Ecological Engineering 108 (2017) 78–82

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Short communication

Ecological role of pyrolysis by-products in seed germination of grass species

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ARTICLE INFO

Keywords:
Smoke water
Petroleum coke
Biochar
Bottom ash
Fly ash
Seed germination

ABSTRACT

Smoke water is well known for its role in seed germination. Many pyrolysis by-products from industry may provide the same ecological function as smoke water, including stimulation of seed germination. Germination responses were assessed for 17 grass species (native to western Canada and commonly used in land reclamation) and 6 pyrolysis by-product solutions (karrikinolide, smoke water, coke, bottom ash, fly ash, biochar) in a laboratory experiment. For 10 of the 17 species studied, germination percentage was significantly increased by at least one pyrolysis by-product, and 3 species were stimulated by all pyrolysis by-products; 3 species had germination reduced by pyrolysis by-products; and almost a quarter of the species were unaffected by pyrolysis by-products.

1. Introduction

Fire is a key ecological process, noted for its influence on ecosystem composition and distribution. The mechanisms that cue seed germination in the post-fire environment could be heat or chemicals released from combustion of plant material (Keeley et al., 1985). Plant derived smoke can be an important trigger in promoting seed germination in a wide range of plant species from Australia, North America and South Africa (Abu, 2014). Karrikinolide, a compound in smoke water, has promoted seed germination (Flematti et al., 2004), and the stimulating effects of smoke on seed germination for land reclamation species have been assessed for Canadian oil sands mines (MacKenzie, 2013). Although some industrial by-products are generated from pyrolysis, including smoke, little research has been conducted on utilization of these pyrolysis by-products to enhance seed germination in reclamation. Bottom ash, fly ash, biochar and petroleum coke are common waste materials from pyrolysis that could be potential resources to promote seed germination for reclamation purposes.

Bottom ash and fly ash are combustion residuals that are treated as waste materials in coal powered energy production. Fly ash has been proposed for soil amendment at low application rates to improve soil physical and chemical properties (Hammermeister et al., 1998; Singh et al., 1997), although high application rates resulted in metal pollution and hindered microbial activity (Wong and Wong, 1989).

When bitumen is converted to heavy crude petroleum, petroleum coke is a by-product from the energy industry and is generated in the cracking process (pyrolysis). Naeth and Wilkinson (2002) found several reclamation grass species showed potential for establishment in soil amended with coke. Despite selected plant species surviving in coke, multiple stresses from water, nutrient deficiencies and potential metal toxicity were observed.

Biochar is created by pyrolysis of biomass at 400–500 °C under complete or partial exclusion of oxygen. Numerous studies found biochar could improve soil fertility, soil nitrification, create habitat for microorganisms (Pandey et al., 2016; Pietikainen et al., 2000) and improve plant productivity (Gurwick et al., 2013), Soil amended with charcoal significantly diminished plant biomass, potentially due to a toxic substance generated during charcoal formation (Gundale and DeLuca, 2007; Singh et al., 2015).

Understanding effects of pyrolysis by-products on seed germination of native grass species will help in industrial waste utilization and in reclamation for various soil conditions. The objective of this study was to investigate the potential ecological role of smoke water, karrikinolide and four industrial pyrolysis by-products (petroleum coke, biochar, bottom ash, fly ash) on germination of seventeen native grass species.

2. Materials and methods

A laboratory germination experiment was conducted to assess six pyrolysis materials (smoke water, biochar, coke, fly ash, bottom ash, karrikinolide). Smoke water was generated by bubbling smoke from a 60 L steel combustion drum through 10 L of distilled water for 1 h by suction. Six kilograms of dry woodchips from local native woodlands was used as fuel. The resultant dark brown smoke water was collected

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http://dx.doi.org/10.1016/j.ecoleng.2017.08.018
Received 13 June 2016; Received in revised form 25 July 2017; Accepted 15 August 2017

Table 1
Scientific and common names of species evaluated and age of the seed.

Species Name	Common Name	Seed Age (years)
Agrostis scabra Willd.	Tickle grass	4
Bouteloua gracilis Willd. ex Kunth) Lag. ex Griffiths	Blue grama grass	3
Bromus ciliatus L.	Fringed brome grass	4
Bromus carinatus Hook. & Arn.	California brome grass	4
Calamagrostis canadensis (Michx.) P. Beauv.	Blue joint	4
Festuca hallii (Vasey) Piper	Plains rough fescue	3
Festuca campestris Rydb.	Foothills rough fescue	4
Koeleria macrantha (Ledeb.) J.A. Schultes	June grass	3
Oryzopsis hymenoides (Roem. & Schult.) Barkworth	Indian rice grass	4
Panicum virgatum L.	Switch grass	2
Schyzachirium scoparium (Michx.) Nash	Little bluestem	2
Sorghastrum nutans (L.) Nash	Indian grass	2
Sporobolus cryptandrus (Torr.) A. Gray	Sand dropseed	3
Stipa comata (Trin. & Rupr.)	Needle and thread grass	4
Stipa curtiseta (Hitchc.) Barkworth	Western porcupine grass	4
Stipa viridula (Trin.) Barkworth	Green needle grass	5
Trisetum spicatum (L.) K. Richt.	Spike trisetum	6

in a glass bottle and stored in a laboratory freezer at −18 °C until use. Smoke water was diluted with distilled water at 1:10 (v/v) for the experiment. Aqueous extracts of solid pyrolysis by-products (biochar, coke, fly ash, bottom ash) were prepared separately by grinding, then stirring, 50 g of material into 500 mL of distilled water at room temperature for 12 h, followed by gravity filtering through Whatman #1 filter paper. Karrikinolide solution was made by diluting solid karrikinolide with distilled water at 1 ppb (=0.001 mg/L) concentration. These solutions were stored in a laboratory refrigerator at 4 °C until use.

Seeds of 17 grass species (Table 1) native to western Canada and used for reclamation were selected on the basis of low, zero or inconstant germination under previous laboratory or field conditions. Three replications, of 25 seeds each, were evaluated for each species, for a total of 357 units (6 pyrolysis materials + a control × 17 species × 3 replications).

Seeds were placed in 90 mm petri dishes lined with paper towels and irrigated with 10 mL of either distilled water (control), smoke water, karrikinolide, biochar, coke, fly ash or bottom ash solutions. Petri dishes were incubated at 23 °C with 12 h of natural light daily. The experiment ran for 1 month until germination ceased. Paper towels were rewetted with their appropriate solutions as needed to keep from drying. Germination was recorded every 3 days; any seed with a radicle at least 1 mm long was considered to have germinated and was removed. Moldy seeds were removed and classified as inert. Mean germination time (days) was calculated as $\sum$ (n× d)/N, where

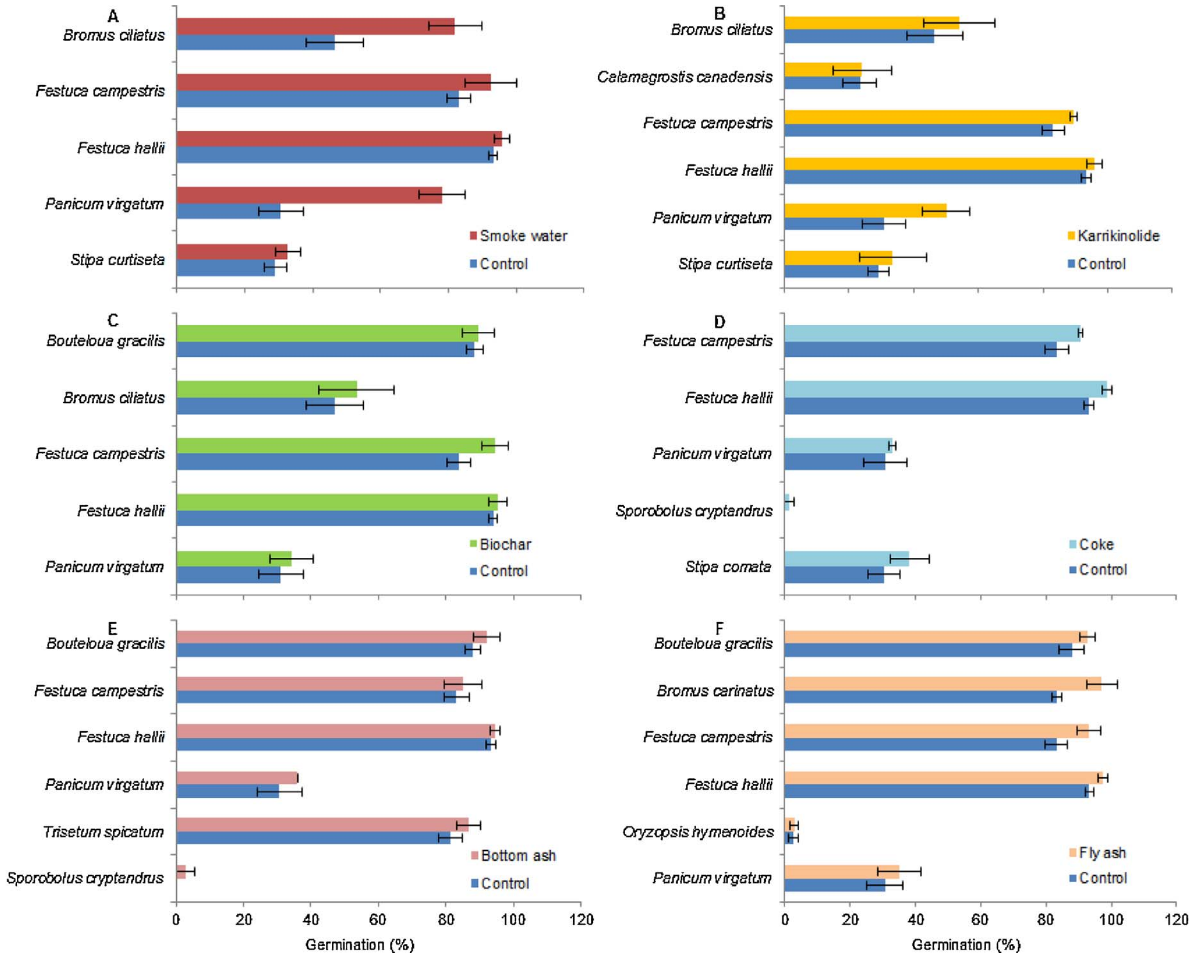

Fig. 1. Species showing a positive germination response to pyrolysis solutions relative to the control. Values are the mean of three replicates ± standard error. A. Smoke water dilution; B. Karrikinolide dilution; C. Aqueous extracts of biochar; D. Aqueous extracts of coke; E. Aqueous extracts of bottom ash; F. Aqueous extracts of fly ash.