GROWTH AND YIELD PERFORMANCE OF SWEET POTATO 'IMELDA' CULTIVAR ON DIFFERENT TYPES OF COCONUT-BASED BIOCHAR AS SOIL CONDITIONER

Cherry Gay A. Pamanilay, Rhod Zymon D. Salvador, Princes M. Panes, Michelle T. Razonales, Isabelo S. Ebano, Rochelle V. Soriano
College of Agriculture
Occidental Mindoro State College
bautistajoyceeann@gmail.com

ABSTRACT

The study explored the result of the utilization of biochar derived from coconut husk, young coconut, and coconut pulp on the growth and yield response on sweet potato (*Ipomoea batatas*). The study is conducted in Occidental Mindoro, where coconut husk and pulp are often treated as waste. The main objectives are to evaluate how these biochars function as soil conditioners, influencing growth metrics such as vine length, leaf count, and fresh biomass, alongside yield factors including the number, length, diameter, and weight of marketable tuberous roots. The research also assessed changes in soil properties, specifically water-holding capacity and bulk density. Employing a randomized complete block design, the study had five treatments: the control (no application of biochar) and four types of biochar (T1-Coconut husk, T2-Young Coconut, T3-Coconut Pulp, T4-carbonized Rice Hull), with 3 sample plants per plot. Carbonization of the coconut substrates was conducted using a steel drum kiln, adhering to established protocols. Sweet potato cuttings with the cut distance 30cm from the tip were planted using a furrow method, ensuring proper spacing and replanting of missing hills. Results showed comparable effects in growth and yield parameters with biochar applications compared to the control, with young coconut biochar resulting in the highest leaf count (mean = 457) and coconut pulp biochar yielding the best overall performance in yield metrics. While all biochar treatments outperformed the control, no significant differences were observed among the biochars, except in tuber diameter. Additionally, application of coconut-based biochar enhanced soil characteristics through increasing water holding capacity and reducing bulk density. In conclusion, coconut-based biochar is an effective soil amendment for sweet potato cultivation, particularly the use of coconut pulp biochar for optimal yield. As this study highlights the potential of using agricultural waste to enhance crop productivity and improve soil quality in resource-limited settings, further study must be conducted with the focus on the proper amount of its application as well as field trials

Keywords: *biochar, cocos, Ipomoea batatas, oryza, soil*

SDG: *SDG 2: Zero Hunger, SDG 15: Life on Land*

INTRODUCTION

Scientifically known as Ipomoea batatas L., sweet potatoes are often called the crop of the poor. This nutritious food is typically eaten as a staple and vegetable. With a global yield of around 131 million tons, sweet potatoes (Ipomoea batatas) rank seventh among the world's most produced food crops. They are the third most produced root crop, with nearly 300 million tons produced annually, following potatoes, which are ranked fourth among food crops (Loebenstein, 2016). In the Philippines, sweet potatoes are locally referred to as "camote." According to data from the PCAARD, Eastern Visayas is the leading sweet potato producer, contributing 98.95 thousand MT, or 18.8% of the total production in 2019.

According to the Office of the Provincial Agriculturist as of 2024, concerning Occidental Mindoro, the average production of sweet potatoes is 109.65 metric tons. However, as per the 2018 data, the total sweet potato production was 14, 726, 165 metric tons. Particularly, Occidental Mindoro contributed 0.09% to this total, amounting to approximately 14,686 metric tons. Notably, San Jose exhibits the highest production, totaling approximately 325.9 MT as of 2023. The Municipality of Calintaan leads a contribution of about 25 metric tons. The mean output of sweet potatoes in Occidental Mindoro is 8.80 hectares, with San Jose being the primary contributor as well to the overall sweet potato yield.

Sweet potatoes exhibit sensitivity to different soil conditions, with their growth and yield outcomes directly influenced by the soil they occupy. Achieving high yield requires addressing the specific compatibility requirements of sweet potato plants, especially in 1 case where there may be lower nutrient demand. Understanding and effectively managing the soil conditions is essential for optimizing the growth and productivity of sweet potato crops.

Sweet potatoes encounter issues related to soil compatibility, which affect their growth and production. In root crop cultivation, especially sweet potatoes, various soil problems can arise, such as soil compaction caused by excessive water or poor drainage. However, the impact of different soil amendments on improving the growth and yield of enhanced sweet potato varieties remains uncertain (Darko, 2020). Additionally, coconut-based waste presents its own set of problems. Waste generated from coconut processing harms soil fertility and creates environmental concerns. By-products from the coconut industry, such as coconut wood pieces, shells, coir, coconut water, outer shells, and fibers, are non-consumable and contribute to negative environmental effects.

The issue of coconut waste is becoming more complex as it accumulates in markets and areas where coconuts are processed. Since coconut waste is organic and decomposes easily, it can lead to environmental problems like greenhouse gas emissions. Over time, this waste accumulates as a residual product in the environment (Dumasari et al., 2020).

The abundant availability of coconut material residues such as the coconut husk, young coconut, and coconut pulp has great potential for biochar as soil conditioner for the root crops specifically for the sweet potato (Ipomea batatas). It suggests that improving soil nutrients through effective amendment can positively influence overall crop productivity (Darko, 2020).

METHODS

Research Design

The study employed the experimental method of research utilizing Randomized Complete Block Design (RCBD). Each experimental block was 0.75 meter in length and 1.5 meters in width, and the planting distance was 30 cm x 75 cm. The plant distance was based on the recommended 44,000 plant density for sweet potato per hectare. Each experimental unit accommodated 5 sweet potato cuttings.

Collection of Rice husk

The different coconut-based substrates were collected at San Jose and Mamburao Occidental Mindoro areas with coconut plantations. Various types of coconut waste were sourced from different locations. Young coconuts were primarily obtained from the wet market in San Jose, Occidental Mindoro, where the pulp was also available for purchase. However, the carbonized rice hull was taken from the Occidental Mindoro State College-Murtha Campus (Upper) because it was readily available.

Drying of Substrates

The different types of coconut-based substrates were sun-dried. The coconut pulp was sun-dried for 2-3 days, while the young coconut was dried for 3-5 days. However, the coconut husk was not sun-dried since it was already dried and ready for carbonization. However, the carbonized rice hull did not have to go through the carbonization process because it was already carbonized when it was taken.

Carbonization of Substrates

The coconut substrate was carbonized using a steel drum as a carbonizing kiln (Ridwan et al., 2017). The drum had three sets of six 1-inch diameter holes at the bottom, middle, and upper layers, along with a lid. Each substrate, coconut husk, young coconut, and coconut pulp were placed in separate drums. A four-inch diameter wooden pole was temporarily placed in the center of each drum to create a hollow space for smoke flow during carbonization. After 5-10 minutes, when the fire was established, the lid was placed, and the upper and middle sets of holes were closed. Stirring occurred every 5 minutes throughout the process. The substrate was considered carbonized when it changed color, lost weight, became smoother or more brittle, and increased in hardness. After 2 hours, the drum was opened, and the cooling process lasted for 8 hours.

Land Preparation

The area measured about 9.75 m x 9.5 m with a total area of 92.63 m². The field was deeply plowed using four-wheel with disc plow and harrowed twice using a four-wheel tractor with rotavator. Spade was used to create a ridge (plot) with a height of 0.25 meters. Large soil chunks were crushed, ensuring a smooth texture. The cultivated plot measured 1.5 m x 0.75 m, with three blocks having a 1-meter distance per plot.

Application of Various Soil Conditioners

Biochar weighing 1.875 kg was introduced or mixed into the soil per plot based on the recommended ratio of 15T/h, equivalent to 15,000 kg per hectare, and a total of 5.625 kg per treatment (Hayashi, 2013). The different types of coconut-based biochar mixed into the soil before planting the sweet potato cuttings.

Selection and Preparation of Planting Material

The desired sweet potato cutting had at least 6 nodes. The cuttings were cut horizontally at 30 cm from the tip. The leaves were eliminated from the part of the cuttings that was to be planted. The prepared cuttings were planted immediately.

Planting of Cuttings

The cuttings were planted using the furrow method and were placed vertically. Three nodes of the cutting were buried in the letter 'L' planting position with 30 cm spacing between hills or between cuttings. After 2 weeks of planting, the missing hills were checked, and replanting was considered to ensure a responsible and effective crop management strategy.

Fertilizer Application

A 45 g of fertilizer per experimental unit of inorganic fertilizer NPK with a grade of 14-14-14 was applied 4 weeks after planting. The last application was made for the next 4 weeks after the first application.

Water Management

The newly planted sweet potatoes were irrigated regularly from the time of planting until 77 DAT, as this period coincided with the El Niño season, which experienced temperatures reaching 43°C on the first day of planting. In contrast, due to heavy rainfall weather conditions that followed, the sweet potatoes received minimal irrigation between the months of June to August during its reproductive stage.

Pest Management

The increased temperatures resulted in a significant presence of various pests. Sweet potatoes were strategically planted along the perimeter fences to deter rodents and enhance crop safety. Rodenticide was applied twice, while pesticide targeting hornworms was similarly applied twice. Furthermore, fences were constructed around the experimental field, supplemented with netting for added protection.

Weeding

After planting for two weeks, agricultural methods were used to eliminate weeds through manual hand weeding. Weeds were immediately removed each time they sprouted in the experimental field.

Harvesting and Post-Harvest Handling

Due to the changing weather conditions, the flowering of sweet potato was delayed, and the timing of harvest was affected. The harvesting of sweet potatoes was conducted 154 days after planting. To avoid injuring tubers, the primary crown of the plant was identified, and a digging pork was used to get underneath the sweet potatoes and loosen up the soil. The harvested tubers were cleaned by removing dirt using water before data gathering.

Data Gathering Procedure

The total Number of Leaves per plant was determined by counting the leaves of the three sample plants three times. The first count was done within 28 days after planting; the next count was done after another 28 days, and the last counting was done after harvesting. The counted leaves were marked using a pentel pen marker to be excluded in the next count. Manual counting was used to record all leaves of the three sample plants. The Length of Vines was obtained from the longest lateral vine of each sample plant. The representative lateral vine was measured from the base to the tip of vines using a meter stick and was expressed in centimeters. The data was measured after harvesting. The Fresh Biomass was determined by measuring the fresh total weight of the plant material of sweet potato including leaves and vines, after it was freshly harvested. This was measured using a digital weighing scale. The Weight of Tuberous Root was determined by measuring the weight of three tuberous roots per plot in grams after harvesting, utilizing a digital weighing scale. The Diameter of Tuberous Root was determined by measuring the diameter of the tuberous roots from a randomly selected sample plant. Measurements were in centimeters, using a digital vernier caliper. The Length of Tuberous Root was determined by measuring all the tuberous roots per plant after harvesting and was expressed in centimeters using a ruler. For Water Holding Capacity, the soil was collected before and after the experiment following the drip loss technique. The result was categorized and interpreted according to the water-holding capacity scale: low (>29%), moderate (30 to 59%), and high (60 to 100%). Bulk Density is the measure of the density of a porous material that makes the density of the soil material (ps) and the amount of porosity. The general scale of bulk density (g/cm3) was interpreted based on the scale by Hazelton and Murphy (2007). Soil pH was measured using a four-in-on soil instrument before and after the application of different types of coconut-based biochar. Before the application of coconut-based biochar, soil pH was taken in different parts of the area even before the experimental plot was built.

Table 1. Water-holding capacity scale

WATER-HOLDING CAPACITY	RATINGS
>29%	Low
30-59%	Moderate
60-100%	High

Data Processing and Analysis

The F-test or Analysis of Variance (ANOVA) for RCBD was used in the analysis of data. Data processing and analysis were done using Statistical Techniques for Agricultural Research (STAR), which was developed by the International Rice Research Institute (IRRI).

RESULT

The influence of different coconut-based biochar types such as soil conditioners on the growth of sweet potato.

The number of sweet potato leaves influenced by different types of coconut-based biochar as a soil conditioner was determined. According to the Tukey Honestly Significant Difference (HSD) results, the effects of Treatment 0, Treatment 1, Treatment 3, and Treatment 4 were statistically comparable to each other. On the other hand, Treatment 2 with a mean of 457 is significantly different from the rest of the treatments.

Data shows that Treatment 1, which is the Coconut husk, obtained a mean of 250.33 cm. On the other hand, sweet potato from T0, without soil conditioner obtained the lowest mean of 192.22 cm.

Treatment 4 in the fresh biomass, which is the carbonized rice hull produced the highest mean of 789 g. Subsequently, Treatment 1 with 759.72 g mean, Treatment 2 with 757 g mean, and Treatment 3 with 713 g. On the other hand, sweet potatoes from T0, without soil conditioner obtained the lowest mean of 709 g

Table 2. The influence of different coconut-based biochar types such as soil conditioner on the growth of sweet potato.

Treatment	Number of Leaves	Length of Vines	Fresh Biomass
T^0 - Soil	226.44	192.22	708.61
T^1 - Coconut Husk	259.56	250.33	759.72
T^2 - Young Coconut	456.89	206.78	756.67
T^3 - Coconut Pulp	191.33	218.11	712.78
T^4 - Carbonized Rice Hull	249	231.55	789.17
F-value	22.88	0.49^{ns}	0.09^{ns}
p-value	0.002*	0.74	0.98
Grand mean	276.64	219.80	745.39

The effect of various coconut-based biochar as soil conditioner on the yield of sweet potato

Data shows that Treatment 3 recorded the highest weight of tuberous roots with a mean of 239 g. On the other hand, Treatment 1 obtained the lowest mean of 111.3 g. Meanwhile, like treatment 3, treatment 2 and treatment 4 are higher than Treatment 0. The average weight of tuberous sweet potatoes ranges from 142 to 198 grams. In comparison, treatment 3 exceeded this average weight. However, treatments 0, 1, 2, and 4 fell below the average weight of sweet potatoes

Table 3. The effect of various coconut-based biochar as soil conditioner on the yield of sweet potato.

Treatment	Weight of Tuberous Roots (g)	Diameter of Tuberous Roots (cm)	Length of Tuberous Roots (cm)
T^0 - Soil	128	35.36	93.33
T^1 - Coconut Husk	111	24.84	106.67
T^2 - Young Coconut	144	29.50	112.33
T^3 - Coconut Pulp	239	39.18	126.33
T^4 - Carbonized Rice Hull	132	25.68	117
F-value	1.99^{ns}	1.36^{ns}	2.22^{ns}
p-value	0.19	0.33	0.16
Grand mean	150.93	30.91	111.13

The diameter of tuberous roots of sweet potato is affected by the different types of coconut-based biochar as soil conditioner. Treatment 3 gathered a highest mean of 39.18 cm. Treatment 1, on the other hand, obtained the lowest mean of 24.84 cm.

Treatment 3 from the length of tuberous roots registered the highest mean of 126.33 cm. On the other hand, sweet potato from T0, without soil conditioner obtained the lowest mean of 93.33 cm.

The influence of coconut-based biochar as soil conditioner on the soil properties of sweet potato

Data shows the water holding capacity of the soil. According to the result, prior to intervention, all soil treatments exhibited a high-water holding capacity of 86%. This finding indicates that both the original soil and the amendments utilized could retain a significant amount of moisture. Subsequently, a significant difference in all treatments was observed. The most notable reduction occurred in Treatment 2 (young coconut), which decreased to 59% categorized as "Moderate" water holding capacity. However, the remaining treatments, Treatment 1, Treatment 3, and Treatment 4, experienced more moderate declines, with their water holding capabilities reducing to 62%, and 61%, respectively.

According to the results, Treatment 1 recorded the highest bulk density at 0.10g/cm3, which is classified as "Very low". Similarly, Treatment 2, with a bulk density 0.07g/cm3, is also categorized as "Very low", despite having a slightly lower value. After application, the Treatment 0, which is registered 0.9g/ cm3 interpreted as "Very low". Similarly, the Treatment 1, 2, 3, and 4 which posted 0.08 g/cm3 is also categorized as "Very low', despite exhibiting a marginally reduced value.

Based on the result on the soil pH, all treatments have a similar effect to the soil which interpreted 4.5 interpreted as "Strongly acid". However, following the application of coconut-based biochar, there were significant differences observed compared to the pre-condition. There is an increase in pH in the soil treated with different types of coconut-based biochar. Young coconut treatment (T2) registered 5.5 interpreted as "Strongly acid". Likewise, the Treatment 1 which is coconut husk and coconut pulp have a similar effect registered 5.4 as

"Strongly acid". Nevertheless, Treatment 4 and 0 are comparable with the pH level 4.5 and 5.0 interpreted as "Very strongly acid".

Table 4. The influence of coconut-based biochar as soil conditioner on the soil properties of sweet potato

Treatment	Water Holding Capacity				Bulk Density				Soil pH			
	Pre	Int.	Post	Int.	Pre	Int.	Post	Int.	Pre	Int.	Post	Int.
T0-Soil	86%	H	62%	H	0.09	VL	0.09	VL	4.5	SA	4.5	SA
T1-Coconut Husk	86%	H	62%	H	0.09	VL	0.08	VL	4.5	SA	5.4	MA
T2-Young Coconut	86%	H	59%	M	0.09	VL	0.08	VL	4.5	SA	5.5	SA
T3 - Coconut Pulp	86%	H	61%	H	0.09	VL	0.08	VL	4.5	SA	5.1	MA
T4-Carbonized Rice Hull	86%	H	61%	H	0.09	VL	0.08	VL	4.5	SA	5.0	SA
Mean	86%	H	61%	H	0.09	VL	0.08	VL	4.5	SA	5.1	SA

Legend: Water Holding Capacity: L-Low; M-Moderate; H-High
Bulk Density: VL-Very Low; L-Low; M-Moderate; H-High;
Soil pH: VSA-Very strongly alkaline; SAL-Strongly alkaline; MAL-Moderately alkaline; MIA-Mildly alkaline: N-Neutral; SA-Slightly acidic; MA-Moderately acidic; SA-Strongly acidic

DISCUSSION

Number of Leaves

Young coconut waste as a soil conditioner significantly boosts sweet potato leaf production. Biochar made from coconuts improves soil's chemical and physical properties, enhancing fertility and promoting healthier plant growth. It improves leaf quantity and quality (Sanchez-Reinoso et al., 2020) and reduces stress, leading to stronger leaves (Hasnain et al., 2022). Biochar application (1.5%) increases total nitrogen, essential for leaf growth (Herviyanti et al., 2020). It also enhances soil properties by increasing pH, organic matter, nitrogen, phosphorus, potassium, calcium, and magnesium, thereby creating an optimal environment for nutrient uptake and plant growth, which leads to more leaves (Maulana et al., 2023).

Vine Length

There was no significant difference in vine length between sweet potatoes with and without coconut-based biochar. Treatment 1 (coconut husk) had the highest mean, while T0 (no biochar) had the lowest. Edussuriya et al. (2023) found biochar increases vine length and leaf number, but environmental factors affect vine length. Gajanayake (2015) noted that high temperatures lead to more vine and leaf growth, but fewer tubers and lower yields. Nazrul (2018) reported sweet potato vine lengths ranging from 165.33 to 230.27 cm at 120 days. The study showed average vine lengths like or exceeding standard values, but no significant difference compared to the control without biochar.

Fresh Biomass

Fresh biomass determines if coconut-based biochar affects vine and leaf growth. No significant difference was observed in fresh biomass, but plants grown without biochar had greater weight than the control. The type of coconut-based biochar used influenced vegetative growth and fresh biomass. High temperatures during the experiment may have affected growth, as heat stress impacts plant development. Gajanayake et al. (2015) noted that high temperatures during mid- to late-growing seasons cause plants to prioritize leaf and vine growth over root development, resulting in fewer tubers and lower yields. Motsa et al. (2015) explained that slower canopy growth limits energy for root development. Our leaf count data showed an increase in leaves during the second count, but despite soil cracking, no maturity indicators were found after inspection and tilling, including in the buffer zone.

Weight of Tuberous Roots

There was no significant difference in the weight of tuberous roots between sweet potatoes with and without coconut-based biochar. Treatment 3 had the highest weight, while Treatment 1 was the lowest. The yield decrease was observed due to factors like drought stress and unpredictable weather. On March 26, 2024, temperatures in San Jose, Occidental Mindoro reached 43°C, signaling the start of El Niño and the planting of sweet potato cuttings. By May, temperatures rose to 44°C (PAGASA, 2024). While sweet potatoes are drought-tolerant after tuber formation, inconsistent rainfall can still reduce yields (Andrade et al., 2016). Photoperiodism, a tropical characteristic, also limits growth to early-ripening varieties during extended growing periods (Pepo, 2018). Drought stress negatively affects storage, root weight, biomass, and root number (Kivuva et al., 2014; Saqib et al., 2017). As seen in fresh biomass, plants focus more on leaf and vine growth. Excessive vegetative growth can reduce tuber yields as plants prioritize leaves and stems over tuber development. A balanced vegetative and reproductive phase enhances tuber production (Widaryanto & Saitama, 2017).

Diameter of Tuberous Roots

There was no significant difference in the diameter of sweet potato tuberous roots between those treated with coconut-based biochar and those without. Treatment 3 had the highest mean diameter, while Treatment 1 had the lowest. According to the Bureau of Agriculture and Fisheries Standards (2010), medium-sized sweet potatoes have a diameter of 51 to 70 mm. Treatment 3, with a diameter of 39.19 mm, falls under the small category. While all treatments produced tubers with below-average diameters, small tubers are still commercially viable. Weather conditions, such as temperature and soil moisture, influenced tuber formation and diameter. High temperatures exceeding 35°C (43-44°C from March to June 2024, PAGASA, 2024) caused heat stress, reducing tuber size and quality.

Length of Tuberous Roots

There was no significant difference in the length of tuberous roots between sweet potatoes with and without coconut-based biochar. Treatment 3 had the highest mean, while T0 (without biochar) had the lowest. After harvest, more pencil roots were observed than tuberous roots. Pencil roots as lignified, smaller roots, while tuberous roots are fleshy and bulky. Pencil roots typically form in low rainfall environments, especially under stress conditions like water deficit and high temperatures, where some lateral roots become pencil roots (Goldman et al., 2023).

Water Holding Capacity

All soil treatments showed a high water-holding capacity of 86%, indicating effective moisture retention by both the original soil and the amendments. A significant difference was observed across all treatments. Coconut biochar improves water holding capacity as a soil amendment by enhancing structural aggregation and promoting beneficial microbial activity, which supports biological processes and increases nutrient availability (Nepal et al., 2023). Experimental results showed that higher biochar concentrations improved water retention in the upper 300 mm of soil and enhanced pH. Coconut biochar also significantly increases nutrient retention, especially in sandy soils (Guarnieri et al., 2021).

Bulk Density

The application of coconut biochar lowers bulk density, which increases soil porosity. Pandian et al. (2016) demonstrated that applying biochar at a rate of 5 t ha^{-1} decreased the bulk density of medium-textured soil from 1.41 to 1.36 Mg m^{-3}. This reduction improves soil structure by increasing pore space, allowing better air and water movement, and ultimately enhancing soil health and plant growth (Pituya, 2017). A study on sandy loam soil showed a reduction in bulk density from 1.41 g/cm^3 to 1.38 g/cm^3, while the current study showed a decrease from 1.56 g/cm^3 to 1.27 g/cm^3 (Boadu et al., 2024).

Soil Ph

Coconut biochar improves soil pH due to its liming effect, neutralizing acidic soils and creating a favorable environment for plant growth. Sweet potatoes tolerate pH levels from 5.5 to 6.8, but the optimal range for maximizing yield and high-quality tubers is 5.8 to 6.0. Biochar, combined with organic matter, enhances soil properties by providing essential carbon and nutrients, improving both physical and chemical characteristics (Herlambang et al., 2019). Soil pH of 6.5 is optimal for nutrient availability. Low pH increases the solubility of aluminum, manganese, and iron, potentially reaching toxic levels, while extreme pH values affect nutrient access and microbial activity (Cornell University, n.d.) Additionally, the alkalinity of biochar helps neutralize acidic soils, boosting fertility and promoting plant growth (Dhar et al., 2020).

CONCLUSION

The use of various coconut-based biochar's had similar impacts on vine length and fresh biomass of sweet potato, but biochar made from young coconut significantly boosted leaf production. When it came to yield, all biochar types performed similarly, although coconut pulp biochar led to superior outcomes in all yield parameters. Despite no notable differences among the biochar treatments in terms of growth and yield, all of them outperformed the control group—except in the case of tuberous root diameter. Moreover, coconut-based biochar improved soil characteristics by enhancing water retention, lowering bulk density, and balancing soil pH.

ACKNOWLEDGMENT

The successful execution of this research paper was made possible through the invaluable contributions of several key entities. We extend our sincere gratitude to the Occidental Mindoro State College-Murtha Campus for generously providing the carbonized rice hull, a vital component of our experimental setup, which significantly streamlined our material acquisition. We are also deeply appreciative of the local communities in San Jose and Mamburao, Occidental Mindoro, whose cooperation facilitated the collection of diverse coconut-based substrates essential for our study.

REFERENCES

Andrade, M.I., Naico, A., & Ricardo, J. (2016). Genotype × environment interaction and selection for drought adaptation in sweetpotato (Ipomoea batatas [L.] Lam.) in Mozambique. Euphytica 209, 261–280 (2016). https://doi.org/10.1007/s10681-016-1684-4

Boadu, K. B., Soadwa, C. O., Adamu, O., Ansong, M., Kaba, J. S., & Anokye, R. (2024). The Impact of Varying Biochar Rate and Particle Size Derived from Bamboo Culm Residue and Coconut Husk Mixture on Lettuce (Lactuca sativa cv. 'Tiberius') Seed Germination and Leaf Morphology. Journal of Sustainability Research. https://doi.org/10.20900/jsr.20160001

Cornell Univeristy. (n.d). Competency area 5: Soil pH and liming. Northeast Region Certified Crop Adviser (NRCCA) Study Resources. https://nrcca.cals.cornell.edu/nutrient/CA5/CA0539.php

Darko, C., Yeboah, S., Amoah, A. A., Opoku, A. R., & Berchie, J.N. (2020). Productivity of sweet potato (Ipomoea batatas (L) Lam) as influenced by fertilizer application in different agro-ecologies in Ghana. Scientific African. https://doi.org/10.1016/j.sciaf.2020.e00560

Dhar, S. A., Sakib, T. U., & Hilary, L. N. (2020). Effects of pyrolysis temperature on production and physicochemical characterization of biochar derived from coconut fiber biomass through slow pyrolysis process. Biomass Conversion and Biorefinery, 12(7), 2631–2647. https://doi.org/10.1007/s13399-020-01116-y

Dumasari, D., Darmawan, W., Iqbal, A., Dharmawan, B., & Santosa, I. (2020). A pro conservation adaptation power model for cococraft craftsmen using coconut waste in Purbalingga, Central Java, Indonesia. International journal of conservation science, 11(1). *11*(1), 87–96.

Edussuriya, R., Rajapaksha, A. U., Jayasinghe, C., Pathirana, C., & Vithanage, M. (2023). Influence of biochar on growth performances, yield of root and tuber crops and controlling plant-parasitic nematodes. https://link.springer.com/article/10.1007/s42773-023-00261-7

Gajanayake, B., Reddy, K. R., Shankle, M.Y., & Arancibia, A.R. (2015). Quantifying Storage Root Initiation, Growth, and Developmental Responses of Sweetpotato to Early Season Temperature. Agronomy Journal. https://doi.org/10.2134/agronj14.0067

Goldman, I. L., Wang, Y., Alfaro, A. V., Brainard, S., Oravec, M. W., McGregor, C. E., & van der Knaap, E. (2023). Form and contour: breeding and genetics of organ shape from wild relatives to modern vegetable crops. Frontiers in plant science, 14, 1257707. https://doi.org/10.3389/fpls.2023.1257707

Guarnieri, S. F., Nascimento, E. C. D., Costa, R. F., Faria, J. L. B. D., & Lobo, F. D. A. (2021). Coconut fiber biochar alters physical and chemical properties in sandy soils. Acta Scientiarum. Agronomy, 43, e51801. https://doi.org/10.4025/actasciagron.v43i1.51801

Hazelton, P. & Murphy, B. (2007). Interpreting Soil Test Results What do all the Numbers Mean? University of Technology Sydney. NSW Government Department of Natural Resources. https://doi.org/10.1071/9781486303977

Hasnain, M., Munir, N., Abideen, Z., Zulfiqar, F., Koyro, H. W., El-Naggar, A., Caçador, I., Duarte, B., Rinklebe, J., & Yong, J.W.H. (2022). Biochar-plant interaction and detoxification strategies under abiotic stresses for achieving agricultural resilience: A critical review. Ecotoxicology and Environmental Safety, 249, 114408. https://doi.org/10.1016/j.ecoenv.2022.114408

Hayashi, K., Gummert, M., & Zaini, Z. (2013). Biochar for future food security: learning from experiences and identifying research priorities. In National Workshop on 53 Biochar for Food Security: Learning from Experiences and Identifying (pp. 37-46). https://doi.org/10.1016/J.RESCONREC.2021.106109

Herlambang, S., B., Sutiono, H. T., & Susantina, R.N. (2019). Application of coconut biochar and organic materials to improve soil environment. IOP Conference Series Earth and Environmental https://doi.org/10.1088/1755-1315/347/1/012055

Herviyanti, H., Maulana, A., Prima, S., Aprisal, A., Crisna, S. D., & Lita, A. L. (2020). Effect of biochar from young coconut waste to improve chemical properties of ultisols and growth coffee [Coffea arabica L.] plant seeds. IOP Conference Series Earth and Environmental Science, 497(1), 012038. https://doi.org/10.1088/1755 1315/497/1/012038

Kivuva, B.M., Githiri, S. M., Yencho, G.C., & Sibiya, J. (2014). Screening sweet potato genotypes for tolerance to drought stress. Field Crops Research, 171, 11–22. https://doi.org/10.1016/j.fcr.2014.10.018

Loebenstein, G. (2016). Sweet Potato, research Neglected important food crop, Regarding Virus research and Propagation systems: A review. Austin J Plant Biol. 2016; 2(1): 1012. https://doi.org/ 10.18517/ijaseit.9.2.7520

Maulana, A., Sukma, V., Napendra, Z., Harianti, M., Prasetyo, T. B., & Herviyanti, H. (2023). Application of biochar from young coconut waste to inactivation of Hg contaminated ex-gold mining soil and corn (Zea mays L.) vegetative growth. AIP Conference Proceedings, 2730, 120007. https://doi.org/10.1063/5.0127760

Motsa, N. M., Modi, A. T., & Mabhaudhi, T. (2015). Sweet potato (Ipomoea batatas L.) as a drought tolerant and food security crop. South African Journal of Science, 111(11/12), 8. https://doi.org/10.17159/sajs.2015/20140252

Nazrul, M. I. (2018). On-farm evaluation of orange fleshed sweet potato varieties under acidic soil of north-east region in Bangladesh. Bangladesh Agronomy Journal, 21(2), 59-65. https://doi.org/10.3329/baj.v21i2.44493

Nepal, J., Ahmad, W., Munsif, F., Khan, A., & Zhou, Z. (2023). Advances and prospects of biochar in improving soil fertility, biochemical quality, and environmental applications. Frontiers in Environmental https://doi.org/10.3389/fenvs.2023.1114752

Pandian, K., Subramaniayan, P., Gnasekaran, P., & Chitraputhirapillai, S. (2016). Effect of biochar amendment on soil physical, chemical and biological properties and groundnut yield in rainfed Alfisol of semi-arid tropics. Archives of Agronomy and Soil Science, 62(9), 1293-1310. https://doi.org/10.1080/03650340.2016.1139086

Pepo P. (2018). The effect of different planting methods on the yield and spad readings of sweet potato (Ipomoea batatas L.) Columella - Journal of Agricultural and Environmental Sciences Vol. https://doi.org/10.18380/SZIE.COLUM.2018.5.1.7

Pituya, P., Sriburi, T., & Wijitkosum, S. (2017). Properties of Biochar Prepared from Acacia Wood and Coconut Shell for Soil Amendments. Engineering Journal. https://doi.org /10.4186/ej.2017.21.3.63

Ridwan, L. W. (2025, May). Coconut Shell Carbonization to Produce Biochar Using a Cylinder Retort Kiln. In Proceedings of the 8th FIRST 2024 International Conference on Global Innovations (FIRST-ESCSI 2024) (Vol. 261, p. 245). Springer Nature. 10.2991/978-94-6463-678-9_23

Sanchez-Reinoso, A. D., Ávila-Pedraza, E. A., & Restrepo, H. (2020). Use of Biochar in agriculture. Acta Biológica https://doi.org/10.15446/abc.v25n2.79466

Saqib, M., Khalid, M., Hussain, S., & Anjum, M. A. (2017). Effect of water stress and planting system on growth, yield and quality of sweet potato. Acta Scientiarum Polonorum. Hortorum Cultus, https://doi.org/10.24326/asphc.2017.6.18

Widaryanto, E., & Saitama, A. (2017). Research Article Analysis of Plant Growth of Ten Varieties of Sweet Potato (Ipomoea batatas L.) Cultivated in Rainy Season. Asian J. Plant Sci, 16, 193-199. https://doi.org/10.3923/ajps.2017.193.199