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Production of Biochar and its Effect on the Onsite Growth of Space Spinach Variety

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ABSTRACT: Biochar is produced from ecofriendly waste biomass also known as an innovative soil amendment technology. It enhances plant growth by enriching soil with Nitrogen, Phosphorus, Potassium (NPK), and carbon. Biochar offers an ecofriendly alternative to synthetic NPK fertilizers increased by soil porosity and surface area. In this context, biochar was produced from various sources such as ground nutshell, saw dust and rice husk. To understand the properties of Biochar, Scanning Electron Microscopy (SEM) was used, a cutting-edge technique that identifies the elemental composition and surface structure of materials like pyrolyzed biochar. SEM analysis tells that carbon is the most abundant element present in all the biochar samples. Potassium content was higher in all biochar pyrolyzed at 500oC. Phosphorus content was found to be decreasing in all samples with an increase in temperature. From the growth analysis it has been concluded that rice husk biochar produced at 400oC and mixed with seed in 1:40 ratio have the highest growth rate. Ground nutshell biochar have highest growth rate when produced at 200oC and mixed with seed in 1:40 ratio. Saw dust biochar have highest growth rate when produced at 600oC and mixed with seed in 1:40 ratio. The growth analysis data were fed in central composite design and the optimum parameters were found to be 400oC for rice husk, 200oC for ground nutshell and 600oC for saw dust. The ideal ratio for mixing biochar with spinach seed is 1:40 for all the biochar.

KEYWORDS: Biochar, Fertilizer, Pyrolysis, SEM analysis

I. INTRODUCTION

Early Germans used fertilizers as manures for increasing the productivity of their farms (Zahraa et al., 2018). Fertilizers were introduced in India in 1961 by the Fertilizer Corporation of India Limited. Without fertilizers plants can grow, but it takes more time (Gaojan et al., 2018). Though it improves productivity in short span of time, it has severe health and environmental effects. Decomposition rate of fertilizers are very low, over usage may cause side effects to humans while consuming the plants, during the production of fertilizers many harmful substances are released into the environment. Phosphate containing fertilizers have high toxic metal contents such as cadmium which are released into the environment in the application stage. These hazardous materials even cause cancer. Nitrogen containing fertilizers alters the pH of the soil to acidic nature due to the release of H⁺ ions during nitrification process. On the other hand a survey conducted by Ministry of Environment, Forests and climate change says about 1.5 Metric tonnes of Municipal Solid Waste are generated in India per day. Out of this only 20% of wastes are processed. Others remain in landfills. If this situation continues, then in 2050 total landfill area will be equivalent to that of the area of Delhi i.e. about 88 sq km (Upreti., 2018). So, effective processing of landfill waste and alternate to fertilizers is the essential one.

Biochar can solve the both issues. Biochar is a stable solid rich in carbon formed by thermochemical conversion in an oxygen-limited environment, known as pyrolysis. Biochar when amended with soil not only serves as a good alternate to fertilizers, but also it bioremediates the fertilizer contaminated soils. Landfill area can be reduced by effective production of Biochar. As Biochar are produced from biodegradable waste it is a value added product. They can be used as sorbents for bioremediation of fertilizer contaminated sites. Due to their good water holding capacity, water supply can be managed effectively in summer seasons. These biochar can increase soil fertility of acidic soils and it also neutralizes acidic nature of soil. Various research works are carried out in national and international levels in this area. Which are as follows

Biomass is pyrolyzed at high temperatures to produce charcoal, syngas, and bio oil. Bio oil can be refined into biofuel. Biochar is primarily composed of carbon, nitrogen, hydrogen, and trace elements.

Biochar is often recognized as the best organic matter form for soil improvement. When applied, biochar absorbs heavy metals and organic contaminants, lowering their bioavailability. It also promotes plant growth. Biochar's slow decomposition rate allows it to keep its soil-amending qualities for longer periods of time, making it a promising agent for bioremediation and soil quality improvement.

Nitrogen is essential for plant nutrition but is typically present in complex forms in soil. Biochar aids in enriching soil with NH_4^+ and NO_3^- by directly adsorbing nitrogen, reducing leaching losses, and promoting populations of nitrifying soil bacteria (Clough and Condon, 2012).

II. RELATED WORK

A nutrient-dense leguminous crop, groundnuts are primarily grown for their oil and seeds worldwide. The residue that remains after removing groundnut seeds from their pods are known as groundnut shells. This is a common agro-industrial waste product that degrades very slowly in the environment (Zheng et al., 2013). Other applications of groundnut shell include its use in composting wet materials, for wastewater treatment, plastic, wardrobes and used as insulation board, metal casting, and a medium for pesticides as well as activated carbon. However, the major disadvantage of its use is large. Groundnut shell, a byproduct of groundnuts, is one such agricultural waste (peanut). Global groundnut production was estimated to be 47 million metric tons in 2020. With a share of almost 40% (~18 million metric tons) of global production, China was the leading producer of groundnuts. Peanut shells, damaged peanuts, kernel skins, and another biomass waste is produced in vast quantities by the groundnut business. 40% of the total weight of ground nuts produced is, on average, wasted as biomass from ground nut shells.

III. MATERIALS AND METHODS

Saw dust, rice husk and groundnut shells are collected from the local market. To increase the surface area and thus enabling better pyrolysis, the coarse particles in saw dust and rice husk are removed and ground nut shell is pulverized using a macerator. The samples should be preheated in a hot air oven at 70°C to remove the moisture content. After pretreatment, the samples should be placed inside the muffle furnace, and the desired temperature (set point) should be entered into the control panel. Once after reaching the set point, the pyrolysed samples are taken out from the furnace and they are spread over a tile to cool down it. Elemental composition of the produced biochar will be analyzed using the following SEM procedure.

PREPARATION OF MEDIA

A set of instructions for preparing different solutions, including sodium phosphate solutions and a phosphate buffer, as well as a phosphate buffered glutaraldehyde fixative.

Monobasic Sodium Phosphate Solution (0.2M),

Option 1: Weigh out 27.6 grams of $\text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$ and dissolve it in distilled water, then dilute to a total volume of 100 milliliters.

Option 2: Alternatively, weigh out 31.21 grams of $\text{NaH}_2\text{PO}_4 \cdot 2\text{H}_2\text{O}$ and dissolve it in distilled water, then dilute to a total volume of 100 milliliters.

Dibasic Sodium Phosphate Solution (0.2M),

Option 1: Weigh out 3.561 grams of $\text{NaH}_2\text{PO}_4 \cdot 2\text{H}_2\text{O}$ and dissolve it in distilled water, then dilute to a total volume of 100 milliliters.

Option 2: Alternatively, weigh out 53.65 grams of $\text{NaH}_2\text{PO}_4 \cdot 7\text{H}_2\text{O}$ and dissolve it in distilled water, then dilute to a total volume of 100 milliliters.

Phosphate Buffer 0.2M (pH=7):

Mix 30.5 ml of Dibasic Sodium Phosphate Solution (0.2M) with 19.5 ml of Monobasic Sodium Phosphate Solution (0.2M).

Phosphate Buffer 0.1M (pH=7):

Dilute 50 ml of the 0.2M Phosphate Buffer (pH=7) prepared in step 3 with distilled water to make up to 100 ml.

Phosphate Buffered Glutaraldehyde Fixative (6%):

Prepare fresh and store in a clean glass bottle.

Mix 50 ml of the 0.2M Phosphate Buffer (pH=7) with 24 ml of 25% Glutaraldehyde in distilled water and 26 ml of distilled water to make up to 100 ml.

Add 27.5 mg/l of calcium chloride to the final mixture.

PREPARATION OF SAMPLE:

Based on the provided steps for preparing sludge samples after media preparation, here's a refined summary:

Step 1: Fixation Schedule

Take an appropriate amount of sludge sample into a test tube. Add an equal volume of 6% glutaraldehyde fixative mix to the tube, gently shaking or tipping it simultaneously to ensure proper mixing. Then, place the tube in a refrigerator to allow for fixation to occur. Let it sit for 1 hour at a temperature of 20°C. After the fixation process is complete, centrifuge the sample to separate the components.

Step 2: Washing

Wash the fixed samples with 0.1M phosphate buffer containing 27.5 mg/l calcium chloride for 2 hours.

Maintain the contents at 4°C during washing.

Step 3: Dehydration of Fixed Samples

Dehydrate the fixed specimens by passing them through a series of solutions with increasing concentrations of ethanol in water, ending with pure ethanol.

During dehydration, remove each solution carefully with a fine pipette or syringe while pouring the next one.

Ensure that the volume of each solution used is at least 10 times the volume of the specimen.

Gradually increase the temperature so that 90-95% strength ethanol solutions are obtained at room temperature.

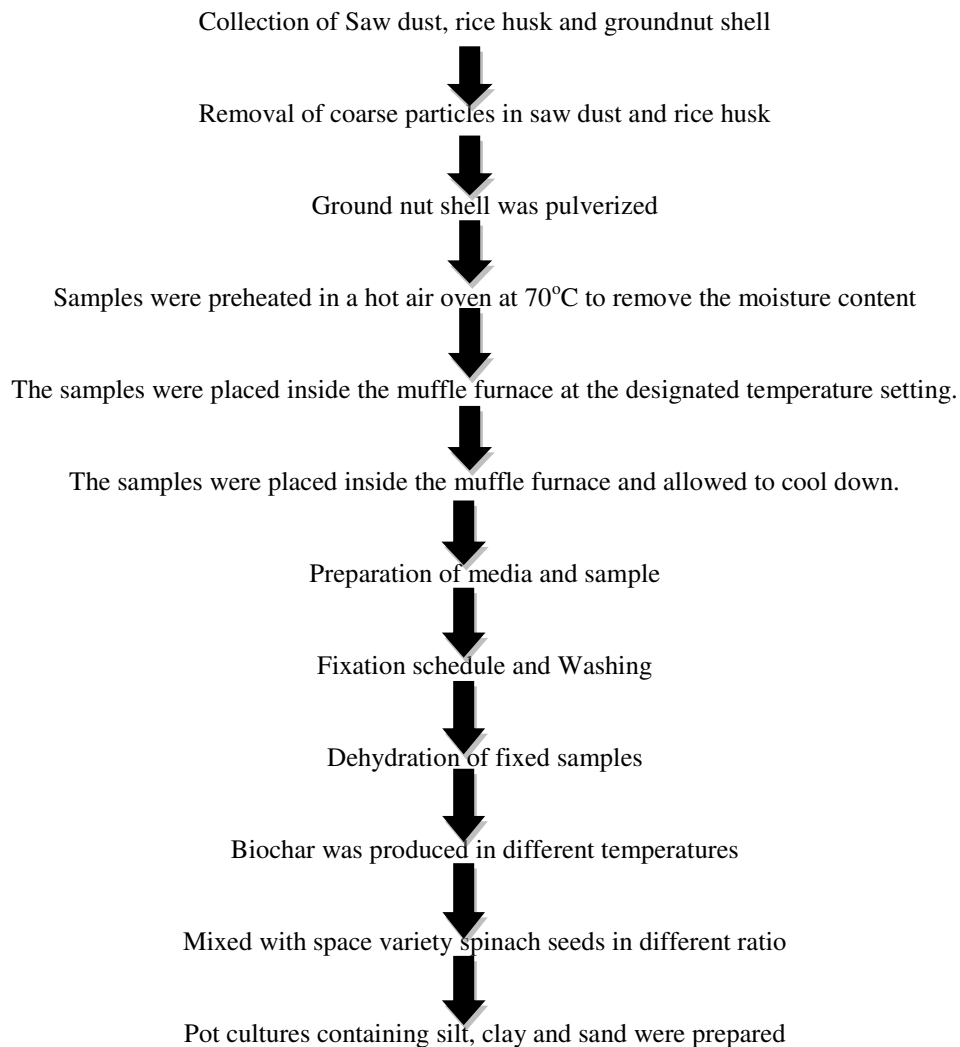
These steps outline the process for fixing, washing, and dehydrating sludge samples after preparation, ensuring proper preservation and preparation for further analysis or storage.

Dehydration Schedule

50% ethanol/ acetone in water	=	10 minutes
70% ethanol/ acetone in water	=	10 minutes
95% ethanol/acetone in water	=	10 minutes
100% ethanol/acetone	=	15 minutes
100% ethanol/ acetone	=	15 minute

After fixation, washing, and dehydration, sludge samples were placed on a sample stub and coated with a 200 Å thick coating of gold using an Ion sputtering apparatus (JFC-1100E, Japan). The samples were then scanned using a scanning electron microscope (JEOL- JSM 5300, Japan) at 4.5 nm resolution, 30 kV accelerating voltage, and an 8 mm working distance.

PROCESS FLOWCHART



The height, weight, total leaf area, total leaf weight and dry weight of each plant were recorded on 4th day, 9th day and 13th day of sowing seeds

EXPERIMENTATION

From Central Composite Design the experimental parameters will be framed. Accordingly the biochar is produced in different temperatures and they are mixed with space variety spinach seeds in different ratio. Pot cultures containing silt, clay and sand are prepared. The Biochar-seed mixture is applied onsite in the pots. The height, weight, total leaf area, total leaf weight and dry weight of each plant were recorded on 4th day, 9th day and 13th day of sowing.

IV. RESULT AND DISCUSSION

To understand the properties of biochar, we used scanning electron microscopy (SEM), a powerful tool that reveals the surface structure and porosity of materials. Our analysis showed that biochar made from plant material has a porous structure with pores about 1 micrometer in diameter, which is influenced by the natural structure of the plant material. This porosity is crucial for biochar's ability to hold water and absorb pollutants in soil and solution systems.

The SEM images revealed a honeycomb-like structure in biochar produced at different temperatures, which comes from the tubular structures present in plant cells. These well-developed pores contribute to a high surface area, making

biochar effective for various applications.

The temperature used to produce biochar significantly affects its properties. Low temperatures result in biochar that releases fertilizer nutrients slowly, while high temperatures produce biochar suitable for environmental remediation. However, biochar produced at low temperatures may have hydrophobic surfaces, limiting its water retention and pollutant adsorption capabilities in soil.

The characteristics and quality of biochar depend on factors like the type and size of biomass feedstock, preparation steps, and pyrolysis product. Moreover, the size of biochar affects its surface area, impacting its effectiveness in various applications.

Biochar produced at low temperatures is robust but can become brittle and undergo pore abrasion when introduced into soil. Research by Qiu et al. illustrated the relationship between heavy metal sorption mechanisms and SEM analysis, showing that lead-loaded biochar has bright zones on its pore surfaces, indicating the presence of silicon and phosphorus, which form lead phosphate silicate precipitates, a crucial mechanism for removing lead from soil and solution systems.

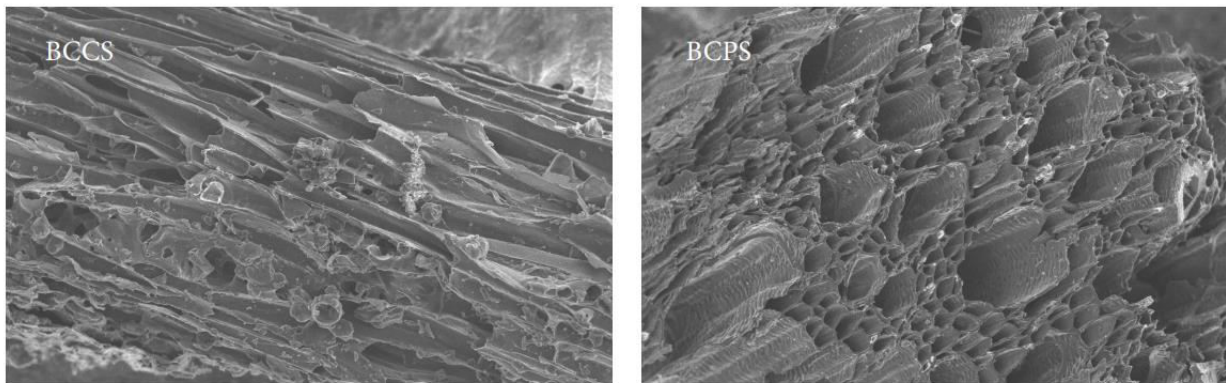


Figure 1 Photomicrograph from SEM

Using SEM-EDX, elements present in the biochar were analyzed.

Based on the results from various experiments and studies on biochar, here are the key findings and conclusions:

Biochar, a valuable resource produced from various sources and temperatures, consistently shows high carbon content. For example, biochar from groundnut shells, sawdust, and rice husk exhibit carbon contents of 64%, 64%, and 74%, respectively, when pyrolyzed at specific temperatures. This is in line with previous studies that highlight carbon as a major component of biochar's elemental makeup.

The phosphorous content in biochar, however, decreases with increasing pyrolysis temperature for groundnut shell and rice husk biochars, indicating its sensitivity to pyrolysis conditions. Notably, the phosphorous content is minimal across all produced biochars, consistent with previous findings.

The application of biochar in agriculture has shown significant benefits, including enhanced plant growth rates. Specifically, mixing biochar with seeds at specific ratios and temperatures can increase growth rates, as seen in rice husk biochar at 400°C and groundnut shell biochar at 200°C. Additionally, biochar has been shown to improve nutrient uptake and neutralize soil pH, making it a valuable resource for sustainable agricultural practices.

Overall, the elemental composition and application of biochar are influenced by feedstock type, pyrolysis temperature, and mixing ratios, highlighting its potential in agricultural and environmental applications.

V. CONCLUSION

Biochar is a highly valuable material in fertilizer technology, offering multiple benefits for plant growth, soil remediation, and nutrient enhancement. Its unique properties include excellent water retention, pH neutralization, and

carbon sequestration capabilities. Moreover, biochar can even facilitate plant growth in saline soils. Our research has shown that carbon is the predominant element in all biochar samples, while phosphorous content decreases with increasing pyrolysis temperature. We have also identified the optimal temperatures for biochar production: 400°C for rice husk, 200°C for groundnut shell, and 600°C for sawdust. Furthermore, our findings suggest that a 1:40 mixing ratio of biochar to spinach seeds is ideal for all biochar types. These results highlight the potential of biochar as a valuable resource for sustainable agriculture and environmental applications.

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