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Biochar, an organic ingredient for production of tree species quality seedlings in nursery

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INTRODUCTION

Biochar is a carbon rich product produced from organic biomass such as forestry wastes, animal manures and crop residues under low-oxygen conditions using thermochemical processes like pyrolysis, torrefaction, gasification and hydrothermal carbonization (Kevin *et al*., 2025). Forest ecosystems occupy about thirty-one percent of the global land area and are crucial for livelihoods, climate regulation and biodiversity conservation. However, rapid deforestation, land degradation and climate change have increased the need for effective reforestation, where high seedling mortality remains a major challenge (Simiele *et al*., 2022). Conventional nursery growing media often suffer from poor structure, low water-holding capacity, nutrient leaching and inconsistent microbial activity, resulting in weak root development and uneven seedling growth. In this context, biochar has gained attention as a promising nursery amendment. It improves water retention, nutrient availability, nutrient storage and microbial activity while also sequestering atmospheric carbon. Biochar acts as a nutrient source, nutrient sink and soil conditioner, showing synergistic effects when mixed with conventional media and producing vigorous seedlings with better post-planting survival (Hossain *et al*., 2020; Tang *et al*., 2013).

Production methods of Biochar and their characteristics:-

Pyrolysis has been used to produce biochar for thousands of years through traditional earthen, brick and steel kilns. The recent thermochemical technologies with different types of reactors for converting biomass into renewable products include torrefaction, hydrothermal carbonization (HTC), gasification, slow pyrolysis and fast pyrolysis.

These modern pyrolysers are also designed to capture the volatiles for the production of bio-oil and syngas along with biochar. Achievements of higher yield and quality of target product are significantly dependent on operating parameters and the properties of the feedstock. Various thermochemical techniques operating with different reaction conditions (operating temperature, heating rate and residence time etc.) for biochar production are summarized in Table 1.

Table 1:- Different methods of biochar production

Method	Process description	Yield (%)	Key characteristics
Slow pyrolysis	• Heating biomass at low temperatures (300-600 °C) • Heating rate (5-7 °C/min) • residence time (> 24 hours)	35-45	High biochar yield, stable carbon
Fast pyrolysis	• Rapid heating at (500- 1000 °C) • heating rate (300 °C/min) • Residence time (for few seconds)	10-20	Produces bio-oil, low biochar yield
Gasification	• Partial oxidation of biomass at high temperatures (800-1000 °C)	5-15	Produces syngas, low biochar content
Torrefaction	• Thermal degradation at (200-300 °C)	30-40	Improves biomass energy density
Hydrothermal Carbonization (HTC)	• Biomass is treated in hot compressed water at (180-250 °C) under pressure		Produces hydrochar, lower stability than biochar

Source: Kevin *et al*. (2025)

Classification of Biomass as Feedstock for Biochar Production:-

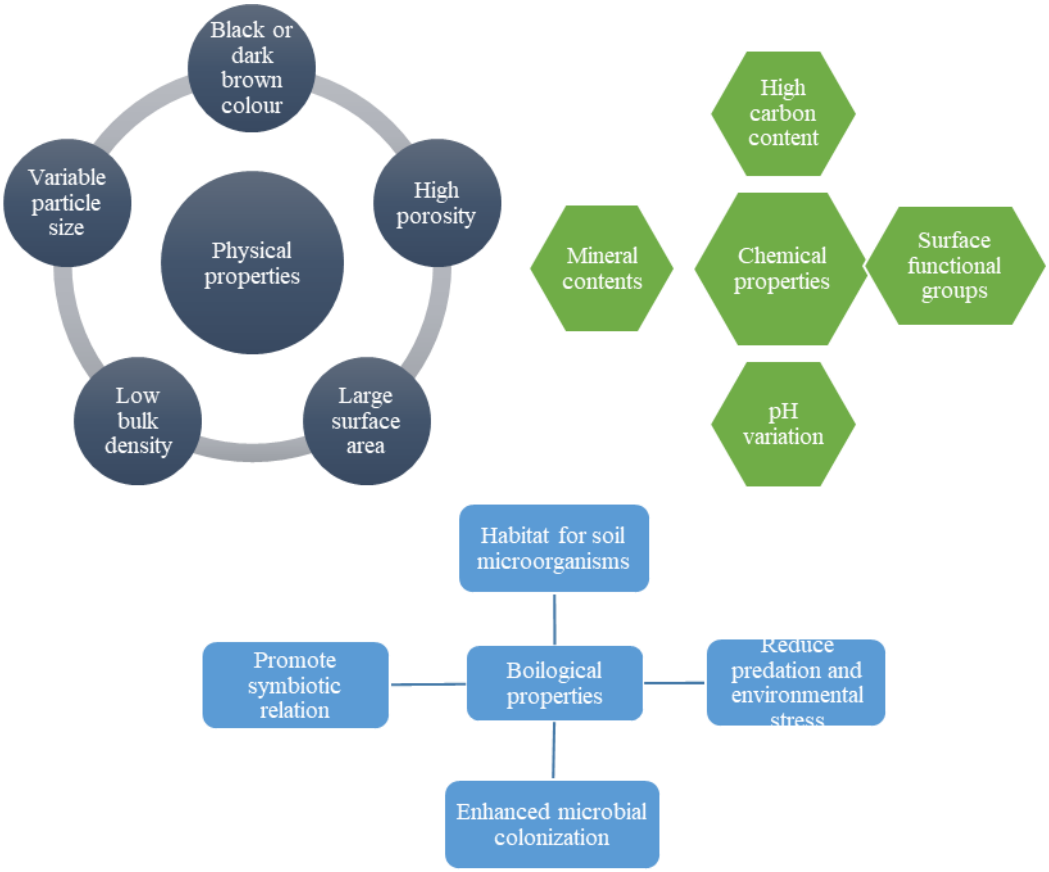
Biomass is the generic term for all organic matter derived from animals and algae as well as plants such as shrubs, trees and crops. Since the types of biomass are diverse and their composition depends on their origin, systematic classification of biomass is required to utilize as a beneficial feedstock in thermochemical processes. In order to utilize biomass as a feedstock more efficiently, it has been classified into 1st to 4th generation based on major biotechnology and summarized in Table 2. Wheat straw, rice straw, husk and bagasse are common feedstocks used widely as a result of having a ready supply and improving soil conditions. one reason for the use of organic waste (poultry litter, cow dung and pig manure) for culturing biochar is that they can enhance the nutrient content of biochar. As forest byproducts such as sawdust and wood waste have high carbon content and high stability, they are used because they are suitable for a long-time carbon sequestration.

Table 2:- Classification of biomass as feedstock for biochar production

Generation	Source	Example Feedstocks	Key Features	Issues
1st Generation	Food crops	Maize, sugarcane, rice, wheat and corn	Easy processing, high carbon yield	Competes with food supply
2nd Generation	Non-food lignocellulosic biomass	Crop residues (straw, husk, bagasse), wood waste and bamboo	Sustainable, abundant and long term carbon storage	Requires pretreatment
3rd Generation	Algal biomass	Macro and micro algae (Seaweeds)	Fast growth, nutrient-rich biochar, non-arable land use	High moisture content, costly processing
4th Generation	Organic waste	Food processing residue, paper mill residue, sewage sludge and animal residue	Doesn't require cultivation space and nutrient rich	Still experimental or under research

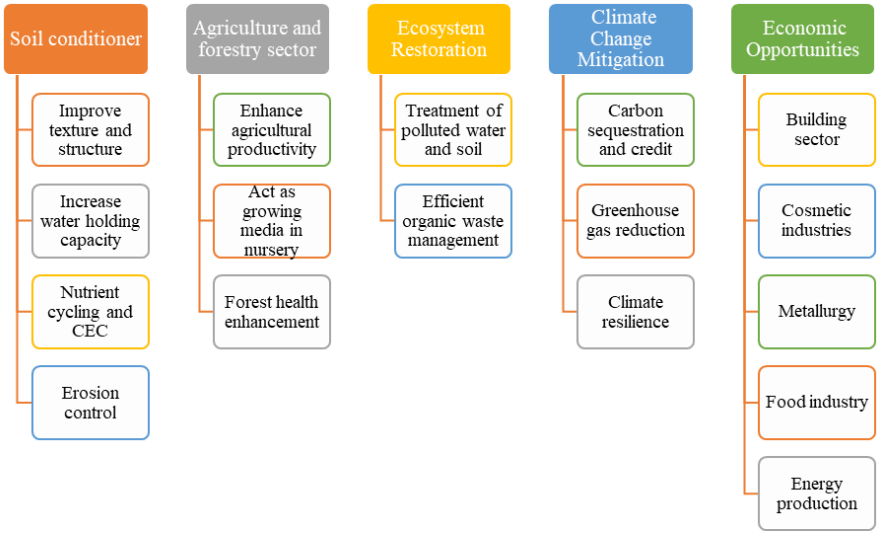
Source: Chun *et al*. (2021)

Properties of biochar:-



Source: Kevin *et al*. (2025)

Importance of biochar:-



Source: Narzari *et al*. (2015)

CONCLUSION

Biochar is a useful and ecofriendly material that connects waste management, plant growth and climate protection. It is made from easily available biomass like crop waste, forest residues and animal waste, and turns these materials into a stable and valuable product. Because of its porous structure and high carbon content, biochar

helps soil and nursery media hold more water and nutrients and supports beneficial microbes. In forest nurseries, the use of biochar improves root growth, seedling strength and overall plant health. Stronger seedlings have a better chance of survival after planting, which is very important for successful afforestation and reforestation programmes. At the same time, biochar stores carbon in a stable form, helping to reduce the effects of climate change. The benefits of biochar depend on how it is made and the type of material used, so proper selection and use are important.

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