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Incorporating Seeds in Activated Carbon Pellets Limits Herbicide Effects to Seeded Bunchgrasses When Controlling Exotic Annuals☆

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ABSTRACT

Revegetation of exotic annual grass—invaded rangeland with preemergent herbicides is challenging because seeding is delayed until herbicide toxicity has diminished, but at this time, exotic annuals can be reinvading. Incorporating seeds into activated carbon pellets may allow seeding to occur at the same time as exotic annuals are controlled with a preemergent herbicide because activated carbon can neutralize the herbicide in the microsite around seeds. I evaluated using activated carbon pellets with six species seeded at the same time imazapic was applied to control exotic annual grasses at two sites. Two of the six species establish enough at one site to evaluate the effects of pellets. These two bunchgrasses had greater density and growth (height, leaf length, number of stems and leaves) when incorporated into activated carbon pellets compared with seeded as bare seed. This demonstrates activated carbon pellets can be used to protect seeded bunchgrasses from imazapic applied to control exotic annuals.

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Introduction

Exotic annual grasses are one of the prevailing threats to the sagebrush ecosystem (Davies et al., 2011). Exotic annual grasses in the sagebrush steppe, especially cheatgrass (*Bromus tectorum* L.) and medusahead (*Taeniatherum caput-medusae* [L.] Nevski), increase fine fuel continuity and biomass and dry out earlier than native vegetation (D'Antonio and Vitousek, 1992; Davies and Nafus, 2013). These alterations to fuel characteristics can promote frequent wildfires that are detrimental to native perennial vegetation and thereby develop an annual grass-fire cycle (D'Antonio and Vitousek, 1992). Exotic annual grasses are also competitive with native vegetation, especially with perennial bunchgrass seedlings (Clausnitzer et al., 1999; Vasquez et al., 2008). Subsequently, invasion by exotic annual grasses decrease biodiversity, degrade habitat for sagebrush-associated species, and reduce quality and reliability of livestock forage (Davies, 2011; Davies et al., 2011).

Revegetation of exotic annual grass—invaded sagebrush steppe with perennial vegetation is needed to restore ecosystem services, decrease the risk of frequent fires, and provide reliable forage. Exotic annual grasses need to be controlled to allow perennial vegetation to establish. Preemergent herbicides are commonly used to control exotic annual grasses (Monaco et al., 2005; Kyser et al., 2007, 2013). One commonly used preemergent herbicide to control exotic annual grasses in the sagebrush steppe is imazapic. Imazapic can provide effective control of exotic annual grasses (Sheley et al., 2007; Davies and Sheley, 2011; Kyser et al., 2013). Seeding of perennial vegetation often occurs a year after the application of preemergent herbicide to limit herbicide damage to seeded species (Davies et al., 2014). However, exotic annual grasses may be reinvading treated areas at this time and thereby reducing the likelihood that seeded vegetation will establish.

Incorporating seeds into pellets containing activated carbon (also called herbicide protection pods [HHPs]; Madsen et al., 2014; Davies et al., 2017) may be a method to allow vegetation to be seeded at the same time preemergent herbicides control exotic annuals. Activated carbon can neutralize herbicides because of its high adsorption capacity (Bovey and Miller, 1969; Coffey and Warren, 1969). Activated carbon pellets are made by incorporating activated carbon, seeds, and other materials into a dough mixture that is extruded through a die, cut to desired length, and dried (Madsen et al., 2014). Activated carbon pellets protected a seeded native and introduced bunchgrass from imazapic damage in a grow-room study (Madsen et al., 2014) and a field study (Davies et al., 2017), respectively. Activated carbon pellets may increase the likelihood of revegetation success of annual grass—invaded rangelands but need further evaluation, especially in the field with more revegetation species and with a greater imazapic application rate.

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The purpose of this study was to evaluate the ability of activated carbon pellets to protect several common revegetation species from imazapic damage. I hypothesized that density and growth of seeded species would be greater when incorporated into activated carbon pellets compared with bare seed when seeded at the same time imazapic was applied to control exotic annual grasses.

Methods

Study Sites

This study was conducted at two annual grass−invaded sites (Coleman Creek and Butte) in eastern Oregon. Climate of study sites is characteristic of the northern Great Basin with cool wet winters and hot dry summers. Both sites were formerly Wyoming big sagebrush (*Artemisia tridentata* Nutt. subsp. *wyomingensis* Beetle & A. Young)−bunchgrass plant communities but have been invaded and dominated by exotic annual grasses. Coleman Creek is 67 km southeast of Burns, Oregon at 1 045 m above sea level. This site is relatively flat (<1° slope) with clay loam soil. Coleman Creek is an SR Clayey 9-12 PZ Ecological Site (R010XC021OR). Butte is 56 km west of Burns, Oregon at 1 464 m above sea level. This site is a south aspect with 9° slope and loam soil. Butte is a Droughty Loam 11-13 PZ Ecological Site (R023XY316OR). Long-term (1981−2010) average annual precipitation was 262 and 264 mm at Coleman Creek and Butte, respectively (PRISM, 2017). Medusahead and cheatgrass were the dominate vegetation at Coleman Creek and Butte, respectively. Precipitation was above average for both sites in the fall and winter, but from May through July, Butte and Coleman Creek only received 57% and 48% of their average for these months (PRISM, 2017). Sites were fenced to excluded livestock and wildlife during the experiment.

Experimental Design and Measurements

The study was implemented at two sites, and each treatment was replicated four times at each site for each seeded species in a randomized block design. Treatments were seeds incorporated into activated carbon pellets (AC) or bare seed (Bare) followed with an imazapic application. These treatments were evaluated with bottlebrush squirreltail (*Elymus elymoides* [Raf.] Swezey), bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] Á. Löve), Sandberg bluegrass (*Poa secunda* J. Presl), Siberian wheatgrass (*Agropyron fragile* [Roth] P. Candargy), Wyoming big sagebrush, and forage kochia (*Bassia prostrata* [L.] A. J. Scott). Each treatment • species combination was randomly assigned to a 3-m drill row with 0.5 m between rows. Drill rows were hand planted to ensure optimal planting depth for each species. Species were seeded at 300 pure live seeds per m. The formulation for the activated carbon pellets was 42% Ca Bentonite, 34% activated carbon, 4% worm castings, 12% compost, 4% superabsorbent powder, 1.6% superabsorbent fine granules, and 2.4% seed by dry weight. Pellets contained on average 6−10 PLS. Dry materials were mixed, and then a dough was created by incorporating liquid Selvol-205 prepared with a 1% solid content. Dough was pushed through a pasta extruder (Model TR110, Rosito Bisani, Los Angeles, CA) with an 8-mm diameter circular die. As dough exited the die, it was cut into 16-mm lengths, producing 8 × 8 × 16 mm pellets.

To prepare the study sites for seeding, annual grass was controlled on 4 and 9 November 2016 with glyphosate (Pronto Big 'n' Tuf, PBI Gordon) applied at a rate of 840 g ae·ha^{-1} with an adjuvant surfactant (R-11 Spreader-Activator, Wilber-Ellis, San Francisco, CA) at Butte and Coleman Creek, respectively. Glyphosate was applied with a manual pump backpack sprayer (Solo, Newport News, VA) with a tank pressure of 138 kPa. During application, temperature was 19°C and 20°C, relative humidity was 18% and 26%, and average wind speed was 4 km·hr^{-1} and 3 km·hr^{-1} at Coleman Creek and Butte, respectively. After snow melt, bare seed and pellets were seeded on 14 and 16 March 2017 at Coleman Creek and Butte, respectively. Within 24 hours of seeding, imazapic (Panoramic 2 SL, Alligare, Opelika, AL) was applied at 175 g ae·ha^{-1} using a manual pump backpack sprayer (Solo, Newport News, VA) with a tank pressure of 138 kPa. During imazapic application, temperature was 17°C and 10°C, relative humidity was 58% and 36%, and average wind speed was 2 km·hr^{-1} and 3 km·hr^{-1} at Coleman Creek and Butte, respectively.

Density of seeded species was determined by counting all seedlings in drill rows in early August 2017. Plant height, leaf length, culms per plant, and leaves per plant were also measured in August 2017 on 10 randomly selected seedlings in each treatment replication. When fewer than 10 seedlings were in a treatment replication, all seedlings were measured. Exotic annual grass cover and density were measured by randomly placing two 0.2-m^2 quadrats in each treatment replication and adjacent untreated areas. Cover was visually estimated in quadrants, and density was determined by counting all individuals rooted in quadrants. Control was determined by comparing treated with untreated areas.

Statistical Analyses

Analysis of variance (ANOVA) was used to compare seeds incorporated into activated carbon pellets with seeding bare seed when imazapic was applied to control exotic annuals (TIMCO Spotfire + v. 8.2). Data were analyzed individually by species and by site. Means were considered different if P values were ≤ 0.05 and reported with standard errors (mean + standard error). Data that violated assumptions of ANOVA were square root transformed. All data reported were original data (i.e., nontransformed).

Results

Exotic annual grass control was 100% in treated plots at both study sites. At Coleman Creek, all seeded species failed to establish (i.e., seedlings failed to survive until sampling date) and thus the following results only apply to Butte. Squirreltail and Siberian wheatgrass densities were greater in the AC treatment compared with the Bare treatment ($P = 0.030$ and 0.049, respectively). Density of squirreltail was 24.4 ± 9.7·m^{-1} and 0.0 ± 0.0·m^{-1} in the AC and Bare treatment, respectively. Siberian wheatgrass density was 4.4 ± 1.3·m^{-1} and 1.7 ± 0.6·m^{-1} in the AC and Bare treatment, respectively. Bluebunch wheatgrass, Sandberg bluegrass, Wyoming big sagebrush, and forage kochia failed to establish any individuals in most plots, and thus their densities did not differ between treatments ($P > 0.10$).

Squirreltail was on average 5 cm tall in the AC treatment, while it was not present in the Bare treatment (Fig. 1A). Siberian wheatgrass height varied by treatment (see Fig. 1A; $P = 0.018$). Siberian wheatgrass was almost three times taller in the AC compared with the Bare treatment. Siberian wheatgrass leaf lengths varied by treatment (Fig. 1B; $P = 0.014$). Siberian wheatgrass leaves in the AC treatment were 300% longer than in the Bare treatment. Squirreltail stem density was approximately three stems per plant in the AC treatment (Fig. 2A). Siberian wheatgrass stem density per plant was four times greater in the AC compared with the Bare treatment (see Fig. 2A; $P = 0.039$). Leaf density of Siberian wheatgrass was three times greater in the AC compared with the Bare treatment (Fig. 2B; $P = 0.050$). Height, leaf length, stem density, and leaf density of bluebunch wheatgrass, Sandberg bluegrass, Wyoming big sagebrush, and forage kochia were not compared between treatments as these species generally failed to establish any individuals in most plots.

Discussion

Activated carbon pellets show promise to decrease preemergent herbicide effects on seeded species, thereby allowing these species to be seeded at the same time exotic annuals are controlled. This research and prior research (Madsen et al., 2014; Davies et al., 2017)