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Original Research

Comparison of Postfire Seeding Practices for Wyoming Big Sagebrush☆

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ABSTRACT

Wildfires in the Great Basin have resulted in widespread loss of Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young), an ecologically important shrub that has proven difficult to establish from seed. We sought to identify optimal seeding practices for Wyoming big sagebrush in the context of postfire seeding operations involving rangeland drills. In an experiment replicated at three burned sites in the northern Great Basin, we compared Wyoming big sagebrush establishment across treatments differing by seed delivery technique, timing, and rate of seed application. A seed mix containing bunchgrasses was drill-seeded in alternate rows using one of two drill-types (conventional or minimum-till), and a mix containing sagebrush was either delivered by drill to the soil surface in remaining rows or broadcast by hand (simulating aerial seeding) following drilling in fall or winter. Drill-delivery of sagebrush seed was accompanied by drag chains (conventional drill) or imprinter wheels (minimum-till drill) to improve seed-soil contact and was carried out at multiple seeding rates (ca. 50, 250, and 500 pure live seed m^{-2}). During 2 yr following seeding, sagebrush establishment was lower at two sites (yr 1: ≤ 1.2 plants m^{-2}; yr 2: ≤ 0.8 plants m^{-2}) compared with a third site (yr 1: ≤ 4.1 plants m^{-2}; yr 2: ≤ 2.0 plants m^{-2}) where treatment differences were more pronounced and significant. Wherever density differed between treatments, it was consistently higher in certain treatment levels (minimum-till > conventional drill, drill-delivery > broadcast-delivery, fall broadcast > winter broadcast, and higher rates > lower rates). Densities declined between years at two sites, but we did not find evidence that declines were due to density-dependent mortality. Results indicate that seeding success can likely be enhanced by using a minimum-till imprinter seeding method and using seeding rates higher than typical postfire seeding recommendations for Wyoming big sagebrush.

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Introduction

Land management agencies of the United States have developed programs for actively seeding degraded areas on public lands, including areas affected by wildfire and invasive weeds (DOI and USDA, 2006; DOI, 2015). As the focus of seeding has increasingly shifted toward restoration of native plant communities, the importance of delivering "the right seed in the right place at the right time" has become a central concern (PCA, 2015). Many native species require special attention to ensure that seed quantity, placement, and timing of seeding are optimized to promote germination and establishment (Monsen and Stevens, 2004). These considerations are especially crucial in arid or semiarid environments where restoration efforts have historically had limited success (Allen, 1995; Whisenant, 1995; James et al., 2013).

Seeding is commonly carried out following wildfire in degraded sagebrush communities of the Great Basin where lack of postfire perennial recruitment could otherwise lead to dominance by cheatgrass (*Bromus tectorum* L.) or other exotic annuals (Epanchin-Niell et al., 2009; Pyke et al., 2013; Knutson et al., 2014). Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young) is a priority restoration plant because of its importance to biodiversity, ecosystem functioning, and wildlife habitat (Lambert, 2005b; Welch, 2005; Prater et al., 2006; Prevey et al., 2010; Beck et al., 2012). Concerns over population declines of greater sage-grouse *(Centrocercus urophasianus)*, a sagebrush-obligate species, have contributed to interest in restoring Wyoming big sagebrush habitats affected by wildfire (Arkle et al., 2014; Pyke et al., 2015).

Postfire recovery of Wyoming big sagebrush can be slow due to its inability to resprout, short-lived seed banks, and dependence on seed dispersal from unburned areas (Lesica et al., 2007; Schlaepfer et al., 2014; Shinneman and McIlroy, 2016). Efforts to hasten Wyoming big sagebrush recovery through postfire seeding have been undertaken

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for many years but have often failed to achieve desired results (Lysne, 2005; Knutson et al., 2014). Transplanting is an alternative to direct seeding (Dettweiler-Robinson et al., 2013; McAdoo et al., 2013; Palma and Laurance, 2015) but presents logistical challenges for treating large areas affected by wildfire.

The poor success of Wyoming big sagebrush seedings can be attributed in part to the general difficulty of plant establishment in areas with low moisture availability and exotic annual grass competition (Boyd and Obradovich, 2014; Knutson et al., 2014; Brabec et al., 2015), as well as the possibility that seed used in past seedings was not well-adapted to local conditions (Brabec et al., 2015, 2017; Richardson et al., 2015). Poor establishment of seeded Wyoming big sagebrush could also be a consequence of suboptimal seeding practices, including improper timing of seeding, insufficient seeding rates, unsuitable seedbeds, or failure to place seeds in appropriate microsites (Monsen and Stevens, 2004). A variety of different options are currently available for seeding Wyoming big sagebrush in postfire settings, but not all options have been widely applied or rigorously tested (Boltz, 1994; McArthur and Stevens, 2004; Lambert, 2005b; Lysne, 2005; Shaw et al., 2005; Welch, 2005; Meyer and Warren, 2016).

Postfire seeding commonly involves the use of rangeland drills to sow grass-dominated seed mixes during the fall season (Monsen and Stevens, 2004; Knutson et al., 2014). Drill-seeding works well for relatively large seeds that can tolerate burial at 0.6 cm or more (Stevens and Monsen, 2004), and seeding carried out in the fall allows overwintering seeds to break dormancy, if needed, and emerge as soon as conditions become favorable in spring (Monsen and Stevens, 2004; Hardegree et al., 2013). However, standard drill-seeding techniques are not ideal for sagebrush species whose small seeds (technically achenes, < 3.0 mg seed^{-1}; Richardson et al., 2015) may require light for germination (Meyer et al., 1990) and whose seedlings may fail to emerge when seeds are buried deeper than $0.3-0.5$ cm (Jacobson and Welch, 1987; McArthur and Stevens, 2004). Furthermore, minimal seed dormancy in Wyoming big sagebrush (Meyer and Monsen, 1992) means that fall-planted seeds might germinate precociously and risk frost-induced mortality during winter (Sakai and Larcher, 1987; Boyd and Lemos, 2013).

For situations where both large-seeded species (e.g., perennial grasses) and small-seeded species (e.g., sagebrush) are desired components of postfire seed mixes, separate seeding operations for each seed size have been recommended (Stevens and Monsen, 2004; Shaw et al., 2005). One option is to drill the larger seeds followed by aerial broadcasting of smaller seeds (Stevens and Monsen, 2004). This approach has the disadvantages of added cost for separate drilling and broadcasting procedures and presents the possibility that broadcast seeds will land in suboptimal microsites, including drill furrows where they might become buried, or on surfaces between furrows where they might have insufficient soil contact. Another option is to plant both large and small seeds using modified rangeland drills capable of placing different seed mixes in separate rows (Stevens and Monsen, 2004; Shaw et al., 2005; Truax Co., Inc, 2016). Drill disks can be removed or raised above ground level on rows designated for small seeds, which ensures that small seeds are kept away from drill furrows and spatially segregated from potentially more competitive large-seeded species. The addition of chains or imprinter wheels on rows with small seeds may further enhance their establishment by improving seed-soil contact (Shaw et al., 2005; Ott et al., 2016; Truax Co., Inc., 2016).

The question of how much sagebrush seed to use for postfire seedings requires careful consideration. Seeding rates[1] for Wyoming big sagebrush in the range of ca. $50-265$ pure live seed (PLS) m^{-2} have been recommended by several authors (Plummer et al., 1968; McArthur and Stevens, 2004; Lambert, 2005a; Meyer, 2008; Jacobs et al., 2011; Meyer and Warren, 2016), but few studies have experimentally tested multiple rates or examined rates above this recommended range. Boltz (1994) reported instances of higher sagebrush densities at ca. 620 PLS m^{-2} compared with ca. 200 PLS m^{-2} in postfire seeding trials, and mine reclamation studies have demonstrated that sagebrush density can increase in response to increased seeding rates up to ca. 1400 PLS m^{-2} (Booth et al., 1999; Williams et al., 2002; Hild et al., 2006). These findings suggest that sagebrush establishment in postfire seedings might be enhanced by using seeding rates higher than typical recommendations. However, the benefits of higher seeding rates should be weighed against not only increased monetary costs but also possible diminishing returns due to density-dependent mortality at higher seedling densities (Harper, 1977; Burton et al., 2006). Some studies suggest that competition within dense stands of sagebrush seedlings may have a negative effect on survivorship (Owens and Norton, 1989; Boyd and Obradovich, 2014).

Continuing research on postfire seeding of Wyoming big sagebrush is warranted given current uncertainty over best seeding practices and the possibility that underutilized options might prove advantageous for future seeding efforts. We report results from an operational-scale experiment comparing the efficacy of practices for seeding Wyoming big sagebrush following fire in the northern Great Basin. This paper expands on previous work covering responses of Wyoming big sagebrush and other species to drill-seeding using different drill types (Ott et al., 2016); we present results of additional treatments including simulated aerial broadcast seeding in fall and winter and multiple seeding rates. Ott et al. (2016) found that Wyoming big sagebrush establishment was higher when seed was delivered through a minimum-till drill as opposed to a conventional drill, but they did not examine seeding rate effects nor compare drill-delivery with broadcasting. We hypothesized that seed delivery using either drill type would be more effective than broadcasting due to better seed placement and seed-soil contact. We also hypothesized that winter broadcasting would lead to higher establishment than fall broadcasting due to reduced incidence of frost damage associated with earlier germination. We expected that seedling densities would be higher at higher seeding rates, although mortality due to seedling competition might also be higher. We also anticipated that seeding success might vary among three contrasting sites included in our study.

Methods

Study Area

Three Wyoming big sagebrush sites in the northern Great Basin were selected following summer wildfires in 2007, 2008, and 2010 (Table 1). Each site was occupied by mature sagebrush before burning but burned with sufficient intensity to kill existing shrubs. The fire at Mountain Home likely burned with lower intensity than fires at the other sites, as evidenced by higher residual litter and rapid postfire

Table 1
Attributes of postfire seeding study sites in the northern Great Basin.[1]

	Mountain Home	Scooby	Saylor Creek
Location	42°58'42"N, 115°37'57"W	41°51"16"N, 113°2'46"W	42°39'43"N, 115°28'18"W
County, state	Elmore, ID	Box Elder, UT	Elmore, ID
Wildfire date	6 July 2007	22 September 2008	29 June 2010
Fall seeding date	29-30 October 2007	18-19 November 2008	27-28 October 2010
Winter seeding date	18 January 2008	29 January 2009	15 February 2011

[1] See Ott et al. (2016) for an expanded version of this table with ecological site and soils information.

[1] Seeding rates originally given on a per-weight basis are standardized here using the conversion factor 2.14 million seeds/lb. for Wyoming big sagebrush (Meyer, 2008).

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