A Rapid-Test for Biochar Effects on Seed Germination

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ABSTRACT

Biochar is being evaluated globally as an amendment to improve soil characteristics (e.g. soil water holding, nutrient exchange, microbiology, pesticide and chemical availability) to increase crop yields. Unfortunately, with the wide variety of biochars, there are no rapid tests to determine those biochar types most effective to improve soil characteristics amenable for higher crop yields. Seed germination is a critical parameter for plant establishment and may be a rapid indicator of biochar quality. We adapted a procedure used at the Oregon State University Seed Laboratory to develop a "rapid-test" for screening the effects of biochar on seed germination. For this study soils were amended with 1% biochar by weight. We used 11.0 cm square x 3.5 cm deep clear plastic containers fitted with blotter paper for seed germination. The paper was pre-moistened with de-ionized (DI) water, followed by placement of seeds (25 in a uniform 5 x 5 pattern), and covering the seeds with 15 g of the soil-biochar mixtures. Two South Carolina Coastal Plain soils, the Norfolk (Fine-loamy, kaolinitic, thermic Typic Kandiudult) and Coxville (Fine, kaolinitic, thermic Typic Paleaquults), were used. 18 biochars were evaluated that were produced from 6 feedstocks (pine chips, poultry litter, swine solids, switchgrass, and two blends of pine chips and poultry litter); with biochar from each feedstock made by slow pyrolysis at 350, 500 and 700 °C. Germination of cabbage, carrot, cucumber, lettuce, oat, onion, ryegrass and tomato were used to evaluate the effects of soil and soil amended with biochar. Results indicated differences in seed germination and shoot dry weight due to soil type and possibly soil x biochar feedstock interactions. Other measurements including pH of the soil-biochar mixtures will be evaluated. This test method can also be used for a rapid evaluation of effects on seed germination of biochar used to ameliorating effects of heavy metals and effects other soil amendments/ treatments in addition to biochar.

OBJECTIVE

To develop a relatively rapid throughput procedure for evaluating the effect of biochar on seed germination and development. Important was developing a procedure that could quickly separate determine which biochars enhance or inhibit germination. Such a screening procedure provides a means of *a priori* selecting or avoiding biochars to amend specific soils for agricultural crop production.

METHODS AND MATERIALS

Building upon Oregon State University Seed Testing Laboratory methods we developed a method to evaluate the effect of biochar amended soil on seed germination. Figure 1 outlines the general procedure developed.

Flowchart for Rapid-Test of Biochar Effects on Seed Germination

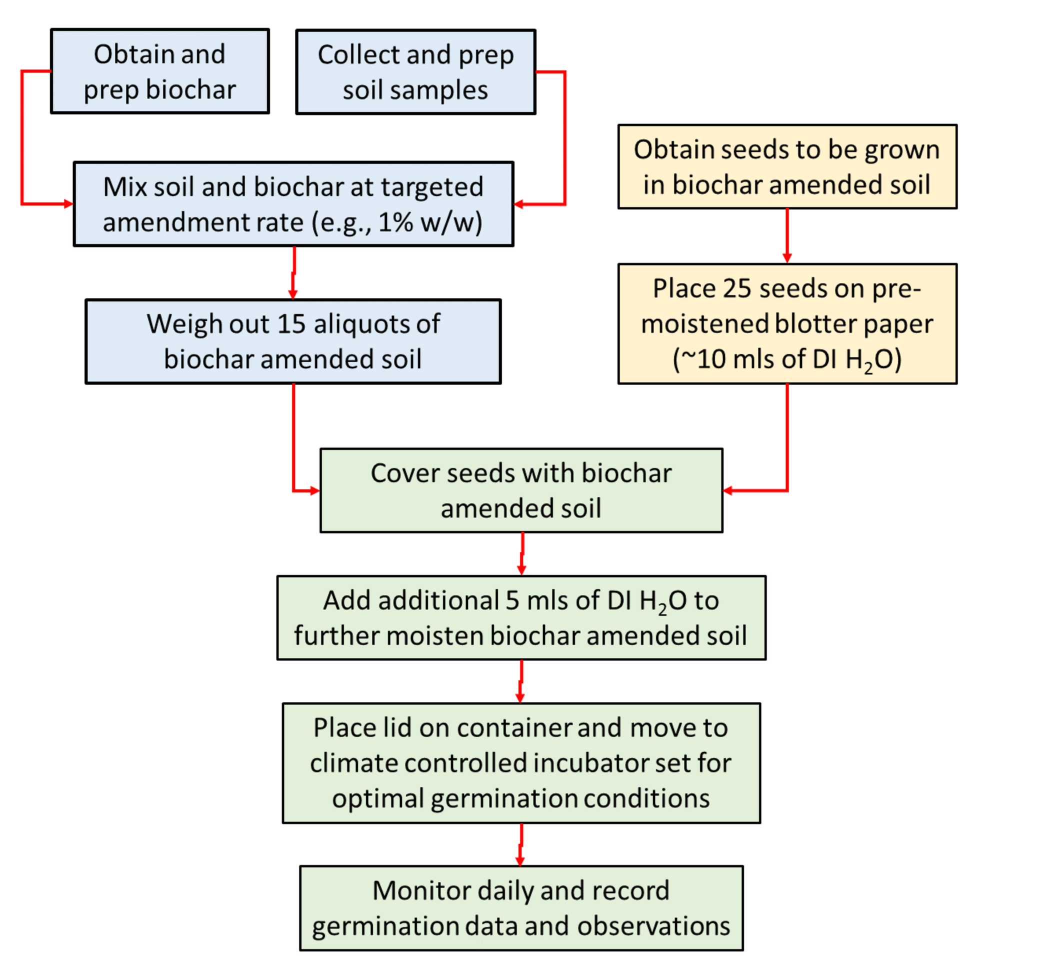

Figure 1. Generalized procedure for screening the effects of biochar on seed germination.

Methods Highlights

- Small rectangular acrylic plastic seed germination containers (Figure 2) with 15 g/soil+biochar per container. The soil were amended with 1% biochar (w/w).
- Two soils from Florence, SC were used in this study: Norfolk, Fine-loamy, kaolinitic, thermic Typic Kandiudults (loamy sand typical pedon); and Coxville. Fine, kaolinitic, thermic Typic Paleaquults (fine sandy loam typical pedon).
- Eight species of plants typically used for phytotoxicity testing, which are agriculturally important and represent different end uses (Oats, Cabbage, Carrot, Cucumber, Lettuce, Onion, Ryegrass and Tomato).
- 25 seeds per experimental unit (plastic germination containers) with 4 replicates (see Figure 2).
- Controls (seeds in un-amended soil) and 18 biochar treatments made from 6 feedstocks (see Table 1 for details on biochars used).
- Plants grown under growth chamber conditions for germination and approximately for one week after emergence (see Figure 5).
- Response endpoints: emergence (cotyledon showing) and shoot dry weight 7 days after full emergence.
- Statistics: Data arcsine transformed for % germination and log10 transformed for shoot dry weight/plant. Weighting was employed if variance is greater than a factor of 10 among treatments. ANOVA (without biochar control), Bonferroni's test for comparison of biochar response to control plants.

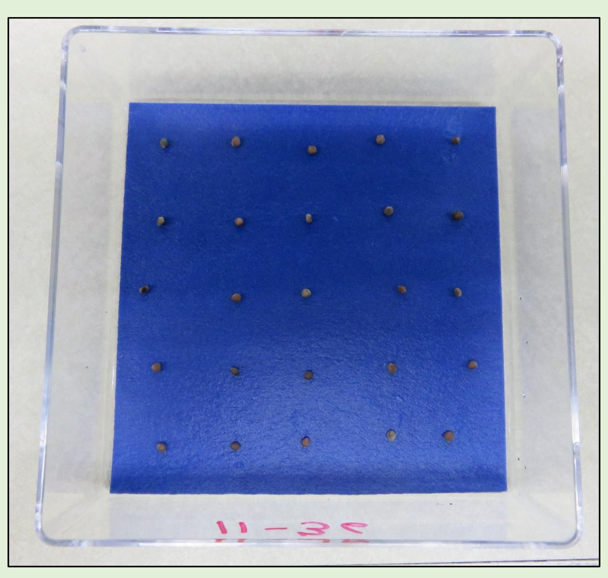

Figure 2. Clear plastic germination box, moistened blue blotter paper and 25 seeds placed in a 5 x 5 array..

METHODS AND MATERIALS (continued)

Table 1. Listing of 18 biochars, made from 4 different feedstocks and two blends of feedstocks., used in this study. Biochar pellets were ground to dust before mixing with the soil at a rate of 1% (w/w). Sample codes and production temperature are reported. †HTT = Highest Temperature Treatment feedstock reached during pyrolysis.

Feedstock	HTT (°C)†	Sample Code
100% Pine Chips	350	PC-350
100% Pine Chips	500	PC-500
100% Pine Chips	700	PC-700
100% Switchgrass	350	SG-350
100% Switchgrass	500	SG-500
100% Switchgrass	700	SG-700
100% Swine Solids	350	SS-350
100% Swine Solids	500	SS-500
100% Swine Solids	700	SS-700
100% Poultry Litter	350	PL-350
100% Poultry Litter	500	PL-500
100% Poultry Litter	700	PL-700
50% Pine Chips:50% Poultry Litter	350	55-350
50% Pine Chips:50% Poultry Litter	500	55-500
50% Pine Chips:50% Poultry Litter	700	55-700
80% Pine Chips:20% Poultry Litter	350	82-350
80% Pine Chips:20% Poultry Litter	500	82-500
80% Pine Chips:20% Poultry Litter	700	82-700

Figure 3. Left: stock mixtures of soil and biochar; Center: 15 gram aliquots of biochar amended soil; and Right: Covering seeds with biochar amended soil.

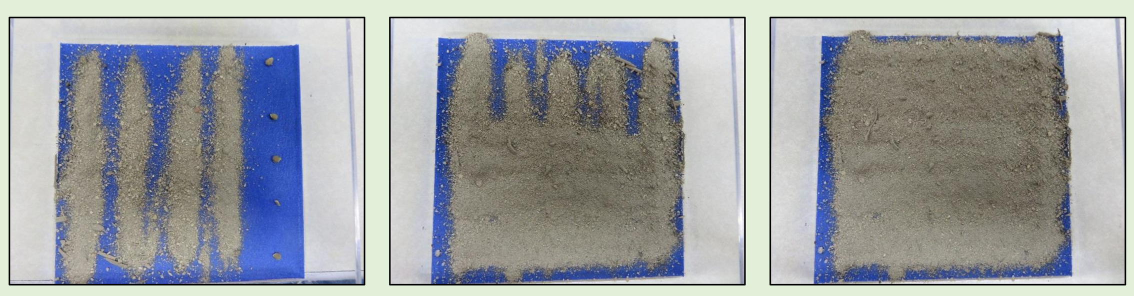

Figure 4. Left to right: Progression of covering seeds with biochar amended soil.

Figure 5. Left: Germination boxes in climate-controlled growth chamber; Center: Early emergence; Right: Seedlings approximately 1 week after emergence.

Figure 6. Processing Ryegrass samples to obtain shoot dry weights. Left: Ryegrass shoots in biochar amended Norfolk soil; Center: Clipping Ryegrass shoots; Right: Ryegrass shoots in tared weighing tins prior to oven drying.

RESULTS

Table 2. Results of Analysis of Variance for seed germination test. P values in bold are significant at p < 0.05. †HTT = Highest Temperature Treatment feedstock reached during pyrolysis.

Species	Response	n	Feedstock	HTT (°C)†	Feedstock * HTT (°C)	Soil	Feedstock * Soil	HTT (°C) * Soil	Feedstock * HTT (°C) * Soil
Cabbage	% Emerg.	144	0.734	0.394	0.347	**0.036**	0.455	0.688	0.538
Carrot	% Emerg.	144	0.252	0.280	0.055	**<.0001**	0.174	0.153	**0.008**
Cucumber	% Emerg.	144	0.602	0.258	0.529	**0.016**	0.083	0.243	0.098
Lettuce	% Emerg.	144	0.638	0.110	**0.030**	**0.040**	0.094	0.728	0.325
Oat	% Emerg.	143	0.704	0.282	0.486	0.304	0.847	0.813	0.331
Onion	% Emerg.	144	0.065	0.519	0.152	0.994	0.329	0.174	0.116
Ryegrass	% Emerg.	144	0.245	0.894	0.718	0.595	**0.026**	0.467	0.899
Tomato	% Emerg.	144	**0.002**	0.496	0.899	**<.0001**	**0.027**	0.391	0.859
Cabbage	Shoot DW	144	0.075	0.126	0.856	1.000	**<.0001**	0.960	0.690
Carrot	Shoot DW	144	**0.001**	0.664	0.135	**<.0001**	0.673	0.422	0.729
Cucumber	Shoot DW	144	**0.001**	0.088	0.072	**0.016**	0.217	**0.008**	0.074
Lettuce	Shoot DW	144	**<.0001**	**0.006**	**<.0001**	**<.0001**	**0.001**	0.366	0.253
Oat	Shoot DW	143	**0.024**	0.595	0.457	0.367	0.058	0.762	0.105
Onion	Shoot DW	144	0.281	0.585	**0.005**	**<.0001**	0.544	0.271	0.092
Ryegrass	Shoot DW	144	**<.0001**	0.991	0.194	0.805	0.281	0.782	0.437
Tomato	Shoot DW	144	**0.002**	0.333	0.351	**<.0001**	0.913	0.418	0.128

RESULTS (Continued)

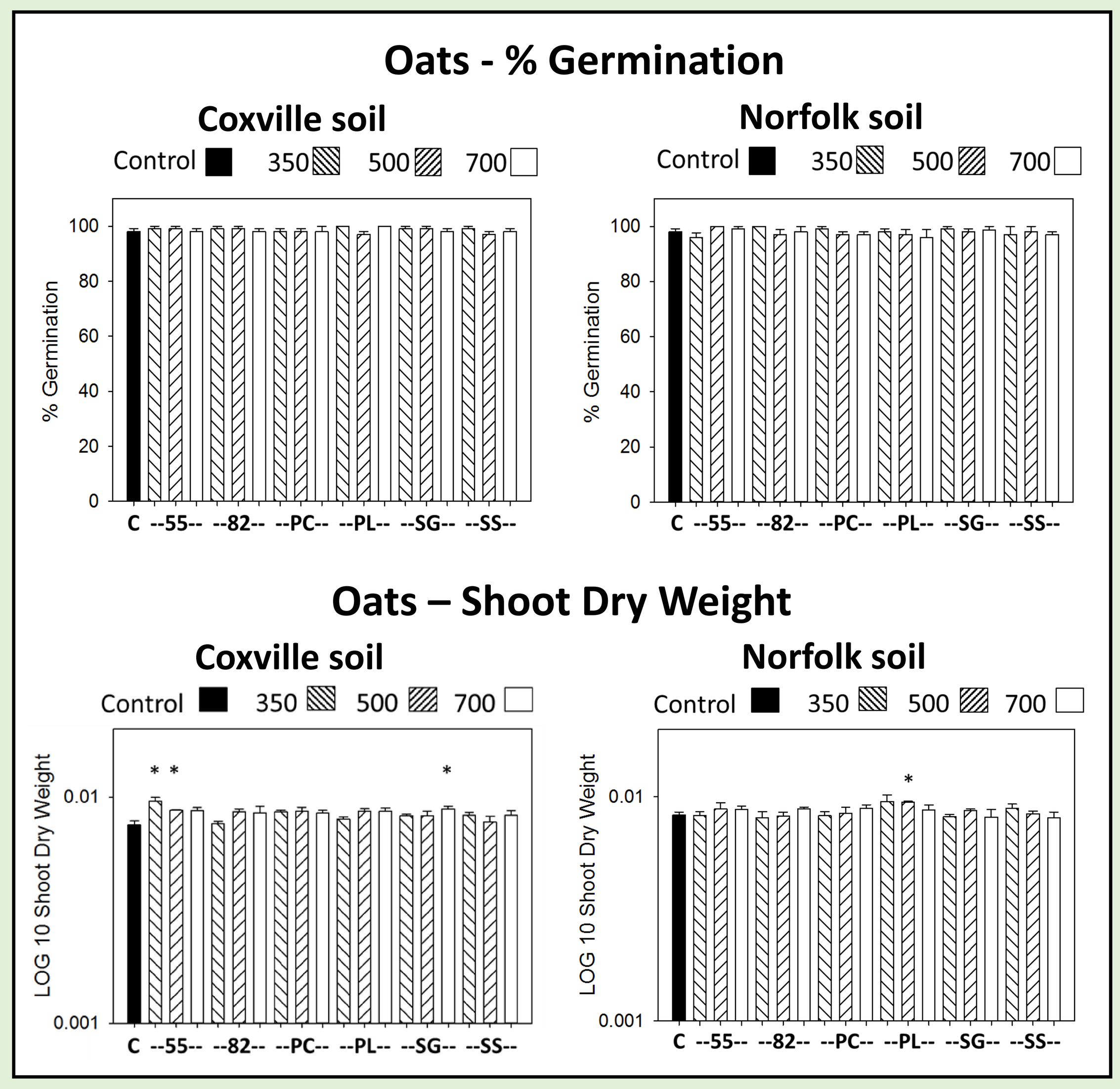

Figure 6. Effect of biochar treatments on % germination and shoot dry weight for oats. Left graphs for Coxville soil and right graphs for Norfolk soil. An "*" above a bar indicates significant difference from controls at p<0.05. Bars are +/- standard error for 4 experimental units.

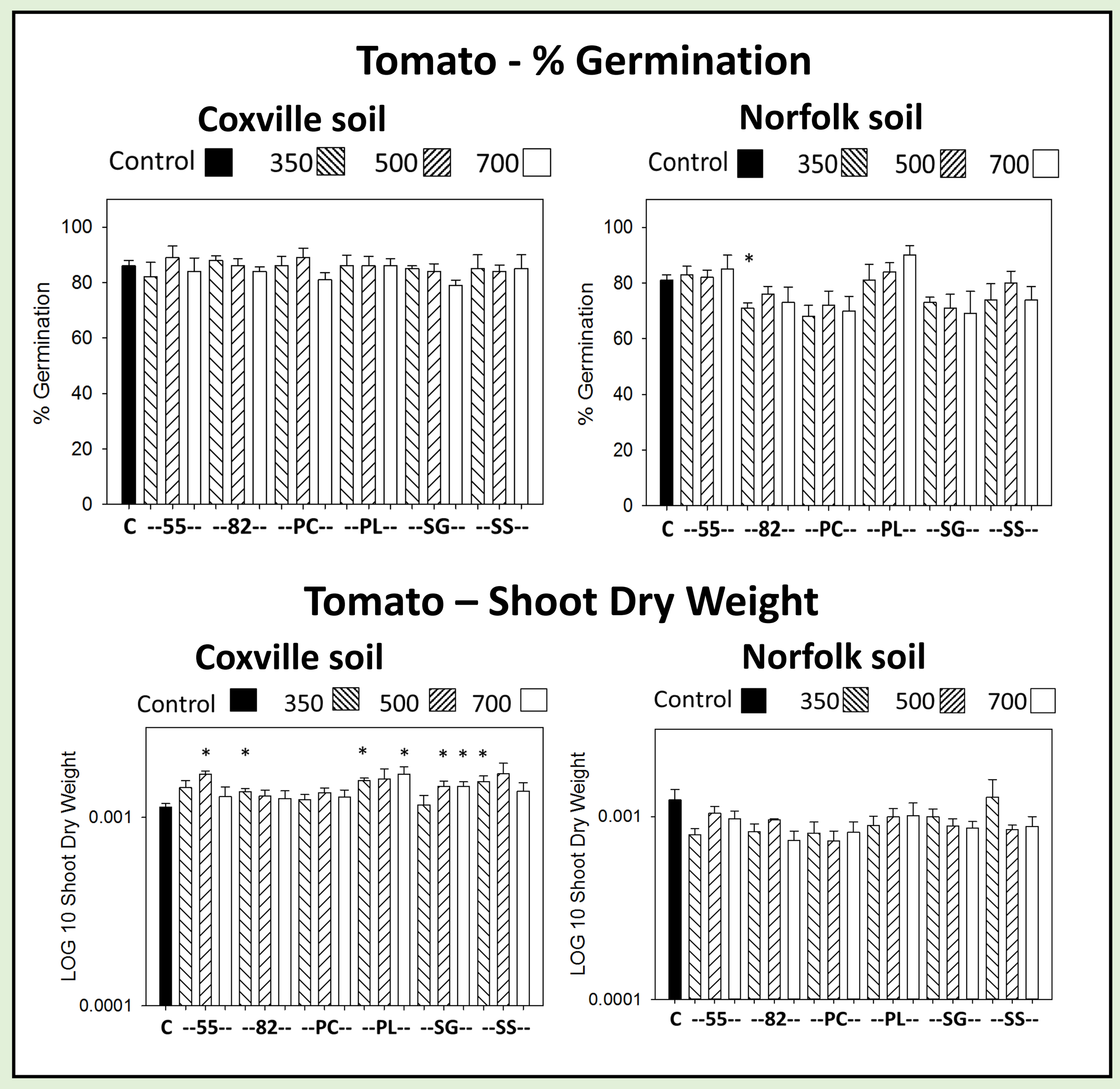

Figure 7. Effect of biochar treatments on % germination and shoot dry weight for tomato. Left graphs for Coxville soil and right graphs for Norfolk soil. An "*" above a bar indicates significant difference from controls at p<0.05. Bars are +/- standard error for 4 experimental units.

CONCLUSIONS

- The procedure we developed is simple to use and provides a relatively rapid means of screening the effects of biochar amended soil on seed germination and shoot dry weight.
- Significant soil and biochar effects on germination can be detected 7 days after full germination.
- The largest effect on germination we observed was the influence of soil type on germination.
- Biochar feedstock was significant for 6 of 8 species for shoot dry weight (Table 2), which may be an early indicator of crop productivity.
- The main effects we observed are primarily on shoot dry weight (Figures 7 and 8) and not on % germination as shown for tomato and oats.

ADDITIONAL RESEARCH

- We are also evaluating the effect of amending soil with biochar on soil pH, electrical conductivity and available soil P as the factors may also affect seed germination and shoot dry weights.
- Another area of active research for us is the use of biochar to remediate contaminated soils. This procedure will be used to evaluate the use of native plant seeds to establish native plant communities on remediated soil to reduce wind and water erosion of contaminated soil materials.

CONTACT INFORMATION

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