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Can biochar be used as a seed coating to improve native plant germination and growth in arid conditions?

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ABSTRACT

Direct seeding is a common large-scale restoration practice for revegetating arid and semi-arid lands, but success can be limited by moisture and temperature. Seed coating technologies that use biochar may have the potential to overcome moisture and temperature limitations on native plant germination and growth. Biochar is a popular agronomic tool for improving soil properties, such as water availability and nutrient retention and has been recently marketed, but not tested, as a seed coating. We analyzed the effect of biochar seed coating thicknesses on the germination and growth of four plant species native to western United States: mountain brome (*Bromus marginatus*), prairie junegrasss (*Koeleria cristata*), Wyeth's buckwheat (*Eriogonum heracleoides*), and western yarrow (*Achillea millefolium*). Across different temperature and water potential treatments using environmental chambers and polyethylene glycol (PEG) solutions, biochar coating applied at different thicknesses had either a neutral or negative effect on germination for all species. In the field, biochar seed coatings slightly improved mountain brome root weight and prairie junegrass cover. Our results, alongside the high economic expense of native plant seed and direct seeding operations, suggest that biochar, by itself, may not be an appropriate seed coating for improving native plant establishment.

1. Introduction

Direct seeding in the western United States is a common restoration practice, but germination and seedling emergence can be major barriers to successful revegetation (Chambers, 2000; James et al., 2011). Seedbed conditions are highly variable for temperature and moisture (Hardegree et al., 2003). Not only do the conditions need to occur that allow seeds to germinate, but for some species the range of temperature and moisture needed for emergence and growth is narrow (Fyfield and Gregory, 1989). Seed coatings that facilitate germination and initial growth may be especially useful in situations where nutrients and water are limited (Taylor and Harman, 1990; Madsen et al., 2012). A recent tool marketed for restoration is biochar, a fine, carbon rich material that is a byproduct of pyrolysis of materials such as wood, waste organic materials, and agricultural crop residues at temperatures above 400 °C under complete or partial elimination of oxygen (Lehmann, 2007; Beesley et al., 2011). Because of its porous structure, large surface area, and negatively charged surface area (Liang et al., 2006; Downie et al., 2009), biochar has potential to increase water holding capacity and plant-nutrient retention in many soils (Gaskin et al., 2007; Laird et al., 2010; Kammann et al., 2011; Basso et al., 2013) and is commonly used to amend food crop soils (Blackwell et al., 2009). Companies now market biochar as a seed coating to improve germination and growth by increasing water availability and uptake, which appears counterintuitive given the hydrophobicity of biochar (Page-Dumroese et al., 2015). Until now, no research has been conducted or published about the effects of biochar seed coatings on plant germination and growth.

In this study, we evaluate the effect of biochar seed coating at various thicknesses on germination and growth of four native species commonly used for arid and semi-arid land restoration in

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the western U.S. Our goal was to determine the germination of non-coated and biochar-coated seeds in a controlled laboratory setting and under uniform field conditions. We hypothesized that germination of native species treated with biochar coatings would differ from non-coated seeds when exposed to different temperature and water potential conditions and that growth of native species treated with biochar seed coatings would differ from non-coated seeds when sown in a common field.

2. Materials and methods

2.1. Biochar seed coating

Mountain brome (*Bromus marginatus*), prairie junegrass (*Koeleria cristata*), Wyeth's buckwheat (*Eriogonum heracleoides*), and western yarrow (*Achillea millefolium*) seeds (hereafter brome, junegrass, buckwheat, and yarrow) were obtained from Washington State (U.S.A.) (Table 1). These species are adapted to a wide range of climatic and soil conditions making them suitable for revegetating and stabilizing disturbed sites in western North America. The biochar was created by heating ponderosa (*Pinus ponderosa*) and lodgepole (*Pinus contorta*) pine logs at 600 °C for 8 h residence time in a kiln and then crushing the material to a particle size range of 0.42–2 mm. A bench-top rotostat batch mixer equipped with an air dryer for curing was used to combine ingredients (a proprietary blend of biochar, standard alcohol [PVOH] polymer, and seeds). See Table 2 for chemical and physical properties of the biochar, which was applied at 1:1, 2:1, and 4:1 by seed weight. Seeds/kg, viability (tetrazolium chloride test [TZ]), and germination of coated and non-coated seeds were determined (Table 1) following standard seed testing guidelines (AOSA, 2013; ISTA, 2013). Seeds/kg was determined with eight, 100-seed samples. The TZ test was conducted on four, 100-seed samples. Brome, junegrass, and yarrow were germinated at alternating 20 °C (16 h dark)/30 °C (8 h light) and counts finished after 15, 30, and 18 days, respectively. Buckwheat seeds were chilled 28 days in moist conditions and stratified and non-stratified seeds were germinated at alternating 15 °C (16 h dark)/25 °C (8 h light) and counted for 30 days. After analysis, buckwheat seeds required further cleaning on a gravity table to remove inert matter.

Table 2
Chemical and physical composition of biochar seed coatings produced from beetle-killed ponderosa and lodgepole pine logs. Chemical characteristics of the biochar were performed at the Analytical Sciences Laboratory, University of Idaho, Moscow (U.S.A.) and physical characteristics were performed by the U.S. Environmental Protection Agency in Corvallis, Oregon (U.S.A.).

Volatile matter (%)	16.8
Fixed carbon (%)	77.7
Ash content (%)	5.5
Carbon (%)	86.0
Nitrogen (%)	0.18
Calcium (mg/mL)	5100
Magnesium (mg/mL)	930
Potassium (mg/mL)	2400
Phosphorus (μg/g)	280
Sulfur (μg/g)	120
Chromium (μg/g)	110
Copper (μg/g)	30
Iron (μg/g)	13,000
Manganese (μg/g)	480
Zinc (μg/g)	53

2.2. Germination experiment

Seeds were germinated using the water potential control system developed by Hardegree and Emmerich (1992) under three constant temperatures replicated in environmental chambers (Hardegree and Burgess, 1995). The water potential control system consists of a membrane-bottom germination cup, the bottom of which is in contact with a solution reservoir of polyethylene glycol (PEG). PEG was mixed with water to yield osmotic solutions with a water potential of −0.033, −0.5, and −1.0 MPa. These solutions were mixed separately for each temperature to account for the thermal dependence of PEG-solution water potential (Michel and

Table 1
Mean characteristics (standard deviation) of non-coated and biochar-coated seeds of four native species acquired in Washington State and used in the germination and field study. Viability (tetrazolium chloride test [TZ]), germination, and seeds/kg of non-coated and biochar-coated seeds were determined at the U.S. National Seed Laboratory (Macon, Georgia), generally following established International Seed Testing Association (ISTA, 2013) and Association of Official Seed Analysts (AOSA, 2013) guidelines. Wyeth's buckwheat germination was determined for non-stratified and stratified (chilled 28 days) seeds.

	Purity %	Viability (TZ) %	Germination %	Seeds/kg
Mountain brome				
Moses Lake, WA				
Non-coated	99.7	81.8 (14.7)	79	95,678 (1102)
1:1		81.3 (15.9)	73	58,043 (525)
2:1		82.8 (13.3)	89	38,146 (124)
4:1		85.5 (10.4)	81	22,050 (226)
Prairie junegrass				
Eltopia, WA				
Non-coated	98.4	80.0 (8.1)	63	4,027,723 (52,644)
1:1		76.0 (16.1)	63	2,296,662 (36,453)
2:1		77.8 (7.2)	70	1,832,234 (31,554)
4:1		67.0 (8.7)	74	1,115,655 (31,451)
Wyeth's buckwheat				
Moses Lake, WA			Non-strat, strat	
Non-coated	75.7	54.0 (2.9)	9, 16	369,797 (2798)
1:1		45.5 (14.1)	6, 11	251,924 (3283)
2:1		35.5 (9.3)	6, 13	180,347 (3018)
4:1		23.3 (9.0)	0, 5	112,479 (2967)
Western yarrow				
Moses Lake, WA				
Non-coated	98.7	89.8 (10.2)	91	4,641,311 (98,942)
1:1		93.0 (5.9)	86	2,568,930 (112,269)
2:1		86.3 (11.2)	89	1,598,317 (38,327)
4:1		88.5 (10.7)	88	1,183,714 (29,974)