The Potential of Biosolids and Other Amendments for Revegetation of Lead/Zinc Mine Tailings with Three Biomass Crops: Greenhouse Study

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Background

- Mine tailings are produced by mining and processing of economically-important minerals, and usually characterized by:
  - Poor soil structure.
  - Devoid of vegetation cover.
  - Heavy metal (HMs) content.

Background

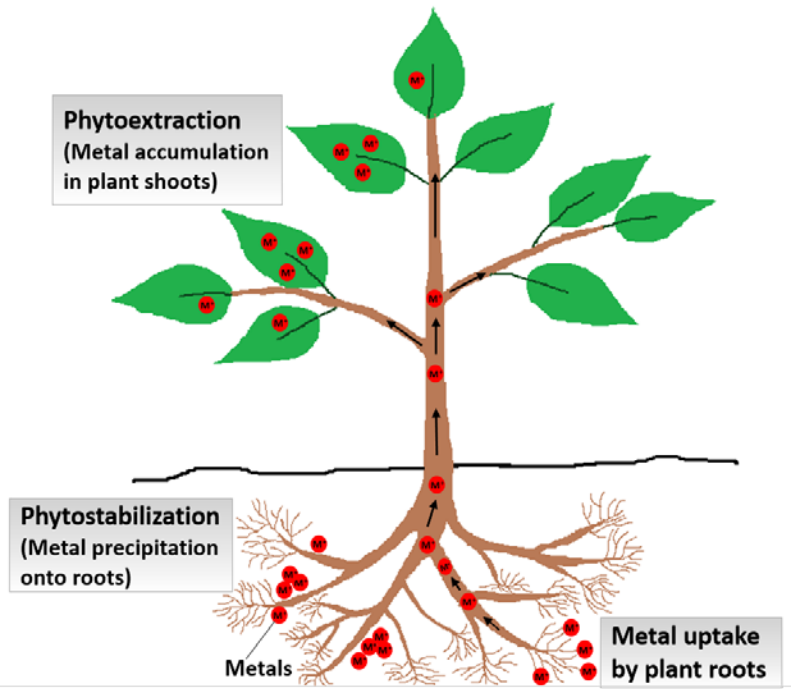
- Tailings revegetation is required to achieve:
  - Land Reclamation.
  - Long-term stabilization.
  - Enhanced restoration.

Background

- Tailings Phytoremediation involves two mechanisms:

- Phytostabilization:
  - *In-situ* immobilization.

- Phytoextraction:
  - Removal of HMs accumulated in plant tissue.



Background

- Mine tailings are typically difficult to revegetate due to:
  - Poor soil structure.
  - Lack of essential nutrients.
  - Metal toxicity.
- Adding appropriate soil amendment should be considered when dealing with tailings revegetation.

Background:

Rich Organic Amendments:

- **Biosolids (BS):**
  - BS contain up to 50% organic matter which serve as:
    - Carbon and nutrients source for microorganism.
    - Binding agents for aggregate formation and stabilization.

Background:

Rich Organic Amendments:

- **Biosolids (BS):**
  - BS contain a full range of nutrients that are necessary for plant growth.
  - Increasing soil Cation Exchange Capacity (CEC).
  - Reduce HMs bioavailability by forming strong complexes.

Background:

Rich Organic Amendments:

- **Biochar (BC):**
  - Increase water holding capacity.
  - Increase CEC.
  - Decrease bioavailablity of HMs such as Cd, Pb, TI, and Zn.
  - Elevate C/N ratio, thus reduce nutrients leaching.

Background:

Other Amendments:

- **Soil Secrets Products:**
  - TerraPro supramolecular humus (HS)
    - Molecular compounds called organic acids and characterized by long lasting in soil.

  - Protein crumblies (P)

    - large organic compounds made of amino acids and rich in nitrogen.

Background:

Other Amendments:

- **Soil Secrets Products:**
  - MycoMaxima (mycorrhizal fungi) (MF).
    - MF plays an important role of establishing a symbiotic relationship with plant roots.
    - Increase water and nutrients uptake.

Goal and Objectives

- The primary goal is to establish a vegetative cover to achieve long-term stabilization of tailings.

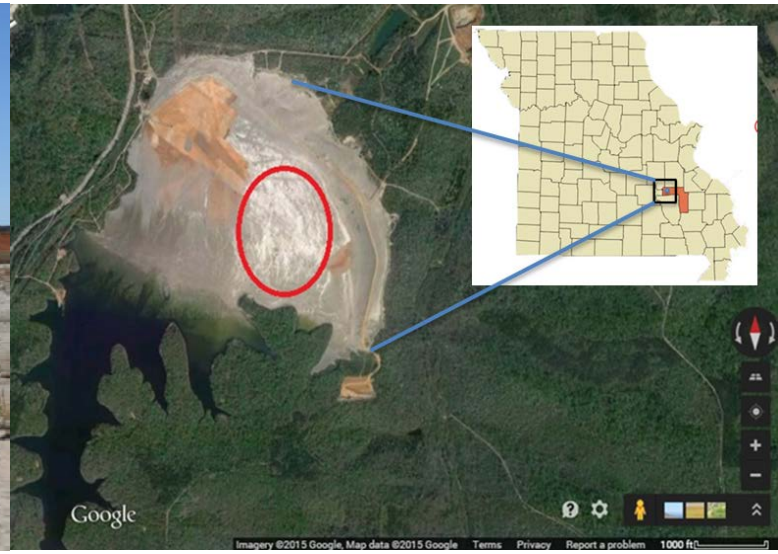
Objectives:

- Investigate the effectiveness of BS, BC, and other amendments for revegetation of lead mine tailings with biomass crops.

- Assess the impact of soil amendments on physicochemical and biological properties of tailings that are important to sustain a long-term vegetation cover.

Experimental Work:

- Site Description:
  - Mine Tailings Impoundment.



Located at latitude 37.7050462 and longitude -91.1067999 Iron County, Viburnum MO, US.

Experimental Work:

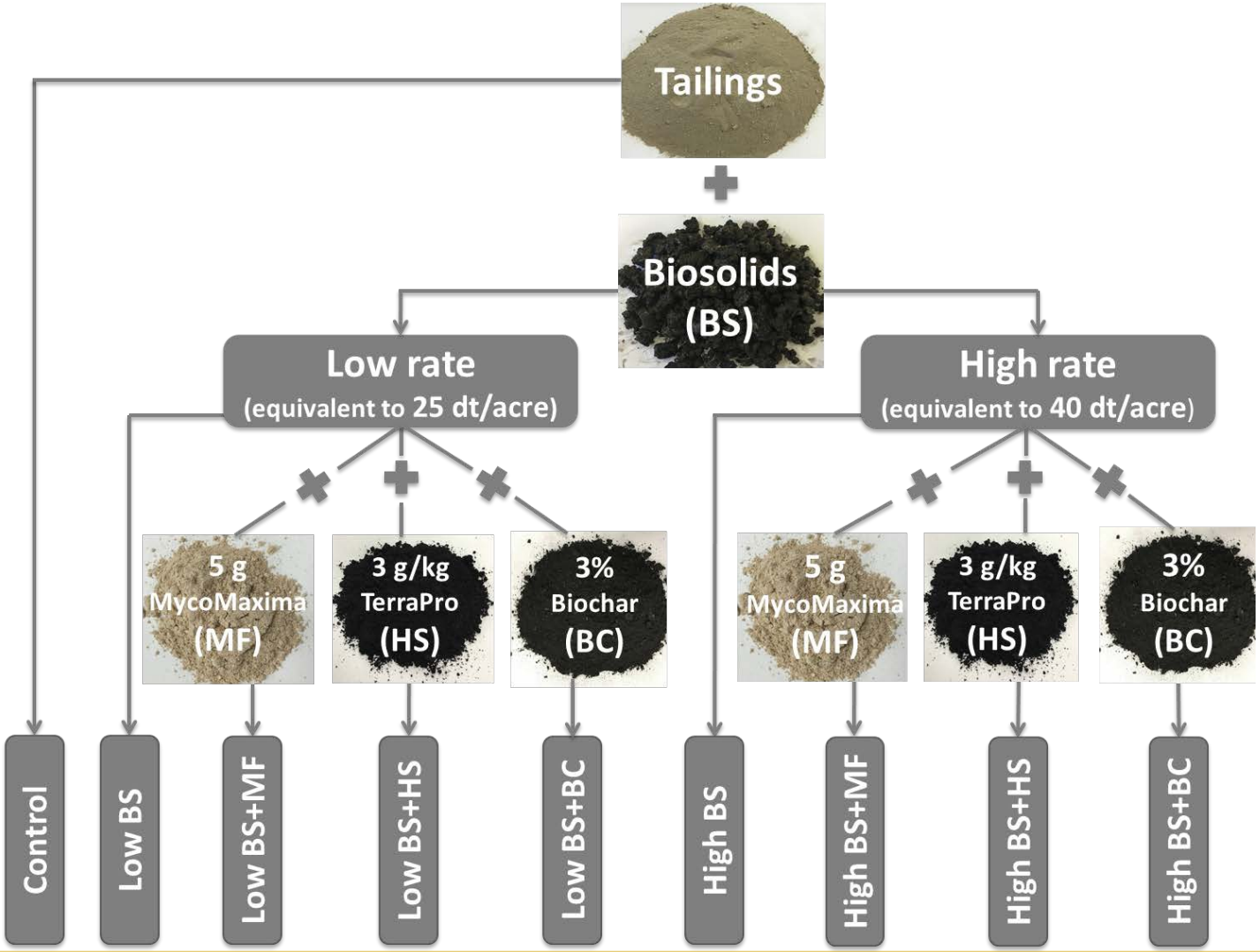
- Physicochemical properties of tailings.

Properties	Tailings
pH	7.6
CEC meq/100g	3.6
O.M. %	0.1
Bray I P lb/Ac	33
Ca lb/Ac	947
Mg lb/Ac	273
K lb/Ac	48
As (mg/kg)	52.3
Cd (mg/kg)	13.67
Co (mg/kg)	39.25
Cr (mg/kg)	11.49
Cu (mg/kg)	0.999
Pb (mg/kg)	3553
Mo (mg/kg)	2.536
Ni (mg/kg)	70.67

- High pH.
- Low CEC.
- Very low organic matter.

Experimental Work:

- Greenhouse pot experiment:
  - Treatment combinations:



Experimental Work:

- Why BS+BC combination?
  - BC application affects soil nitrogen dynamics.
  - BC adsorption of ammonia (NH_3) decreases NH_3 and NO_3 losses during BS application.
  - Nitrogen use efficiency by slow mineralization.

Experimental Work:

- Why BS+HS combination?
  - Supramolecular humic acids (HS):
    - Resist decay and characterized by long lasting in soil.
    - Affect HMs bioavailability by forming soluble or insoluble metal organic complexes.
    - Known to increase micronutrients availability especially Fe in soil with high pH.

Experimental Work:

- **BS chemical composition**
  - Rich in N, P, K

Properties	Biosolids
Total solids %	3.7
Total organic nitrogen (mg/kg)	58300
Ammonia (mg/kg)	8220
Total Kjeldahl nitrogen (mg/kg)	66500
Nitrate (mg/kg)	69.1
Nitrite (mg/kg)	ND
Total phosphorus (mg/kg)	14200
K (mg/kg)	3140
Cd (mg/kg)	ND
Cr (mg/kg)	24.6
Cu (mg/kg)	522
Pb (mg/kg)	31.5
Mo (mg/kg)	ND
Ni (mg/kg)	22.4
Zn (mg/kg)	735
Hg (mg/kg)	2.1

Experimental Work:

- **BC chemical composition**

parameter	Biochar
pH	8.64
CEC	5.5
Nitrogen %	0.318
phosphorus %	0.123
Ca %	0.507
Mg %	0.155
K %	0.123
As (mg/L)	0.5
Cd (mg/L)	0.21
Co (mg/L)	1.381
Cr (mg/L)	9.22
Cu (mg/L)	0.418
Pb (mg/L)	23.25
Mo (mg/L)	0.829
Ni (mg/L)	59.57

Experimental Work:

- Three species:

  Willows Poplars Miscanthus

- Harvested after 6 month growth.
- Aboveground and root biomass were determined.
- Root segments were collected for mycorrhizal colonization estimation.
- Fresh bulk and rhizosphere soil samples for Soil dehydrogenase activity (DHA) measurement.
- Shoot, root, and soil samples for HM and nutrient analysis .

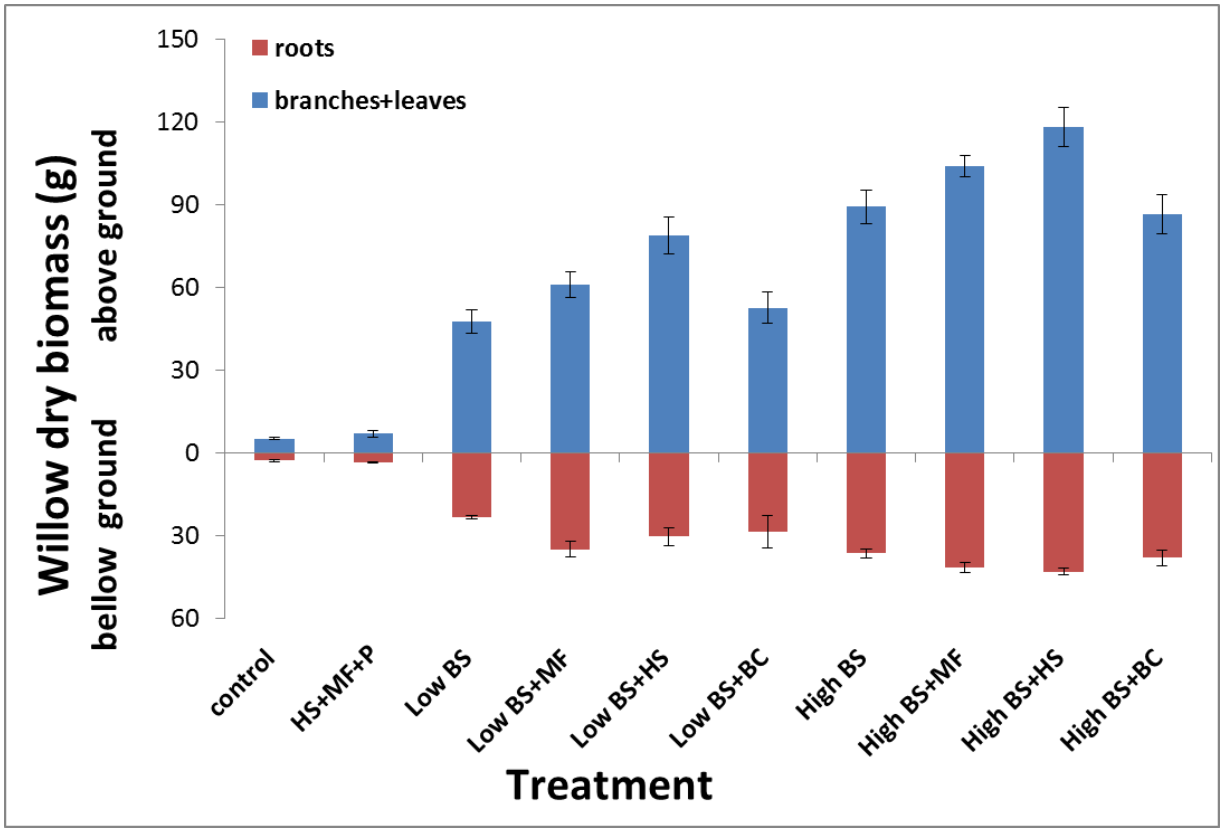
Results:

- Willows:

- Willow leaf chlorosis in control treatment caused by nutrient deficiency.

Results:

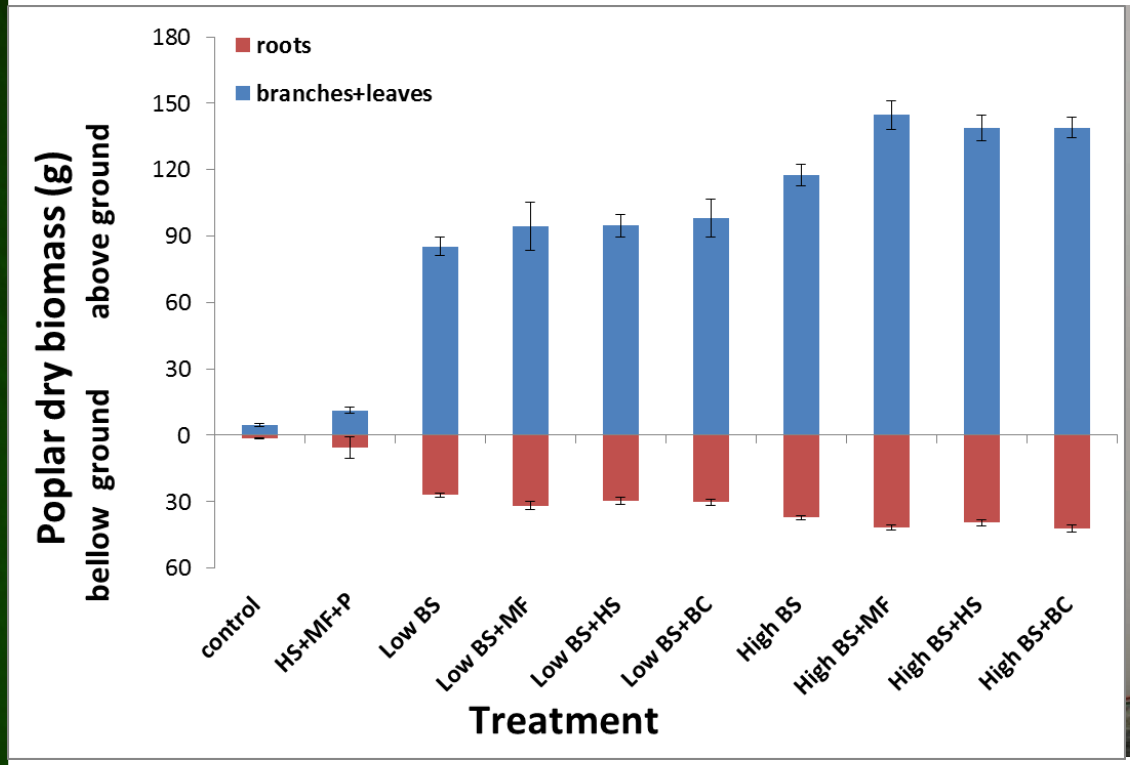
- Willows biomass:



- Up to **9** and **17** fold increase in aboveground biomass with **LowBS** and **HighBS**, respectively.
- Up to **16** and **23** fold increase in aboveground biomass with **LowBS+HS** and **HighBS+HS**, respectively.

Results:

- Poplars biomass:



- Up to **19** and **26** fold increase in aboveground biomass with **LowBS** and **HighBS**, respectively.

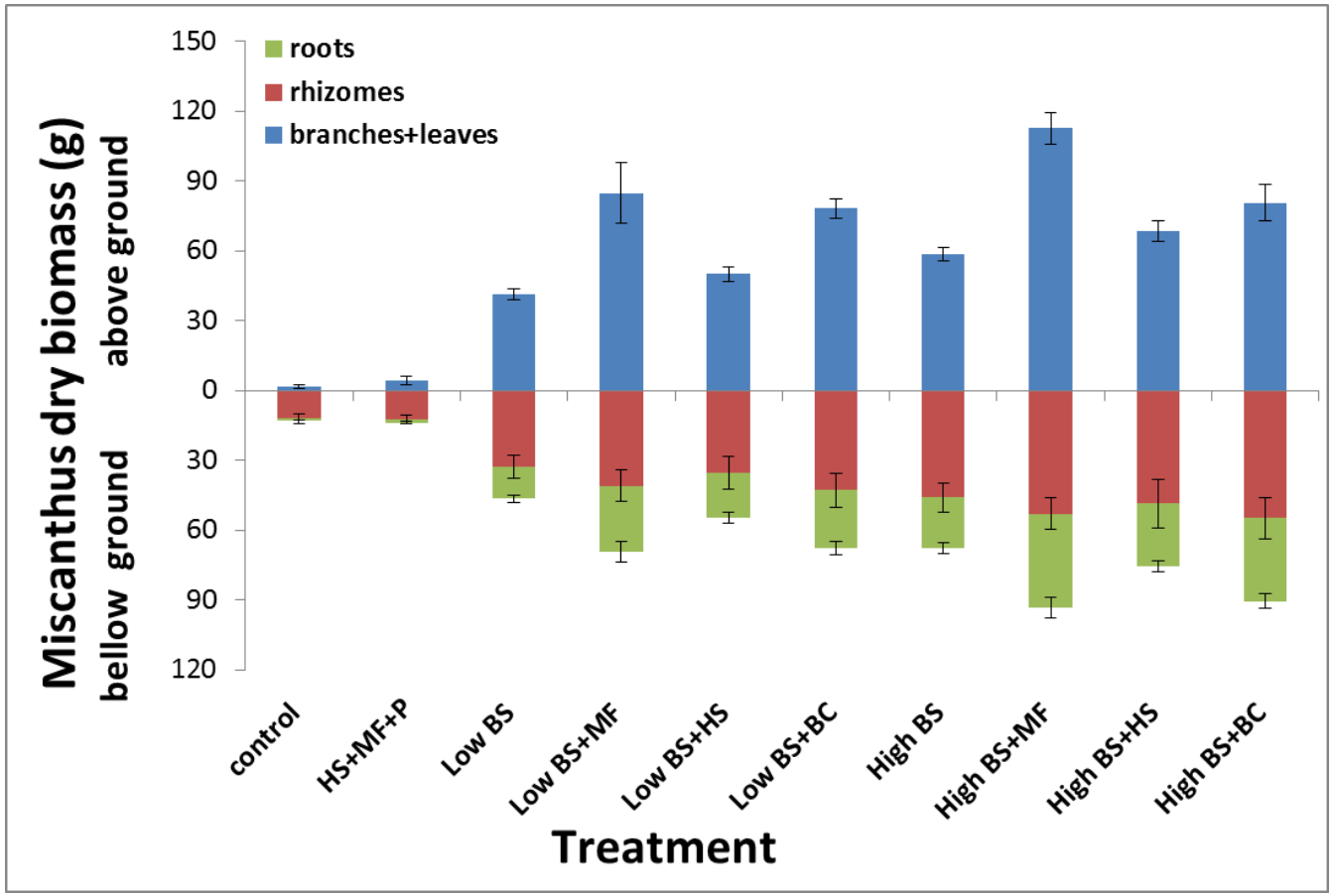
Results:

- Miscanthus:

- New growth of miscanthus rhizomes induced by BS application.

Results:

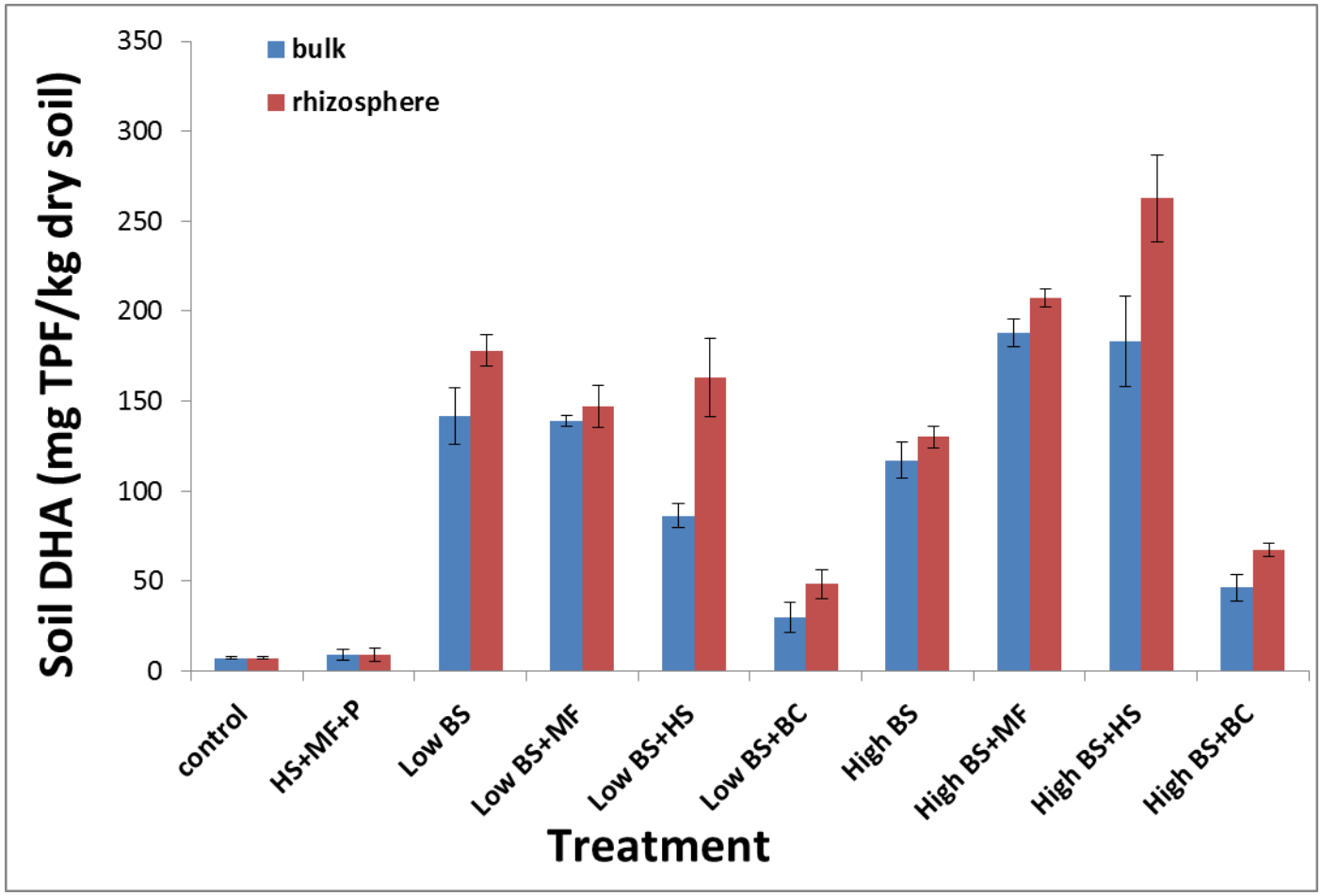
- Miscanthus biomass:



- **MF** addition significantly increased shoots biomass, up to **44** and **58** fold, when combined with **LowBS** and **HighBS**, respectively.

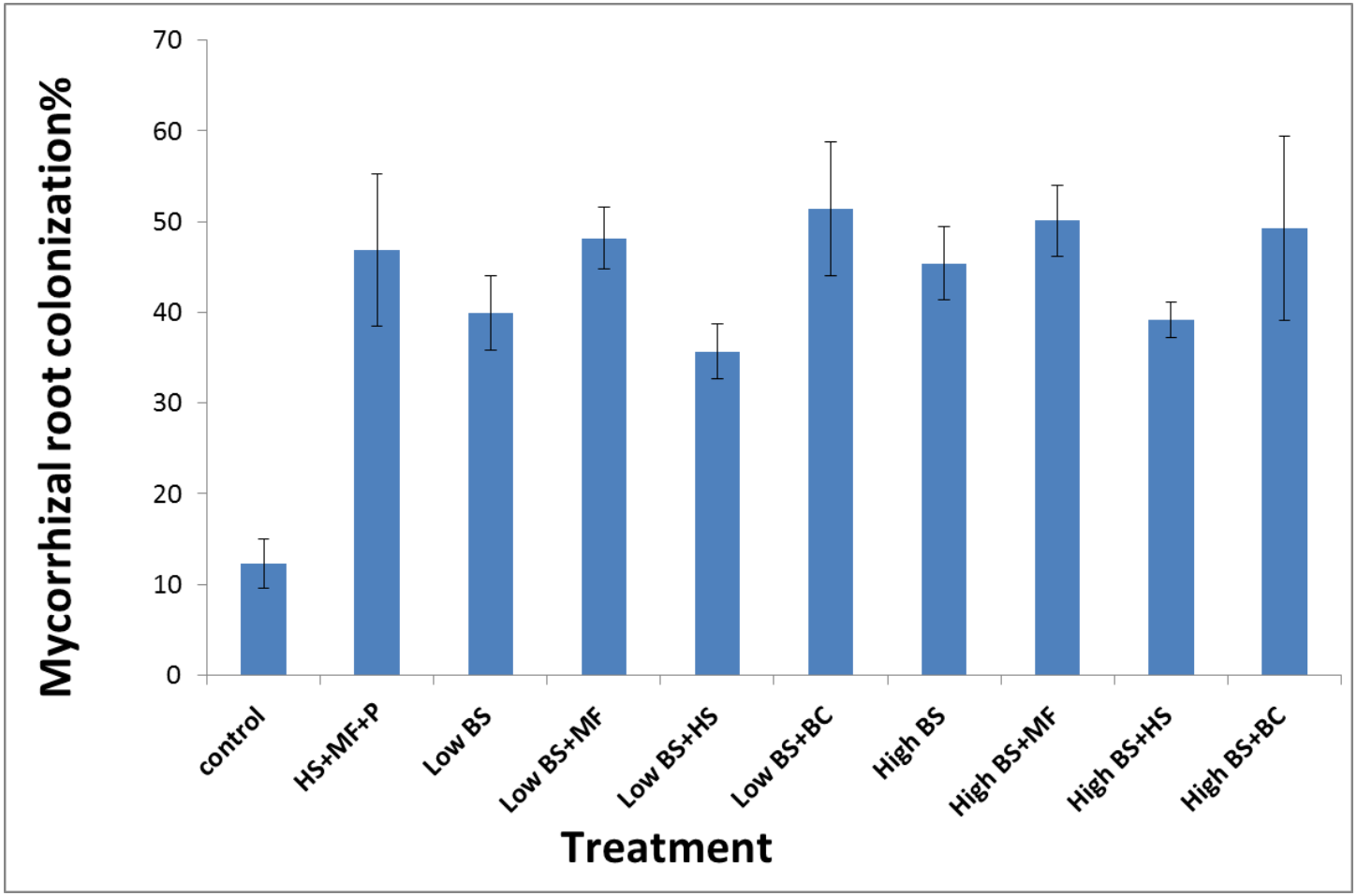
Results:

- Soil DHA: Willows



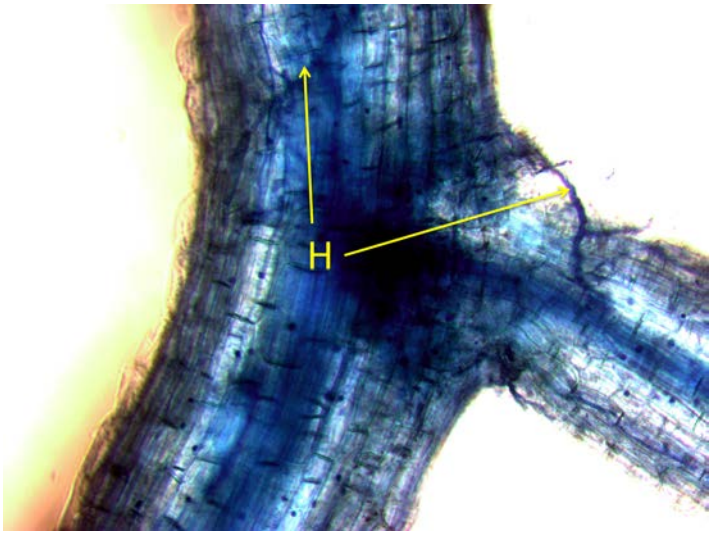
Results:

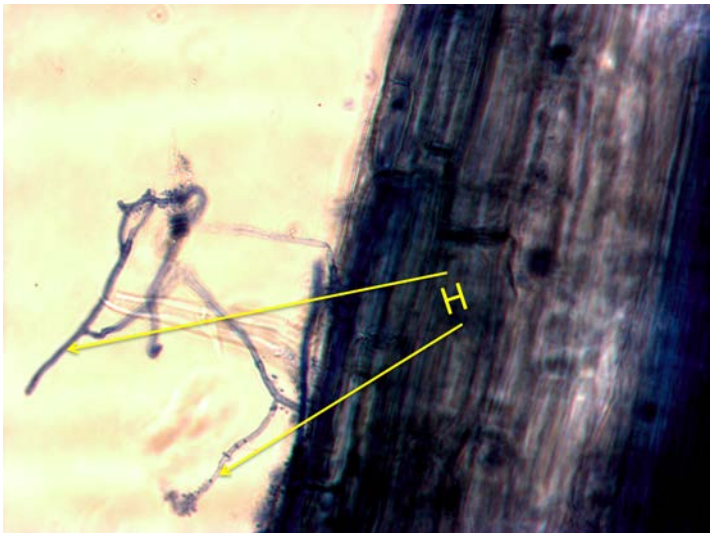
- Mycorrhizal colonization on plant roots: willows

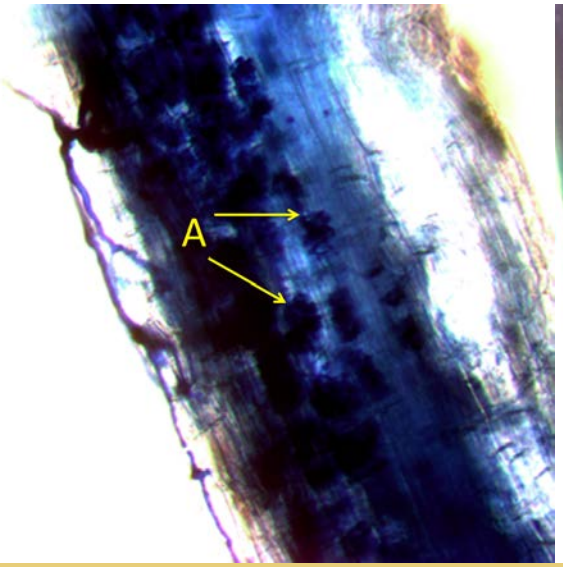


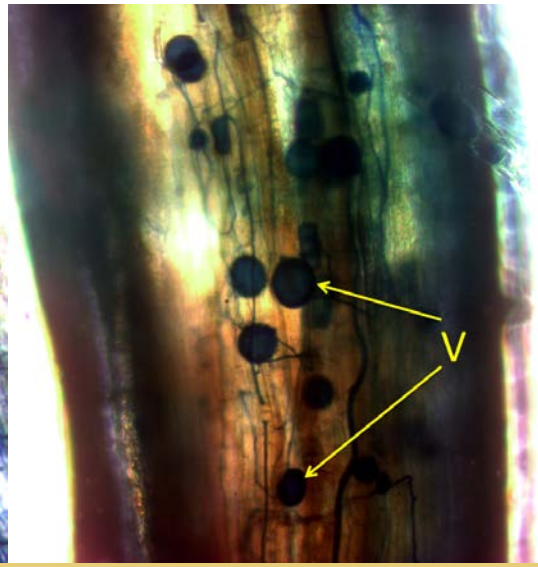
Results:

- Mycorrhizal root colonization:









Where:

H, hyphae
A, arbuscules
V, vesicles

Ongoing Analyses:

- Analyzing plant tissue for HMs and nutrients.
  - Leaves.
  - Roots.
- Analyzing soil samples for:
    - pH
    - Electrical conductivity (EC)
    - CEC
    - Organic matter (OM)
    - Total nitrogen (TN)
    - Total organic carbon (TOC)
    - HMs and nutrients
- Translocation factor (TF) will be calculated to assess the suitability of species for phytoextraction or phytostablization.

Conclusions:

- BS dramatically improved plant growth compared to un-amended tailings.
- Combinations of BS with other amendments further enhanced plant growth.
- BS significantly increased tailings microbial activity which is considered the potential indicator of soil quality.

Conclusions:

- Mycorrhizal colonization was observed on plants roots in all treatments, indicating that treatments stimulated growth of indigenous populations.

- BS application is recommended when dealing with mine tailings revegetation.

Future Work

- Pilot-scale trial to investigate:
  - The potential for lower application rate of BS with/without BC and MF for tailings revegetation under field conditions.
  - Intercropping with nitrogen fixing legumes.
  - Long-term effectiveness of BS and other amendments for revegetation of mine tailings.

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THE DOE RUN COMPANY

SOIL SECRETS
Unlocking the Secrets to a Healthy Soil

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  - Andrew Van Buren
  - Audrey Hofherr

Thank You

Questions?

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