Debunking Biochar Myths | Volume 4

Examining Biological Properties

BIOCHAR TODAY

Examining Biochar's Biological Properties

The Debunking Biochar Myths Series continues with its fourth volume, shifting focus from chemical complexities to the often-misunderstood biological characteristics of biochar. While biochar is widely recognized for its stability and carbon sequestration potential, misconceptions continue to persist about its interactions with the living soil ecosystem. Too often, the biological dimension of biochar is treated as uniform and passive, with little regard for the dynamic roles it plays in shaping microbial life belowground.

This volume addresses that gap. It challenges the tendency to oversimplify biochar's biological functions—particularly its influence on microbial communities, enzyme activity, and biogeochemical cycles—by dissecting 25 persistent myths that cloud both public understanding and practical application.

ntle such preconceptions.

To foster a more precise and comprehensive understanding, this e-book addresses these assumptions by organizing prevalent myths into central themes. This approach aims to illuminate the intricate biological composition and reactivity of biochar:

- **Microbial Habitat & Activity:** Biochar's porous structure offers a protective environment for microorganisms, influencing their activity and respiration, and countering the myth that it's sterile or harmful to beneficial soil microbes.
- **Nutrient & Carbon Cycling:** Biochar, despite its stable carbon, supplies bioavailable carbon and essential nutrients to microbes, challenging its perception as merely an inert carbon sink.
- **Microbial Communities & Diversity:** Different biochar types and application rates shape microbial community structure and diversity, impacting bacterial and fungal populations, though high rates can sometimes cause declines.
- **Stress Mitigation & Unintended Effects**: Biochar helps alleviate soil acidity and contaminants, protecting microbes. However, it can also introduce toxic elements or organic compounds that may inhibit microbial function.

Moreover, biochar is not a biologically inert substance. A combination of physical structure, chemical composition, and environmental context governs its interaction with microbial ecosystems. By clarifying the science behind these interactions, this volume aims to refine how biochar is perceived, evaluated, and implemented in biological soil management strategies.

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DEBUNKING BIOCHAR MYTHS

Biochar is a dead, inert material that doesn't interact with living soil organisms

Biochar actively supports habitats for microorganisms due to its porous nature and by promoting the formation of stable soil micro-aggregates. It significantly influences soil biological health by stimulating microbial activity and function, and by altering soil physical and chemical properties to create optimal conditions for biodiversity

Bolan et al., 2024

EXAMINING BIOLOGICAL PROPERTIES

Biochar is quickly decomposed by soil microbes, offering no long-term carbon storage benefits

Unlike many organic amendments that readily decompose, biochar's stable carbon structure, created through pyrolysis, allows for long-term carbon sequestration in soil, lasting for hundreds of years.

Azzi et al., 2024

DEBUNKING BIOCHAR MYTHS

Biochar immediately reduces all microbial activity in the soil

Biochar application can initially lead to a positive priming effect, causing a temporary increase in the mineralization of native soil organic carbon. However, after this initial period, biochar often stimulates a negative priming effect, thereby stabilizing soil carbon over time

Bolan et al., 2024

EXAMINING BIOLOGICAL PROPERTIES

Biochar provides a direct and readily available food source for all soil microorganisms

While some fresh biochar can contain soluble and labile carbon fractions that are easily accessible to microorganisms, the majority of its carbon content is stable and non-bioavailable. Microbes preferentially utilize the bioavailable fraction over the recalcitrant fraction.

Mukherjee et al., 2022a

DEBUNKING BIOCHAR MYTHS

Biochar is not a source of essential nutrients for soil microbes

Biochar contains minerals present as ash materials and inherited nutrients from its original feedstock, including essential macro- and micro-nutrients like P, Ca, Mg, and Si, which are bioavailable for soil microorganisms. The nutrient concentration often increases after pyrolysis due to a 'concentration effect' caused by a decrease in biochar yield.

Hossain et al., 2020

EXAMINING BIOLOGICAL PROPERTIES

Biochar's influence on soil microbial communities is short-lived

While initial shifts in microbial communities can be temporary, the stable carbon provided by biochar applications leads to long-term stability for microbial communities and sustained positive impacts on soil's biological health and ecological function. Some studies have observed that certain changes in functional diversity might not be visible after longer periods.

Bolan et al., 2024

The larger the biochar particle size, the more beneficial it is for microbial habitat

Biochar particle size significantly influences soil microbial responses. Fine biochar particles can increase soil pH and improve soil microbial diversity, providing a better habitat for microorganisms compared to larger particle sizes.

Sarfraz et al., 2020

EXAMINING BIOLOGICAL PROPERTIES

All biochars offer the same level of suitability for microbial colonization

The suitability of biochar for colonization by microbial communities varies depending on its physical properties and porous structure. For instance, Miscanthus and wood-based biochars exhibited significant differences in porosity, with wood-based biochar being better able to host microorganisms.

Giagnoni & Renella, 2022

DEBUNKING BIOCHAR MYTHS

All types of biochar have the same effect on soil microbial responses

The impact of biochar on soil microbes varies significantly depending on its characteristics, which are determined by the feedstock and pyrolysis temperature. For instance, biochar from lignocellulose or agricultural biomass is better at inhibiting N2O emissions, while biochar made at lower temperatures can enhance nutrient retention but leads to more CO2 release.

Kerner et al., 2023

EXAMINING BIOLOGICAL PROPERTIES

Biochar application always increases microbial diversity regardless of the amount

While biochar can generally enhance the diversity of bacteria and fungi, higher rates of biochar application can sometimes lead to a decline in microbial diversity. The optimal application rate depends on the biochar type and the specific soil conditions.

Bolan et al., 2024

Biochar provides no protection to microorganisms from environmental stressors

Microbes can adhere to the interior or exterior surface of biochar through loose interactions, which not only provide shelter and nutrients but also offer protection from pollutants.

Kayoumu et al., 2025

EXAMINING BIOLOGICAL PROPERTIES

All soil microbes react uniformly to biochar

Biochar's impact on soil microorganisms varies greatly depending on its source material, pyrolysis temperature, and soil conditions, leading to diverse microbial responses

Huang et al., 2023

DEBUNKING BIOCHAR MYTHS

Polycyclic aromatic hydrocarbons (PAHs) in biochar are always toxic to all microbes

While some polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) in biochar can be microbial inhibitors, certain types, especially low molecular weight oxygenated VOCs (LMWO-VOCs), can selectively promote specific microbial populations. These compounds have also been shown to directly harm microbial soil pathogens, benefiting plant growth.

Dutta et al., 2017

EXAMINING BIOLOGICAL PROPERTIES

Biochar doesn't actively engage with microbes or their functions in soil

Biochar actively interacts with microbes and their extracellular polymeric substances (EPS) by offering habitat, nutrients, and facilitating communication and electron transfer, thereby enhancing pollutant removal and soil fertility.

Kayoumu et al., 2025)

DEBUNKING BIOCHAR MYTHS

Biochar application improves soil microbial activity and nutrient availability

While biochar can restore microbial biomass and enhance the availability of carbon (C) and nitrogen (N) to microorganisms, its effects on specific enzyme activities and nutrient limitations can vary depending on the biochar feedstock and application rate. Importantly, biochar application may increase phosphorus (P) limitation for soil microbes, suggesting the need for external P supplementation.

Barbosa et al., 2024

EXAMINING BIOLOGICAL PROPERTIES

Biochar has no negative side effects on soil biological health

Depending on pyrolysis conditions and feedstock materials, biochar can contain toxic compounds such as polycyclic aromatic hydrocarbons (PAHs), potentially toxic elements (PTEs), and persistent free radicals (PFRs). These contaminants can inhibit microbial activity, cause oxidative stress, and negatively impact overall soil health.

Mukherjee et al., 2022b.

DEBUNKING BIOCHAR MYTHS

All biochars are equally effective as microbial carriers

Biochar's effectiveness as a microbial carrier varies significantly based on its properties, which are determined by pyrolysis temperature and biomass feedstock type, influencing nutrient content, functional groups, and overall suitability for microbial life.

Bolan et al., 2023

EXAMINING BIOLOGICAL PROPERTIES

Biochar passively adsorbs pollutants and does not affect microbial activity

Biochar actively interacts with microorganisms, serving as a nutrient source, providing a protective habitat, and influencing microbial activity through various mechanisms. It can either synergistically enhance or antagonistically inhibit microbial functions, depending on its properties and the environmental context.

Mukherjee et al., 2022b

DEBUNKING BIOCHAR MYTHS

High salt content in biochar is not an issue for soil biology

Biochars synthesized from certain feedstock materials can be enriched with soluble salt contents. Application of these biochars can increase soluble salt concentrations in soils, contributing to soil salinity issues and potentially reducing microbial diversity

Han et al., 2016

EXAMINING BIOLOGICAL PROPERTIES

Biochar's particle size has a major impact on microbial habitat

While initial studies suggested smaller particle sizes provided more surface area for microbial biomass, subsequent research found no significant long-term difference in fungal growth within pore spaces after incubation. The overall porous network of the biochar, rather than just particle size, appears to be a key factor for microbial habitat

Jaafar et al., 2015

DEBUNKING BIOCHAR MYTHS

Biochar solely impacts bacterial communities, with little effect on fungi

Biochar application can influence both bacterial and fungal communities, with observed shifts in their relative abundances and diversity depending on the biochar type and soil conditions. For example, biochar from maize straw favored bacterial populations but decreased fungal populations in some calcareous soils, while promoting arbuscular mycorrhizal fungi in others.

Yin et al., 2021

EXAMINING BIOLOGICAL PROPERTIES

Biochar's influence on soil microbial communities is short-lived

While some temporary changes in microbial community structure and respiration can occur, the long-term storage of carbon following biochar applications provides successive stability for microbial communities and positive impacts on the biological health and ecological function of soil.

Giagnoni & Renella, 2022

DEBUNKING BIOCHAR MYTHS

Biochar types and application rates consistently increase beneficial bacterial populations

Biochar's influence on microbial communities is highly variable, with different biochar types and application rates leading to diverse shifts in dominant microbial groups, and not always a consistent increase in beneficial bacteria.

Sharma et al., 2025

EXAMINING BIOLOGICAL PROPERTIES

Biochar acts independently of other soil amendments in its biological effects

The application of biochar along with the co-addition of other materials, such as N, P, and/or K fertilizers or composts, can have a greater impact on microbial communities than using biochar alone. This indicates synergistic effects when biochar is combined with other amendments, leading to enhanced microbial activity and soil health.

Chen et al., 2022

DEBUNKING BIOCHAR MYTHS

Any feedstock material is equally suitable for producing biochar that benefits soil microbes

The feedstock used to produce biochar is a critical factor that significantly impacts the soil microbial community. For example, manure-based biochar can support a more complex microbial network and stimulate bacterial richness, while straw-based biochar may improve bacterial diversity, demonstrating feedstock-dependent variations in microbial response.

Bolan et al., 2023

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