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Soil Enrichment Using Biochar from Mahogany Fruit Shells: Effects on Monggo Plant Growth and Soil Properties

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Abstract — Soil is crucial not only to specific ecosystems but also for global functions that are essential to support life on Earth. However, this is threatened due to soil deterioration. Therefore, the need to address this issue requires new solutions from renewable resources. This study aspired to produce Biochar using organic waste material, mahogany fruit shells, through enrichment with compost tea. Five (5) samples were tested on each treatment: alternative biochar, commercial biochar, and untreated soil, and subjected to the following parameters: stem height, number of leaves, root length, number of secondary roots, number of tertiary roots, NPK content, and pH level of soil. Experimental results revealed that the commercial group resulted in taller monggo plants compared to the other groups due to their high potassium content. In contrast, the alternative group sprouted more leaves owing to its high phosphorus content. Longer roots were observed in the commercial group with more neutral pH level. Moreover, the number of tertiary roots in the commercial group was greater, due to the nutrients in the soil. Additionally, with regard to NPK Content, although the soil's nitrogen content was the same in all three treatments, the levels of Phosphorus were found greater in the alternative group, while the commercial group showed the highest level of potassium content. In terms of soil pH, the alternative group has the highest level. The study suggests that the alternative biochar from mahogany fruit shells enhances soil properties, supporting plant growth.

Keywords* — *biochar, mahogany fruit shell, soil fertility, stem height, leaves, root length, secondary roots, tertiary roots, NPK content, pH level of soil

I. Introduction

Throughout the centuries, agriculture has stood firm as one of the major pillars supporting the continual propagation and evolution of humanity and their endeavors. It encompasses numerous diverse arrays of activities that could benefit differing communities, and natural or manmade ecosystems alike. With the incorporation of practices of crop production, livestock farming, integrating forestry, fisheries, and drawing from the varying qualities in each local soil's richness, these continue to pave the path for global economic growth, food security, and expanded livelihood to a generally lower-class economic demographic. Moreover, sustainable farming methods not only secure long-term food production but also safeguard soil fertility and resilience,

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as to ensure a more renewable ecosystem which can mitigate against climate change, ensuring a sustainable agricultural legacy for future generations.

Undoubtedly, agriculture serves as a foundational pillar of humanity with it offering sustenance, livelihoods, and economic prosperity to communities across the globe. Amidst this, an element emerges as one of the pivotal components in ensuring a thriving agriculture: soil. Soil is a complex ecosystem teeming with all sorts of life. This has provided sustenance which has been essential to humans and to all living things. For instance, food security depends on good soil, which also provides for a person's essential needs and serves as a foundation for crops by supporting plant roots. A quarter of all terrestrial animals call the soil home, and it is responsible for 95% of the world's food production (The Royal Society, 2020).

The significance of soil transcends agriculture as it also plays a vital role in addressing climate change and conserving biodiversity. Soil has a key role in storing carbon and water, reducing climate change and preventing floods. As well as, preserve biodiversity by providing habitat and essential resources for a wide range of organisms, including microorganisms, insects, plants, and small animals.

However, the rapid development of the economy and society has resulted in soil degradation all across the planet. As a consequence of these actions, the decrease of the NPK content of soil arises. In addition, low nutrient soil absorbs necessary nutrients needed for a plant to grow resulting in the decrease of plant growth and imbalanced pH levels. Moreover, the decrease of NPK content can result in humans missing or developing less of essential nutrients that are supposedly present in the food that individuals consume.

To respond to the issues caused by soil pollution, the use of organic waste materials has been utilized by other researchers and farmers. According to studies, the utilization of biochar can be useful in making an adequate solution to this problem (Rawat et al., 2019), with the use of compost tea, the researchers will be able to increase the surface area of the alternative biochar, thus giving way to the accommodation of beneficial microorganisms that assist in the growth of a plant. It is also high in carbon, which makes it good for a process called cation exchange that stores nutrients so that they are readily available and easily accessible for the plants. Furthermore, biochar may facilitate the mineralization of organic pollutants by moderating the pH level of the soil therefore enhancing the soil fertility.

With all these, the researchers have come to the idea evaluating plants growth and development with the application of biochar made from an organic waste component known as the mahogany fruit shell. The researchers also considered the contribution of the mahogany fruit shell biochar through aiding the increase of NPK content of the soil to be able to support plant growth. This study is hopeful to become the solution to the growing problem that is the lack of nutrients found in soil.

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Literature Review

Mahogany Fruit Shell

Mahogany fruit shells were featured in a journal: ScienceDirect (2023) entitled "Utilization of sky fruit husk agricultural waste to produce high quality activated carbon for the herbicide bentazon adsorption." The paper written by V.O Njoku, Md. Azharul Islam, M. Asif, and B.H. Hameed stated that activated carbon (AC) is one of the most used and effective adsorbents due to its unique surface structure and porosity. It also added that the results presented in this study suggests that the SFHAC is a very promising adsorbent with high active surface area for the removal of herbicide bentazon.

The study by Dong et al. (2024), Facile Heteroatoms Modification of Biochar Production from Mahogany (*Swietenia macrophylla*) Pericarps for Enhanced Suppression of Polycyclic Aromatic Hydrocarbon Pollutants," explores the potential use of biochar derived from mahogany pericarps (mahogany fruit shells) as a means to reduce pollutants. This research demonstrates the efficacy of this component in suppressing polycyclic aromatic hydrocarbons (PAHs), a common air pollutant sharing characteristics with lead and arsenic, which are frequently found in soil. The application of mahogany pericarps biochar for remediation results in a reduction of PAHs. Moreover, the study highlights the significance of temperature in biochar production through pyrolysis, noting that biomass was produced within the temperature range of 300°C to 900°C. Biochar

Rawat, Saxena, and Sanwal (2019) discuss the composition and benefits of biochar in their book chapter titled Biochar: A Sustainable Approach for Improving Plant Growth and Soil Properties. Biochar is produced through the thermal degradation of biomass in an oxygen-limited environment, a process known as pyrolysis. The resultant material is black, highly porous, finely grained, lightweight, and possesses a wide surface area and alkaline pH, all of which contribute to its effectiveness as a soil amendment. Its composition includes carbon, hydrogen, sulfur, oxygen, nitrogen, and various minerals present in the ash fraction.

The application of biochar to soil addresses concerns regarding agricultural soil degradation by improving soil quality. It stabilizes biomass, which, when incorporated into the soil, can alter the soil's physical and chemical properties, leading to enhanced crop yields and reduced environmental pollution. The unique characteristics of biochar, such as its high cation exchange capacity and ability to retain nutrients and water, make it a valuable tool in sustainable agriculture practices. Moreover, Takeo Tokunari (nd) menitioned that biochar should have beneficial properties, such as improving the soil's water-holding capacity due to its porous structure, increasing nutrient holding capacity since biochar has a negative electric charge that highly attracts positive ions, holding the nutrients and releasing them gradually, promoting soil microbial activity, and neutralizing acidic soil. In the study conducted by Mohamed et al. (2017), entitled The Role of Tailored Biochar in Increasing Plant Growth and Reducing Bioavailability,

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Phytotoxicity, and Uptake of Heavy Metals in Contaminated Soil, the researchers explored the use of microwave-assisted catalytic pyrolysis with potassium phosphate (K_3PO_4) and clinoptilolite to enhance the sorption capacity of biochar for heavy metals. The resulting biochar exhibited a high cation-exchange capacity (CEC), increased surface area, and elevated concentrations of essential plant nutrients.

These characteristics contributed significantly to the reduction of heavy metal (Pb, Ni, and Co) bioavailability and phytotoxicity in contaminated soils. Furthermore, the application of this tailored biochar led to an improvement in plant growth rate by up to 145%. The study emphasized that the strategic use of catalysts and additives can not only increase the efficiency of microwave-assisted pyrolysis but also enhance the physical and chemical properties of the resulting biochar, making it more effective for environmental remediation and agricultural applications. Adekiya et al. (2020), investigated the impact of biochar application on soil quality and erosion. The researchers evaluated how different levels of biochar affected a tropical sandy loam soil. According to their findings, biochar significantly reduced soil loss compared to the control treatment. The highest soil loss (355.5 and 365.1 g/m²) was observed in the untreated control plots, whereas the lowest values (118.0 and 68.25 g/m²) were recorded in plots with biochar application. The study further revealed that increasing the amount of biochar applied corresponded to a significant reduction in soil erosion. Additionally, the chemical properties of the soil improved with the application of biochar. These improvements were attributed to biochar's ability to retain soluble organic matter and inorganic nutrients, thereby enhancing soil fertility. In addition, Chintala et al., (2013) published a study entitled "Effect of Biochar on Chemical Properties of Acidic Soil." Biochar was incubated with acidic soil (clayey, smectitic, acid, mesic, shallow, Aridic Ustorthent) for 165 days. Using microwave pyrolysis (at 650°C), the biochar was made from two biomass feedstocks, including switchgrass (Panicum virgatum L.) and corn stover (Zea mays L.). At all treatment rates, applying biochar made from corn stover resulted in a comparatively higher rise in soil pH than applying biochar made from switchgrass. Biochars' ability to improve the chemical characteristics of acidic soil was consistent with their chemical make-up. Furthermore, Ju et al., (2019), mentioned that biochar has a strong adsorption capacity for organic pollutants, and the process can be understood as the accumulation and collection of organic pollutants on biochar. The application of biochar can significantly improve the content of soil organic matter, alkali-hydrolyzed nitrogen, ammonium nitrogen, and accessible potassium; however, the more biochar added is not better. Excessive application of biochar can inhibit the content of nutrients. The use of biochar in soil remediation can not only minimize the damage wrought by soil wastes to the atmosphere and water-based environment, but it can also eliminate pollutants from the soil and improve its quality. Also, biochar has

advantages in dealing with water pollution and lowering greenhouse gas emissions, therefore biochar research is essential for sustainable development.

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According to the study of Al-Wabel et al., (2015), adding biochar greatly improves a variety of soils' nutrient availability and retention. Enhancing the physical, chemical, and biological characteristics of the soil improves soil fertility. However, a biochar's ability to supplement or increase the amount of nutrients available in the soil depends on its production conditions and feedstock. Biochars made from feedstocks rich in nutrients have a relatively high concentration of easily available nutrients. Although the addition of biochar generally increases soil fertility, this effect is more noticeable in poorer soils (such as those that are acidic or severely leached) than in originally fertile soils. The application rate, soil type, crop species, and quality of the biochar all affect how well an amendment of biochar affects crop development, with varying degrees of success.

Pyrolysis

The research study conducted by Berek & Hue (2016), entitled "Characterization of Biochar and Their Use as an Amendment to Acid Soils" described the methods of producing biochar and its assessment and application to the soil. Within this study, the authors indicated that the biochar was made in a pyrolysisprocess with a 300°C to 450°C range of temperatures. Subsequently, all course biochar was air dried followed by oven dried for 48 hours at 70°C, crushed, sieved to pass a 60-mesh sieve (0.25m), and stored before use.

In relation to that, Ganepsan et al., (2016), reiterated that biochar produced in the pyrolysis does contain a high energy which is in some cases comparable to the coal used in industries as feed stocks for fuel. The high carbon content and microporous structure of the biochar make it useful for various kinds of applications in industry. In agriculture, it is used to upgrade the soil quality. The rate of carbon sequestration in soil increases by the addition of biochar. It improves soil quality by reducing the pace at which nutrients in the soil break down. Other than heavy metals, it is a low-cost method of removing chemicals including tetracycline, phenol, and many more.

In addition, Prurapark et al., (2020), also stated that pyrolysis is the thermal degradation of a variety of chemicals or materials at temperatures between 400 and 800 °C in an oxygen-free environment or one with a small amount of oxygen with products derived from the pyrolysis process typically being categorized intro three types based on their condition. These include gas, a liquid resembling oil, and char.

Vermicompost

Saha et al. (2020) emphasized the role of vermicompost in balancing the underground soil environment, enhancing plant growth, and improving above-ground conditions. The study detailed the procedures for producing vermicompost, including the selection of appropriate earthworm species and the construction of a vermiculture unit in a cool, shaded area. Organic waste materials, cow dung, and chopped dry leaves are mixed in a 3:1 ratio. A 3 cm vermiculture bed is first prepared with sawdust, followed by layers of fine sand and soil, each also 3 cm thick, and all

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moistened with water. Partially decomposed organic materials are then layered over the bed, and earthworms are released into the top layer. Vermicompost is ready within 45 to 50 days, indicated by a black, granular texture, which is then sieved before application to crop fields.

Further supporting this, Lim et al. (2014), in their review titled The Use of Vermicompost in Organic Farming: Overview, Effects on Soil and Economics, elaborated on the multifaceted benefits of vermicompost for soil fertility. They highlighted that vermicompost enhances soil aeration, porosity, water retention, and bulk density. Chemically, it improves soil pH, electrical conductivity, and organic matter content, all of which contribute to increased crop yield. However, the researchers noted that the beneficial effects of vermicompost are not solely due to its nutrient content but may also be attributed to plant growth-promoting substances like hormones and beneficial microbes. Despite its advantages, the high levels of soluble salts in vermicompost can be detrimental if overapplied. Thus, moderate application is recommended to optimize its positive effects.

Significance of NPK to Plant Growth

Yahya Barita et al. (2018), published a study entitled “The influence of granting NPK fertilizer and nano silica fertilizers on the growth of Ganyong plant (Canna edulis Ker.),” that discusses how granting NPK and nano silica fertilizers can affect the growth of plants. It is stated in the study that NPK fertilizer is often used for increasing plant growth. The N element in NPK fertilizer generates chlorophyll, nucleic acids, nucleotides, and amino acids (proteins) in plants. P serves as both a storage and a pathway for energy in NPK fertilizer. As an enzyme activator and helper in transporting absorbed results from the leaf to the plant tissue, the key element in NPK fertilizer functions as an enzyme activator.

Impact of Biochar in Plants

In the study of Rahayu et al., (2022), Effect of various types and doses of biochar on hybrid maize growth, discussed the application of biochar as an alternative to increase soil fertility, as well as promoting the growth and yield of maize in red-yellow Mediterranean soil. According to them, utilizing biochar produced highest leaves number. Increasing the number of leaves will increase the fresh weight of plant because the leaves are organs for photo synthesis. Leave formation is important for the role of nutrients because it plays a role in the formation of new cells and components of organic compounds in plants that affects the increase of the number of leaves.

Additionally, Sutanto et al. (2024) also conducted a study to assess the effects of different types of biochar on the growth of Echinacea purpurea entitled, “Analysis of Growth and Yield of Echinacea Purpurea with the Addition of Biochar and Plant Growth Regulator.” The authors state that both husk and charcoal biochar showed no significant differences in terms of any growth metrics, especially in the number of leaves.

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The husk and charcoal biochar resulted in similar averages for plant height, while their effects on C-organic content were almost identical. Moreover, both types of biochar contributed to an increase in secondary metabolites like flavonoids, indicating their potential to enhance metabolic processes.

Moreover, Yang et al., 2024, provides insight into how biochar influences root processes at the metabolic and microbial levels. They found out that biochar enhanced amino acid metabolism and root signaling molecules, leading to increased microbial diversity in the rhizosphere. Additionally, the authors also emphasized that biochar can positively influence secondary root development, particularly through its effects on amino acid metabolism and secondary metabolites, suggesting that while biochar may not always increase root size, it can support secondary root growth by improving the underlying metabolic processes.

Lastly, the study conducted by Abiven et al., (2015), "Biochar amendment increases maize root surface areas and branching: a shovel omics study in Zambia," aimed to look at how biochar affects root architecture in a tropical field environment. Furthermore, they mentioned that the incorporation of biochar as an amendment in the soil yielded substantial benefits, manifesting in the development of more extensive root systems and subsequent increases in crop yields. The observed enhancement in yields can be attributed to the notable expansion of root systems, suggesting a potential facilitation of improved uptake of immobile nutrients. This is particularly significant in soils characterized by infertility or regions experiencing prolonged dry spells, where the augmented root systems act as a valuable mechanism for optimizing nutrient absorption.

The positive correlation between biochar amendment, root system development, and increased yields underscores the multifaceted advantages of utilizing biochar in agricultural practices, especially in challenging soil conditions.

II. Methodology

Research Design

This study follows the Posttest Only Control Group Design. It is composed of five (5) soil samples in Treatment A with the alternative biochar and five (5) soil samples in Treatment B with commercial biochar, the treatment groups were used to test the parameters of plant growth: stem height, number of leaves, root length, number of secondary roots, number of tertiary roots; and the parameters of NPK content found in soil; and pH level of the soil. The parameters of the study were only measured after the conducting of the treatments.

Research Environment

The mahogany fruit shells, as well as the production of biochar, were sourced from the researchers' farm located in Brgy. Dansullan, Polanco, Zamboanga del Norte. Soil samples were obtained from Sergio Osmeña, Zamboanga del Norte, as recommended. The planting of mung

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bean (*Vigna radiata*) and subsequent evaluation were conducted at Zamboanga del Norte National High School – Turno, Dipolog City. *IJLLT 2(1):10-14*

Details of the Procedure

A. Collection and Preparation of Materials

Mahogany Fruit Shells

The researchers collected a total of 4kg of mahogany fruit shells. The above-mentioned component was picked from the researchers' farm located at Brgy. Dansullan, Polanco Zamboanga del Norte. The researchers gathered the mahogany fruit shells and placed the collected material on a drying rack over a span of 48 hours for dehydration. The dehydrated mahogany fruit shells were then sliced into fourths using a machete. The researchers were then able to start the process of biochar production with the use of a pyrolytic stove.

Soil Samples

The researchers collected a total of 10kg of clay soil from Sergio Osmeña, Zamboanga del Norte, Philippines. The soil gathered was placed into 3-liter plastic pails and was taken to Dansullan, Polanco, Zamboanga del Norte, until the soil was ready to be combined with the biochar. Subsequently, the soil was finely crushed with a hammer to prepare it for the treatment process.

Compost Tea

The researchers collected a total of 500g of vermicompost from Dansullan Polanco, Zamboanga del Norte. The500g of vermicompost was then combined with 1 gal of tap water and was placed in a 40L HDPE open head drum for 48 hours. To be able to produce an aerated compost tea, the researchers utilized an oxygen air bubbler during the brewing process.

B. Construction of Pyrolytic Stove

The top and bottom of a 55-gal steel drum with a diameter of 23 inches was cut open along with the top of a 30-gal steel drum with a diameter of 18 inches. A six (6) inch diameter circle was cut into the center of the bottom portion of the 30-gal steel drum in order for a perforated metal cylinder to be welded into it. A metal chute with a door was attached to the underside of the 30-gal steel drum where the six (6) inch diameter circle was cut. Using four (4) evenly spaced steel rods, the 30-gal steel drum was connected to the inside of the 55-gal steel drum. Circles were then cut into the centers of the cut top portions of the steel drums to be used as lids for the pyrolytic stove in order to connect a steel tube to the pyrolytic stove.

The steel tube attached to the pyrolytic stove serves as a passageway for the gas emitted by the sublimation process of pyrolysis in order to direct it toward a condenser attached to the other

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end of the steel tube. Another steel tube was attached to the other end of the condenser to serve as an exit for the liquid produced from the condensing process, called bio-oil. And steel tin was left on the other end of the steel tube to act as the bio-oil container.

C. Production of Biochar

The researchers started the pyrolytic process by igniting the fire of the pyrolytic stove until the temperature reached 500 °C using a thermometer. The researchers then took 4kg of mahogany fruit shells and placed them inside the pyrolytic stove. The process of pyrolysis took place over the span of 4 hours and was closely monitored by the researchers every 30 minutes. The researchers were aware that the process of pyrolysis had concluded when the mahogany fruit shells turned into a lightweight black residue with a fine-grained texture and was a form of charcoal. Once the process of pyrolysis had taken place, the researchers collected the alternative biochar from the pyrolytic stove to dry naturally for 5 hours.

The alternative biochar underwent a physical analysis conducted by the researchers in order to identify whether or not the biochar was set for the preparation of treatments. The physical characteristics of the alternative biochar were determined by the texture and color. The researchers utilized a digital weighing scale to weigh the biochar. The alternative biochar was found to weigh 2000g, exceeding the required 750g. The alternative biochar was placed inside a 3-liter pail where it was combined with the diluted mixture of 1000 mL of compost tea.

D. Formulation of Treatments for Plant Growth & Soil Analysis

Treatment A (Soil mixed with Alternative Biochar)

The researchers added 150 g of the alternative biochar soaked in compost tea to 600 6g of soil. This was then mixed thoroughly using an electronic hand mixer for 10 minutes. The soil was then placed inside a P9 flower pot and was labeled as Replicate 1 for Treatment A. This procedure was repeated four more times for Replicates 2, 3, 4, and 5. The treatments were then set aside to acclimate for 48 hours.

Treatment B (Soil mixed with Commercial Biochar)

The researchers added 150 g of the commercial biochar soaked in compost tea to 600 g of soil. This was then mixed thoroughly using an electronic hand mixer for 10 minutes. The soil was then placed inside a P9 flower pot and was labeled as Replicate 1 for Treatment B. This procedure was repeated four more times for Replicates 2, 3, 4, and 5. The treatments were then set aside to acclimate for 48 hours.

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E. Planting of the Monggo Seeds

Prior to planting of the monggo seeds in the alternative, commercial control, and negative control treatments, the researchers obtained 30 monggo seeds. The researchers then prepared the seeds to be tested under a viability and germination test. In order to test the viability of the monggo seeds, they underwent the floating seed viability test where 30 monggo seeds were placed in a water-filled jar and were left alone for 15 minutes by the researchers.

The seeds that floated were determined as viable and were germinated. The researchers used the paper towel seed germination method in the germination of the assessed monggo seeds. Wherein, the researchers moistened two paper towels with water using a spray bottle, the dampened paper towels were then spread on a flat surface inside of a container with a lid, and 10 monggo seeds were evenly placed on one of the paper towels, leaving some space between them.

Then, the second paper towel was placed on top of the first paper towel with containing the seeds. The container with the seeds was then placed out of direct sunlight and at room temperature, the seeds were then observed for 5 to 7 days to see if they would sprout.

The seedlings that sprouted with the most vibrant green leaves and thickest stems after the viability and germination test were then picked and transferred to the prepared flowerpots for both experimental and commercial control with biochar and compost tea. The seeds were then monitored until the monggo plants matured.

F. Observation Period

The researchers monitored and observed the growth of the monggo seeds in terms of plant height and number of leaves over the span of 6 weeks. The researchers also measured the root length of the plant at the end of the 6-week period. After taking the measurements, the researchers recorded and documented their findings in a logbook.

G. Evaluation of Parameters

After the 6-week observation period, a final evaluation took place on the monggo plants sown in the soil mixed with the alternative biochar and the monggo plants sown in the soil with the commercial biochar. An interpretation of the results the of soil analysis also occurred.

Plant growth

A 45cm stainless steel ruler was utilized in the measuring of the plant’s stem height. It was placed at the base level of the plant up to the highest point of the plant’s stem to measure the plant’s stem height in centimeters. In measuring the number of leaves, the researchers counted every visible leaf on the plant, including the tips of newly sprouting leaves.

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As for the root length, the roots were obtained by carefully removing the soil and the plants from their pots by loosening the edges of the soil using a trowel. The researchers then carefully removed the soil and the plant from the pot and carefully broke apart the soil surrounding the plant's roots to ensure that no damage would occur to the roots.

The researchers then measured the root length in centimeters by placing a stainless-steel ruler at the very start of the roots and measuring from there up to the longest root of the plant. They also measured the number of primary roots by counting every major root visible and the number of secondary roots was measured by counting every visible root end there was on the plant.

NPK content and pH level of soil

One kilogram each of the refined soil samples were sent to the Regional Soils Laboratory located at Ipil, Zamboanga Sibugay to be able to test the biochar's effectiveness on the increase of NPK content together with the pH level of the soil. *IJLLT 2(1):10-14*

The results were then interpreted by the researchers to determine the proportion of 4:2:1 as an ideal condition of NPK content in soil and if the replicates' pH measures between 6.3 and 7.2 which is the standard pH where NPK is found.

H. Statistical Treatment

Mean. It is a statistical procedure that shows the general significance of the set of data gathered. It was manually computed by adding all the quantities and dividing the result by the total number of quantities. This statistical tool was used for the experimental observation, making it appropriate for evaluating the stem height, number of leaves, root length, number of primary roots, and number of secondary roots of the monggo plant. The mean was calculated using the formula in equation 1:

$$\bar{x} = \frac{\sum x}{n}$$

Where:

x = Sum of all the quantities

n = Total number of quantities added

Independent Samples T-test. With the use of the software SPSS, a parameter test that compares the means of two independent groups in order to determine if there is a significant difference between the two groups. In this study, it was used to determine if there is a statistically significant difference between the mean of Treatment A with alternative biochar and the Treatment B with commercial biochar in terms of stem height, number of leaves, root length, number of primary roots, and number of secondary roots of the monggo plant. The level of significance is 95%.

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III. Results and Discussion

Problem 1. *What is the effect on the growth and development of the monggo plants when mahogany fruit shell biochar was added to the soil in terms of:*

a. stem height;
b. number of leaves;
c. root length;
d. number of secondary roots;
e. *number of tertiary roots;*
f. NPK content; and
g. pH level of the soil?

a. Stem Height

The effects of Treatments A and B on stem height were evaluated, and the results are presented in Table 1, which shows the variations in stem height across the different treatments.

Table 1.
Comparison of means in stem height

Stem Height, cm	
Treatment	Mean
A	6.2
B	7.0

It can be derived from Table 1 that the stem height of the monggo plants varies to the given treatments: Treatment A and B. Treatment B exhibited the highest mean at 7.0, whereas Treatment A averaged 6.2. The difference between Treatments A and B is 0.8, thus showing an analogous relation to the said treatments. This implies that incorporating mahogany fruit shell biochar for stem height produces effects comparable to those of commercial biochar. Plants grew just as well or even better in a mixture of crushed mahogany fruit shells and sand than in a commercially prepared mix containing peat and perlite (Gerber & Ramcharan, n.d).

b. Number of Leaves

The impacts of Treatments A and B on the number of leaves were assessed, and the findings are illustrated in Table 2, demonstrating the differences in the number of leaves among the various treatments.

Table 2.
Comparison of means in the number of leaves

Number of Leaves	
Treatment	Mean
A	4.4
B	4.0

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From Table 2, it is evident that the number of leaves of the monggo plants differs across treatments: Treatment A and B. Treatment A showed the highest mean at 4.4, while Treatment B averaged 4.0. The disparity between Treatments A and B is 0.4, indicating a similar relationship between these treatments.

Based on the soils laboratory results, it revealed that Treatment A has a higher phosphorus content as compared to Treatment B, thus attributing to the difference in the number of leaves between the three groups. Phosphorus deficiencies are proven to have a decreased average leaf appearance rate of 10%, thus proving that higher phosphorus content increases leaf production (Guitérrez-Boem et al., 2018). The more the number of leaves, the better, as leaves serve as the site for a plant's food production. With more leaves, plants have more surfaces for chlorophyll storage thus being better for photosynthesis (Petruzello, 2024).

c. Root Length

Treatment effects on root length were evaluated, and the results are shown in Table 3, indicating differences in root length among Treatment A and B.

Table 3.
Comparison of means in root length

Root Length, cm	
Treatment	Mean
A	3.0
B	4.0

Table 3 indicates variations in the root length of the monggo plants across treatments: Treatment A and B. Treatment B exhibited the highest mean at 4.0, and Treatment A averaged 3.0. This highlights a difference of 1 between Treatments A and B, suggesting a comparable relationship between them.

According to Soils Laboratory, Ipil, Treatment B has a higher K content compared to Treatment A, correlating to the difference in the root length between the plants. Potassium deficiencies negate root elongation and the growth of first-order lateral roots, indicating that an increase in potassium leads to better and longer plant roots (Soukup at al., 2019).

d. Number of Secondary Roots

The influence of treatments on the number of secondary roots was examined, with Table 4 presenting the results, highlighting variations in the number of secondary roots across Treatments A and B.

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Table 4.
Comparison of mean in the number of secondary roots

Number of Secondary Roots	
Treatment	Mean
A	4.8
B	4.2

Table 4 illustrates differences in the number of secondary roots among the monggo plants across treatments: Treatment A and B. Treatment A showed the highest mean at 4.8, and Treatment B averaged 4.2. This indicates a difference of 0.6 between Treatments A and B, implying a similar relationship between them. This shows that biochar enhances soil structure and water-holding capacity, leading to improved nutrient retention and availability for plant roots (Edussuriya et al., 2023).

e. Number of Tertiary Roots

The effects of Treatments A and B on the number of tertiary roots were evaluated, and the results are presented in Table 5, which shows the variations in number of tertiary roots across the different treatments.

Table 5.
Comparison of means in the number of tertiary roots

Number of Tertiary Roots	
Treatment	Mean
A	13.4
B	20.6

Table 5 showcases variances in the number of tertiary roots among the monggo plants across treatments: Treatment A and B. Treatment B displayed the highest mean at 20.6, while Treatment A averaged 13.4. This indicates a difference of 7.2 between Treatments A and B, suggesting a distinction in the relationship between them. According to a study by Xiang et al., (2017), biochar promotes root length (+52%) and the number of root tips (+17%), which are crucial for nutrient and water absorption, this supports the ability of the biochar to develop a plant's roots.

f. NPK Content

The NPK content of the soil was assessed through the levels of Nitrogen, Phosphorus, and Potassium present in the soil after the application of Treatments A and B, and is presented in Table 6. It highlights the diverse means of the provided treatments concerning NPK content. NPK content in plant growth is very important as the nitrogen helps in leaf development, meanwhile phosphorus supports in root and flower growth, and potassium improves overall plant health and resistance. Enough NPK level ensure ideal soil fertility, essential for successful agricultural practices (Sumiharto & Hardiyanto, 2018).

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Table 6.
Comparison in the NPK content found in the soil

Treatment	Nitrogen (%)	Phosphorus (ppm)	Potassium (ppm)
A	0-2	16-20	114-150
B	0-2	11-15	>150

Table 6 illustrates differences in the NPK Content among the monggo plants across treatments: Treatment A, and B.

Based on the soil laboratory results, Treatment A and B, resulted in parallel outcomes for the Nitrogen content with 0-2%. While for the Phosphorus, measured in parts per million, Treatment A presented higher levels of phosphorus with 16-20 ppm, followed by Treatment B with 11-15 ppm. As for the Potassium, Treatment B generated a ppm of >150, while Treatment A correspond with 114-150 ppm.

The nitrogen content for all treatments showed a result of only 0-2% meaning none of the soil samples conformed to the standard amount of nitrogen that should be found in the soil. According to Plant and Soil Science eLibrary, 2024, soil should contain around 5% of nitrogen in order to produce more chlorophyll for the plants to exhibit their vibrant green color. If a plant's soil does not meet the standard nitrogen content, it can lead to a lack in chlorophyll causing plants to wilt and be unfit for proper photosynthesis.

With Treatment B showing the most neutral levels of phosphorus according to the results from Soils Lab, Ipil, it is considered as the most customary level for P content. With Treatments A and B being considered too high and too low, respectively. As high phosphorus content reduces a plant's ability to take up required micronutrients and can lead to softer leaves and distorted growth, the results of Treatment A are not considered ideal. And with a deficiency in phosphorus leading to a reduction in crop yield.

According to Ohio State University, 2024, the optimal level of potassium that soil should contain ranges from 120-170 ppm thus proving all treatments to be adequate in terms of potassium content.

g. pH Level of the Soil

Following the application of Treatments A and B, the pH level of the soil was evaluated. The findings are depicted in Table 7, illustrating the variations in pH levels across the different treatments.

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Table 7.
Comparison in the pH level found in the soil

Treatment	pH Level
A	7.6
B	7.2

Table 7 illustrates differences in pH level of the soil after the use of Treatments A and B. Based on the soil laboratory results, Treatment A exhibited the highest mean at 7.6, while Treatment B equated 7.2. There is a comparable association between Treatments A and B, with a 0.4 difference.

According to the Soils Laboratory, Ipil results, Treatment B produced the most neutral pH out of the three treatments. This indicates it to be the most ideal product as neutral pH makes for more available plant uptake, leading to optimal growth and development (Precision Laboratories, n.d.).

With Treatment A having a pH level of 7.6 being considered slightly alkaline, it cannot be considered ideal as soils with alkaline pH restrict the availability of certain nutrients, particularly iron, manganese, and zinc. This can lead to stunted growth, yellowing of leaves (chlorosis), and overall poor plant health according to Hayes (2024).

According to Coelho (2024), high levels of acidity in soil are deemed toxic to plants. With Treatment B having a pH of 7.2, it is considered to have a pH that is slightly acidic. Acidic soil can limit the accessibility of nutrients like phosphorus, calcium, and magnesium resulting in stunted growth, leaf scorch, and poor flowering.

Problem 2. *Is there a significant difference between the growth and development of the monggo plants when mahogany fruit shell biochar and commercial biochar was added to the soil in terms of:*

a. stem height
b. number of leaves;
c. root length;
d. number of secondary roots;
e. number of tertiary roots;
f. NPK content; and
g. pH level of soil?

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a. Stem Height

Table 8.
Summary of Independent Samples T-test for stem height

Treatment	N	p-Value	Decision
A	5		
B	5	0.695	Accept Ho

Ho: There is no significant difference in the quality of the alternative biochar from mahogany fruit shell compared to commercial biochar in terms of plant growth.

Table 8 provides a summary of the comparison between Treatments A and B regarding stem height, with a significance level of 0.05. The findings indicate that the p-value surpasses 0.05, leading to the conclusion that there is no notable distinction among the three groups. This means that all two treatments demonstrate the capability to enhance stem height effectively. Stem height is crucial for the growth of plant because greater height enhanced light capture and photosynthesis efficiency. The extra production of the growth-regulating molecule, which plays a key role in gene regulation in plants, it shows the important role in overall plant growth (Sutanto et al., 2024).

b. Number of Leaves

Table 9.
Summary of Independent Samples T-test for the number of leaves

Treatment	N	p-Value	Decision
A	5		
B	5	0.292	Accept Ho

Ho: There is no significant difference in the quality of the alternative biochar from mahogany fruit shell compared to commercial biochar in terms of plant growth.

Table 9 outlines the comparison between Treatments A and B in terms of the number of leaves, using a significance level of 0.05. The results indicate that the p-value exceeds the 0.05 threshold, implying no significant disparity among the three treatments. Thus, all two treatments are equally effective in enhancing the quantity of leaves. The results of Table 9 aligned with the findings of Sutanto et al. (2024), which suggest that biochar can enhance overall plant productivity without creating significant differences in specific growth metrics, such as number of leaves. This relates to the results of the study on the number of leaves, where no significant difference was observed between Treatments A and B.

c. Root Length

Table 10.
Summary of Independent Samples T-test for root length

Treatment	N	p-Value	Decision
A	5		
B	5	0.065	Accept Ho

Ho: There is no significant difference in the quality of the alternative biochar from mahogany fruit shell compared to commercial biochar in terms of plant growth.

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Table 10 illustrates the comparison among Treatments A and B concerning root length, with the use of the significance level of 0.05. The results indicate that the treatments demonstrate comparable effectiveness in enhancing root length, as the p-value exceeds 0.05, indicating no significant difference between the groups. Beatrice et al., (2024) found that while biochar improved soil conditions, it didn't significantly change the root length, which aligns with our results. In both studies, biochar showed comparable effectiveness across treatments, with no significant differences in root length. This suggests that biochar enhances soil quality and root efficiency.

d. Number of Secondary Roots

Table 11.
Summary of Independent Samples T-test for the number of secondary roots

Treatment	N	p-Value	Decision
A	5	0.278	Accept Ho
B	5		

Ho: There is no significant difference in the quality of the alternative biochar from mahogany fruit shell compared to commercial biochar in terms of plant growth.

Table 11 presents the comparison of Treatments A and B regarding secondary root growth, utilizing a significance level of 0.05. The results show that with a p-value exceeding 0.05, there's no notable difference among the three treatments, implying their equal effectiveness in promoting secondary root development. The research by Yang et al., (2024), highlights that biochar can positively influence secondary root development through its effects on root metabolites, mainly by enhancing amino acid metabolism and promoting secondary metabolites. This states that biochar can improve secondary root growth.

e. Number of Tertiary Roots

Table 12.
Summary of Independent Samples T-test for the number of tertiary roots

Treatment	N	p-Value	Decision
A	5		
B	5	0.003	Reject Ho

Ho: There is no significant difference in the quality of the alternative biochar from mahogany fruit shell compared to commercial biochar in terms of plant growth.

Table 12 compares Treatments A and B in terms of the tertiary roots, using a significance level of 0.05. The findings indicate that the treatments exhibit similar effectiveness in promoting tertiary root development, as the p-value exceeds 0.05, suggesting no significant difference among them. According to Edussuriya et al., (2023), biochar and biochar-based soil amendments and their potential applications for improving the growth, yield, and efficacy of controlling parasitic nematodes in a wide range of root crops.

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IV. Conclusion

1. The commercial group yielded taller monggo plants compared to the alternative group due to its higher potassium content, which was more than sufficient compared to the potassium levels in the alternative group.
2. The alternative group generated a greater number of leaves in contrast to the commercial group. This disparity can be attributed to the alternative group's elevated phosphorus levels.
3. The commercial group yielded longer roots due to its more neutral pH level, which contrasts with the alternative group. This condition contributed to the development of stronger and healthier roots in the commercial group.
4. The commercial group exhibited a higher count of tertiary roots in comparison to the alternative group. This can be attributed to the combined effects of pH levels and the presence of essential nutrients like nitrogen, phosphorus, and potassium within the soil.
5. The soil's pH and its nutrient composition, notably potassium, phosphate, and nitrogen, played a pivotal role in the commercial group's production of more tertiary roots compared to the alternative group. Tertiary roots, stemming and branching from secondary roots, are crucial in seeking out available nutrients and moisture to facilitate optimal nutrient absorption.
6. In the alternative group, the absence of Nitrogen leads to a deficiency in chlorophyll, resulting in the gradual loss of the plants' vibrant green color and eventual wilting.
7. Elevated phosphorus levels in soil can hinder a plant's capacity to absorb essential micronutrients, potentially causing soft leaves and abnormal growth. Conversely, a phosphorus deficiency can result in decreased yield.
8. The ideal range of potassium content in soil is typically considered to be between 120 and 170 ppm. In the alternative and commercial groups, all exhibited sufficient levels of potassium content within this optimal range.
9. The commercial group outperforms the alternative group due to it maintaining the most neutral pH level. In comparison, the alternative group tends to be slightly alkaline.

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