Investigating the Influence of Soil Amendments on Nutrients and Microbial Interactions

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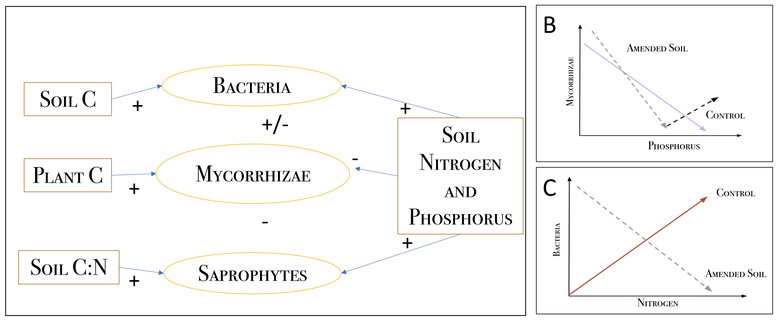
Introduction

- Ecological restoration is becoming an increasingly important tool in managing, conserving, and repairing urban ecosystems.
- The restoration of urban soils, however, presents unique challenges including: high levels of soil nutrients, poor soil structure, and low levels of plant mutualisms including mycorrhizal fungi. These issues make it difficult for plants to establish.
- Restoring soil health generally requires soil manipulation(s) and amendments to create novel habitats, e.g., biochar and compost-tea are thought to improve soil health but quantitative data are largely lacking.
- In this project, our overarching objective was to examine the effects of soil manipulation (sand addition), and amendments (biochar, woodchips, mulch, compost tea) on soil health in an urban soil restoration project.
- We used soil nutrient levels and microbial abundance and activity to test the effectiveness of these treatments.

Conceptual Framework and Hypotheses



To best describe the effects of restoration treatments on soil health, the interactions between *abiotic* (soil nutrients) and *biotic* factors (microbes, mycorrhizal fungi) must be understood (Figure 1). Here, the net effect of amendments depends on three conceptual pools: mycorrhizal fungi, bacteria and saprophytic fungi. The size of these pools can be altered by the flow of C (from plants, soil) and soil nutrient levels (N, P), and the responses of microbial/ mycorrhizal factors to soil nutrients or plant/ soil C may be negative (-) or positive (+). From this model, we generated a series of questions and associated hypotheses:

1. **Do all soil amendments lead to a decrease in soil nutrient levels?**
   - Hypothesis: All treatments reduce levels of soil N and P.

2. **What is the relationship between soil N and P and mycorrhizal colonization across different soil amendments?**
   - Hypothesis: As soil N and P levels decrease following soil amendment, mycorrhizal root colonization will increase (Figure 1B).

3. **How does the addition of compost-tea affect microbial activity?**
   - Hypothesis: Compost-tea stimulates and maintains a large soil microbial community dominated by fungi.

4. **How do saprophytic fungi respond to different soil amendments?**

Hypotheses:

   - As mycorrhizal colonization increases, saprophytic abundance decreases.
   - As soil nutrient levels decrease after amendment, saprophytic fungal activity decreases.

Methods

B	Amended with sand (MIX)	Amended with sand (MIX)	Existing soil (CBG)	Existing soil (CBG)
- Compost Tea	Mulch	Woodchips	Mulch	Control
- Compost Tea	Biochar	Control	Biochar	Woodchips
+ Compost Tea	Woodchips	Control	Biochar	Woodchips
+ Compost Tea	Mulch	Biochar	Woodchips	Mulch

Fig. 2. A) Experiment plots at the Chicago Botanic Garden; B) Layout of soil amendments and treatments.

- **Treatments**: Sixteen plots were established in May, 2018 (Figure 2A, B). Half comprised existing soil (denoted 'CBG'; 34% sand) and half were amended with sand (denoted 'MIX'; 67% sand). Four treatments were then applied to each soil type: biochar 5% v/v, 5 cm mulch, 5 cm woodchips, or no treatment. Compost tea was applied to half the plots. The area was sown with a mixture of grasses and forbs.
- **Soil analyses**: Duplicate soil samples from each plot were analyzed for plant-available (water, HCO_3-extractable) and organic P (H_2SO_4 digest) using the malachite green method, and %N and %C by combustion[1].
- **Microbial analyses**: Root samples were stained using Trypan blue[1], and examined and scored for mycorrhizal and saprophytic root colonization by light microscopy. Microbial biomass was estimated using substrate induced respiration[1].

Results

1. **Do all soil amendments lead to a decrease in soil nutrient levels?**
   - *No*. In fact, the addition of compost tea to sand-amended (MIX) soil produced a significant *increase* in soil P (CBG 27 ± 0.4; MIX 30 ± 1.0 µg g^{-1} soil, mean ± se; p= 0.024). The other amendments had no significant affect on soil %N, %C or P (p > 0.05).

2. **What is the relationship between soil N and P and mycorrhizal colonization across different soil amendments?**
   - Root colonization by arbuscular mycorrhizal fungi was *not* correlated with soil P (p = 0.245) or soil N (p= 0.056).

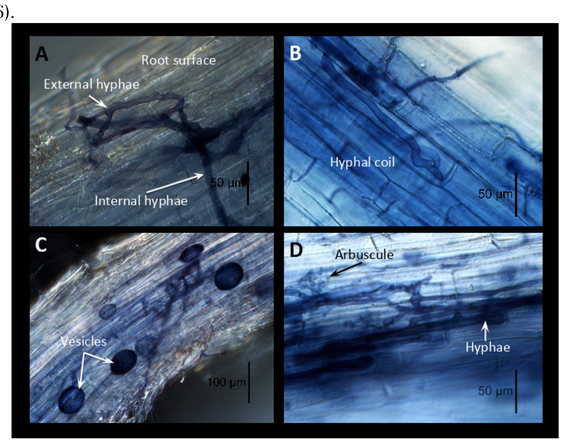


Plate: Arbuscular mycorrhizal structures found in grass roots. A) External and internal hyphae; B) large hyphal coil in enlarged root cell; C) numerous vesicles; and D) hyphae with vestigial arbuscule structures.

Results

3. **How does the addition of compost-tea affect microbial activity?**
   - *Bacterial biomass significantly increased* with the addition of compost tea from 1.36 (0.09) in Tea- plots to 2.86 (0.47) µg g^{-1} soil per day in Tea+ plots.
   - Compost tea reduced *mycorrhizal root colonization* in mulch plots but enhanced colonization in the other treatments (Figure 3).
4. **How do saprophytic fungi respond to different soil amendments?**
   - There was *no* relationship between the abundance of mycorrhizal and saprophytic fungi (p= 0.663).
   - Saprophytic fungal activity was positively correlated with soil P levels (p= 0.05).

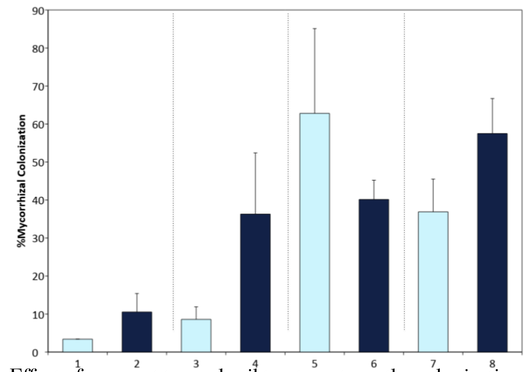


Figure 3. Effect of compost tea and soil treatments on the colonization of roots by arbuscular mycorrhizal fungi.

Conclusions

- Compost tea produced an unexpectedly large effect on soil nutrient and microbial factors and appeared to be a more important factor in restoration than the other soil amendments. The specific composition and effects of compost tea warrant further investigation.
- The negative effect of mulch on mycorrhizal fungi indicates that careful consideration should be used in using mulch in restorations.
- The important indicators of soil health in this system were biotic, i.e., mycorrhizal fungi and bacterial abundances, rather than abiotic (levels of nutrients).

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Literature Cited

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