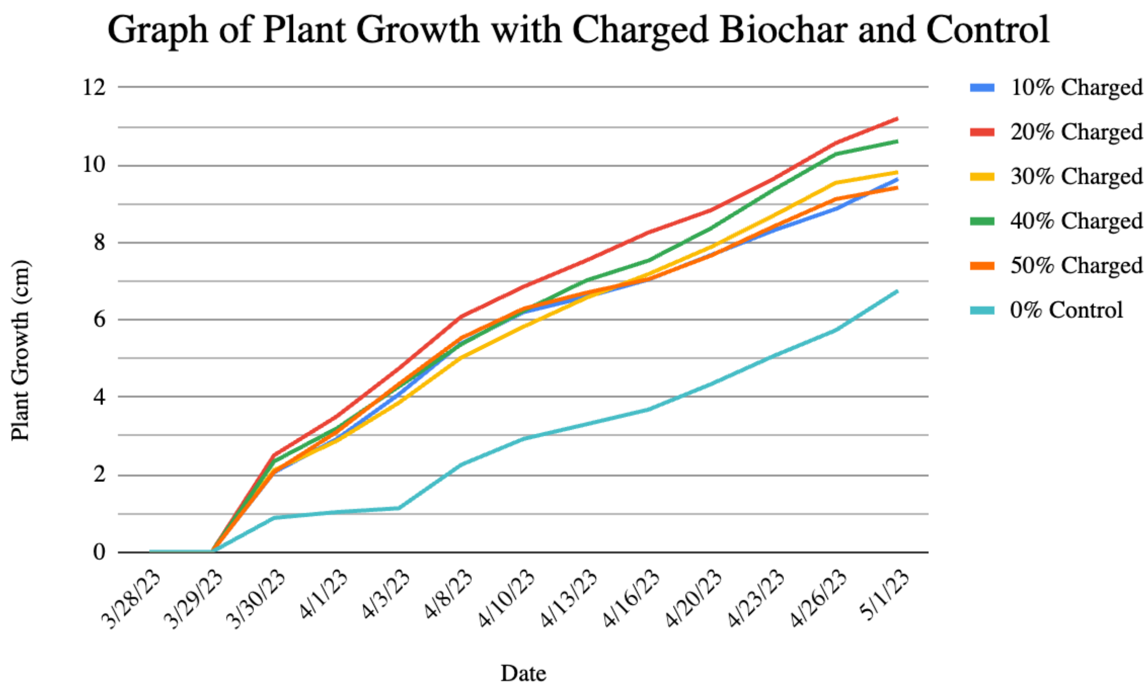


Figure #3

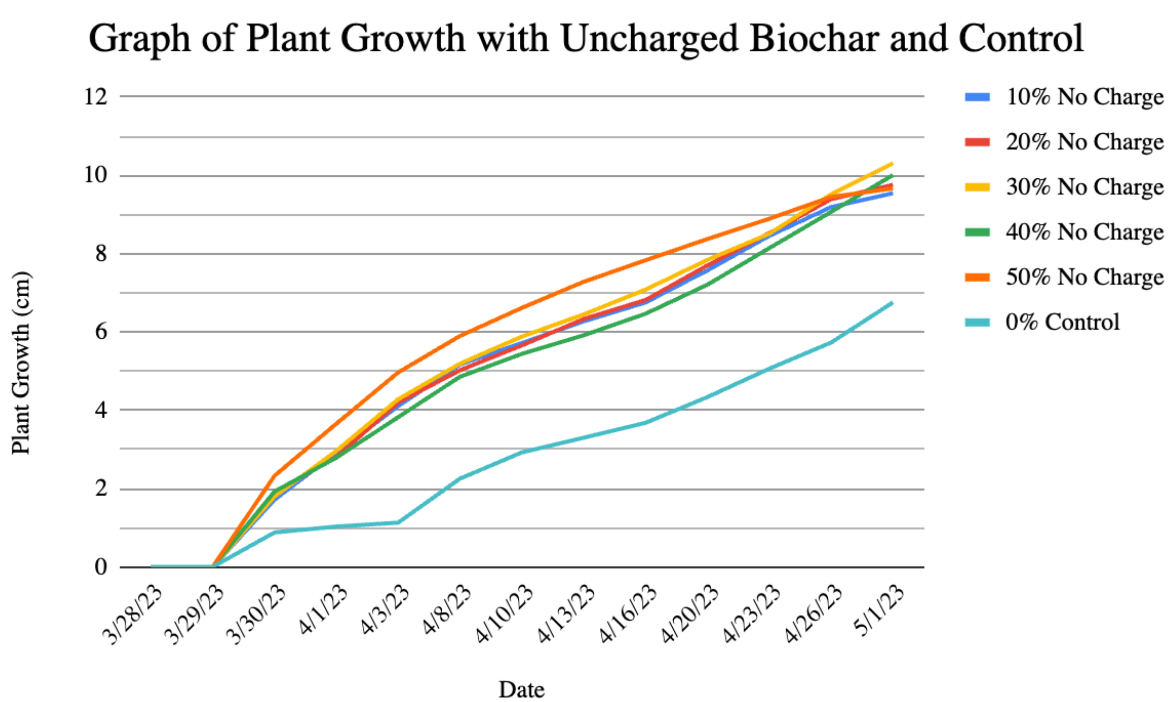
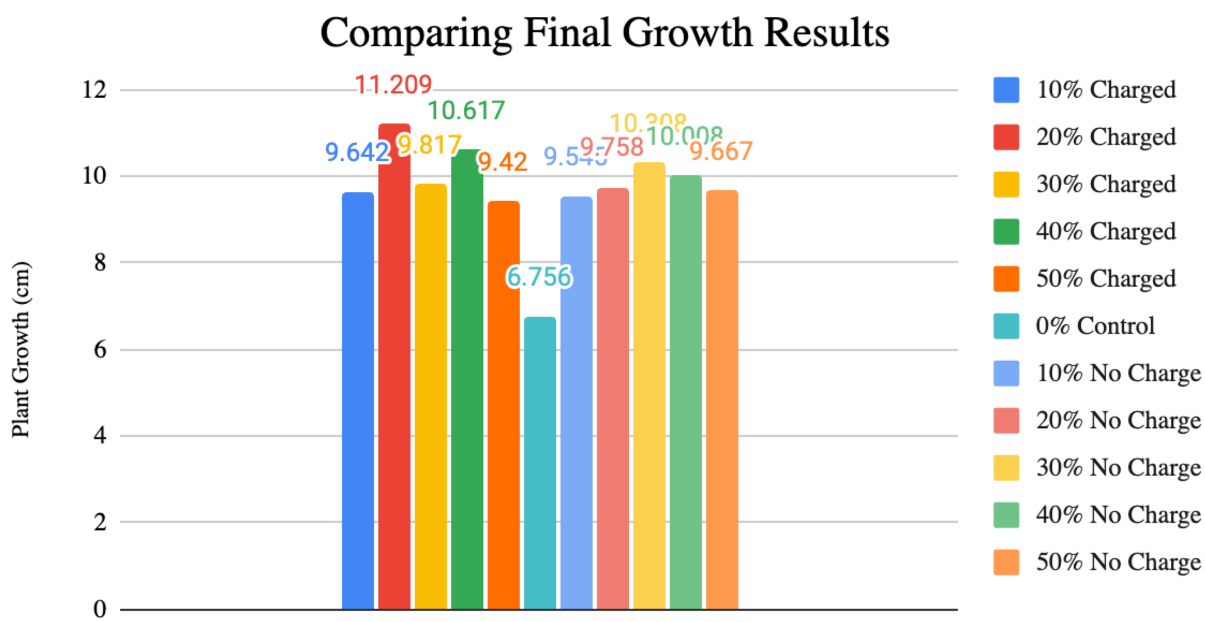


Figure #4



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