Potential Benefits of Biochar and Mycorrhizal Fungi on Shortleaf Pine (Pinus echinata) Restoration in Northcentral Alabama

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Abstract

Coal strip mining has left degraded soils throughout the southeastern United States. These soils tend to have low pH, high bulk density, impacted hydraulic processes, and an accumulation of heavy metals that limit revegetation and reforestation efforts. Shortleaf pine (Pinus echinata) has the adaptability to grow on post-mined sites due to being able to tolerate soils with a low pH. It also has the largest native range of pines in the southeastern United States, making it an ideal species for such restoration efforts. Furthermore, soil restoration using a combination of biochar and mycorrhizal amendments can provide many benefits for degraded soils ranging from increasing carbon sequestration, reducing erosion, promoting plant growth, and immobilizing heavy metals. However, limited empirical field trials have been conducted on the success of these soil amendments on both soil health and tree productivity. To provide restoration recommendations to land managers and landowners, we established a field trial in Winston County, Alabama at a reclaimed mining site. In Spring 2021 we planted Shortleaf pine in a complete randomized block design with 30.5x30.5 m spacing with two treatments: biochar and microbial inoculation in four replicates. We measured soil bulk density, pH, heavy metal content, electrical conductivity, carbon content, and nitrogen content both before and after planting every three months. We will also monitor shortleaf pine survival and growth. Our preliminary results for pH, bulk density, and electrical conductivity are within the expected range for shortleaf pine to do well on this post-mined site. Prior to soil treatments and planting, soil pH was 5.55 ± 0.54 pH, dry bulk density was 1.46 ± 0.14 g/cm^3, wet bulk density was 1.74 ± 0.12 g/cm^3, and electrical conductivity was 273.19 ± 141.33 µS. Soil nitrogen content was 0.15 ± 0.04% and soil carbon content was 2.31 ± 0.76%. The average C:N ratio was 15.8:1. Survival of planted seedlings after three months was 98%. Changes in soil physical and chemical conditions relative to restoration treatments are pending. This study will help support our understanding of biochar's interaction with mycorrhizal fungi inoculation, role in restoration, and use in southeastern United States soils.

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Introduction

The current extent of shortleaf pine (*Pinus echinata)* is estimated to be less than 10% of it's historical range[1] (Figure 1). This stems from a combination of factors such as climate change, pests, and the commercial preference of loblolly pine (*Pinus taeda*). Shortleaf pine has one of the largest native range in the southeastern United States and has potential to be used in widespread land restoration efforts on reclaimed mining sites. This is due to its ability to grow on low quality and acidic soil. Biochar and soil microbial amendments may further enhance restoration potential by increasing carbon sequestration, decrease bulk density, increase pH, and decrease the mobility of heavy metals[2,3].

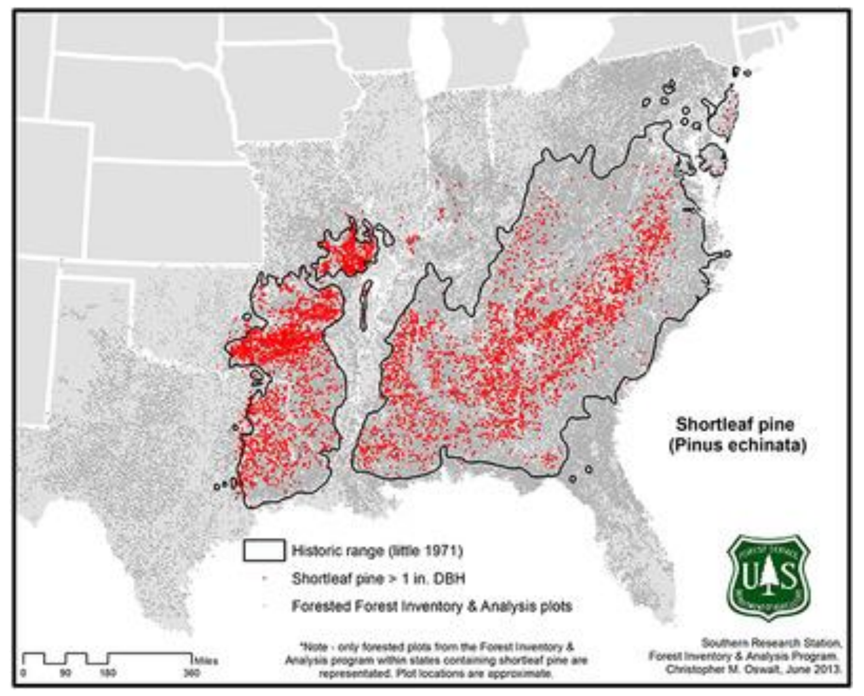

Figure 1. 2012 distribution of shortleaf pine on FIA forest plots within the historic shortleaf pine range . (Source) : Shortleaf Pine Initiative

Objectives

The primary objective of this study is to determine the impact of biochar and microbial soil amendments on soil health indicators and shortleaf pine productivity.

Methods

This study takes place in Winston County, AL. The experiment uses a fully factorial and complete randomized block design with two treatments: biochar and microbial inoculation (Figures 2). We have measured soil bulk density (BD), pH, electrical conductivity (EC), carbon content, and nitrogen content both before and after planting the shortleaf pine.

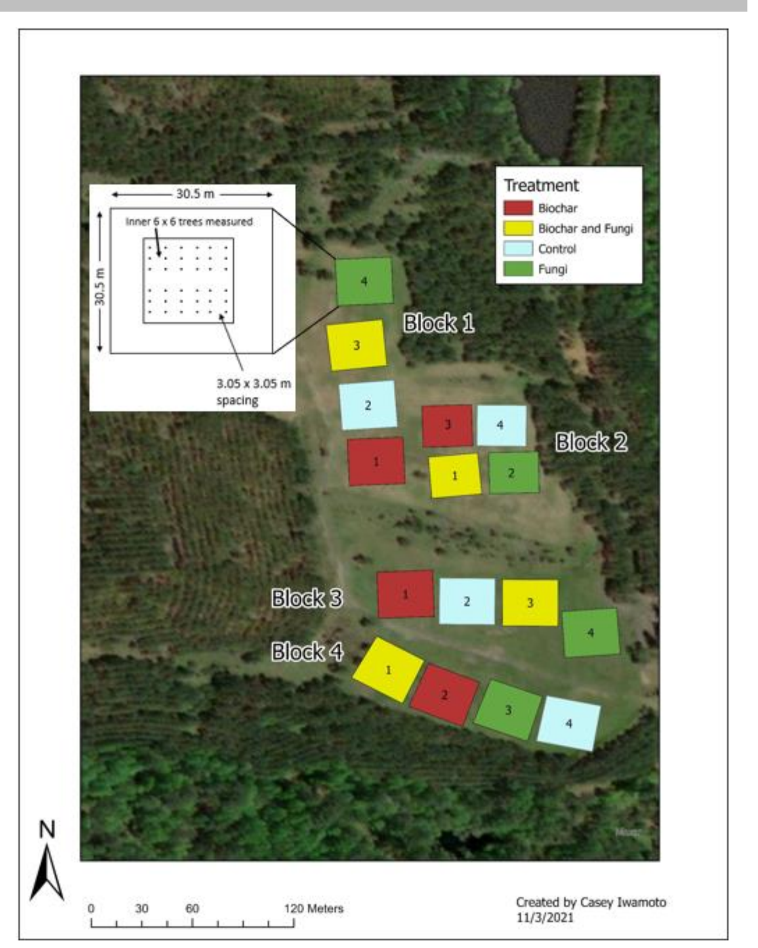

Figure 2. Experimental design and layout

Results

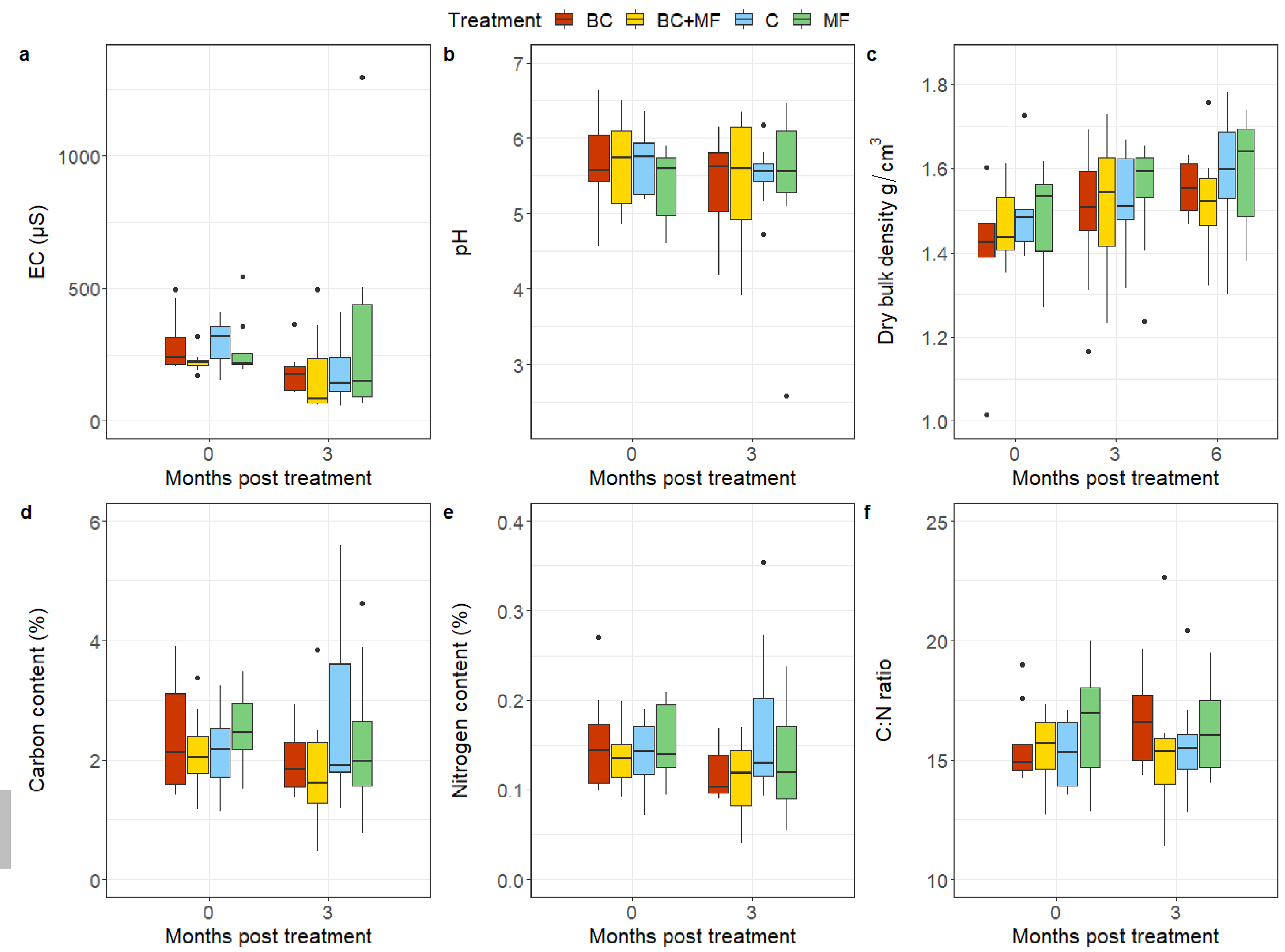

Figure 3. Measurements of soil health indicators at 0 months (pretreatment), 3 months, and 6 months after treatment. BC = biochar, BC+MF = Biochar and mycorrhizal fungi, C = Control, MF = Mycorrhizal fungi. (a) electrical conductivity (b) pH (c) dry bulk density (d) carbon content (e) nitrogen content and (f) carbon to nitrogen ratio.

Table 1. Survival, ground line diameter (GLD), and height of shortleaf pine after one growing season.

Treatment	Survival (%)		GLD (cm)		Height (cm)	
	At planting	End of growing season	At planting	End of growing season	At planting	End of growing season
Biochar	97.91 ± 1.33	77.78 ± 3.40	0.39 ± 0.11	0.66 ± 0.19	20.46 ± 4.77	36.23 ± 10.49
Biochar and mycorrhizal fungi	98.61 ± 1.39	74.31 ± 5.12	0.40 ± 0.12	0.60 ± 0.19	20.18 ± 5.14	34.48 ± 9.48
Control	95.83 ± 0.80	77.78 ± 7.44	0.39 ± 0.11	0.61 ± 0.19	20.78 ± 9.49	35.89 ± 10.37
Mycorrhizal fungi	98.61 ± 0.80	84.26 ± 8.82	0.38 ± 0.11	0.60 ± 0.15	19.81 ± 4.65	36.41 ± 12.91

Summary & Implications

- EC and pH show slight negative trends, while dry bulk density shows a clearer positive trend. C content, N content, and the C:N ratio show little change across the current time period (Figure 4).
- The current survival of shortleaf pine is within our expectations; however, the trees are not large enough to impact the soil yet (Table 1).
- These measurements also do not consider seasonal changes, but with future data collection we expect the soil amendments to:
    - increase soil pH, carbon content, and nitrogen content
    - decrease EC and bulk density.

Figure 4. Shortleaf pine planted Spring 2021

Figure 5. 10 cm soil core

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