Seed Mix Performance and Cheatgrass Suppression on Arid Rangelands

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Research Paper

Seed mix performance and cheatgrass suppression on arid rangelands

By Charlie D. Clements, Dan N. Harmon and Robert R. Blank

On the Ground

- The accidental and subsequent invasion of cheatgrass throughout millions of hectares of Intermountain West rangelands has truncated secondary succession by providing a fine-textured, early maturing fuel that has increased the chance, rate, spread, and season of wildfire.
- The restoration or rehabilitation of degraded rangelands throughout the Intermountain West is very challenging due to annual invasive species that exhibit high growth rates and seed production.
- The use of the pre-emergent herbicide, *Imazapic*, decreased cheatgrass densities >95% during the fallow year and before sowing seed the following fall during this study, which significantly reduced the cheatgrass competition for seedlings of seeded species.
- Seed mix performances were significantly higher in herbicide-treated plots than control plots for both sites for both years. Native, introduced, and native/introduced seed mixes were significantly more successful in the treated plots at the Bedell Flat site compared with the Antelope site for both years.
- Cheatgrass densities were significantly higher in the control plots at both sites for both years compared with herbicide/seed mix-treated plots.
- Success and failure of establishing perennial grasses in restoration or rehabilitation practices is highly dependent on proper seed and seed mix selections, seeding methodologies, and rates as well as favorable precipitation.

Keywords: *Bromus tectorum*, wildfire, restoration, herbicide, perennial grasses.

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The restoration or rehabilitation of degraded rangelands throughout the Intermountain West is challenging due to annual invasive species that exhibit high growth rates and seed production.[1-6] Invasive annual grasses, such as cheatgrass (*Bromus tectorum* L.), outcompete native perennial species for limited resources, especially in arid environments.[4,7-10] The accidental and subsequent invasion of cheatgrass throughout millions of hectares of Intermountain West rangelands has truncated secondary succession by providing a fine-textured early maturing fuel that has increased the probability, rate, spread, and season of wildfire.[11-13] The increase in wildfire size and frequency can significantly reduce recovery of native species and increase annual grass dominance.[5,6,10,13–15] After wildfire, the reduction in perennial grass densities and increased abundance of cheatgrass can significantly influence fire behavior through increased cheatgrass densities and associated fuel loads.[5,10,13,16] The best known method at suppressing cheatgrass and associated fuels is through the establishment of perennial grasses.[5-7,10,17-22] Rehabilitation of cheatgrass-infested rangelands is needed to reduce wildfire threats, reduce soil erosion, allow succession to proceed, and improve grazing and wildlife resources.[6,12] Aggressive and effective weed control methods are essential in reducing cheatgrass densities to improve seedling survivability of seeded species, as well as selecting seed mixes that will improve seeding success.[5,6,19,20,23] Our study was initiated to test native, introduced, and native/introduced seed mix performance and the ability of these seed mixes to suppress cheatgrass densities.

Cheatgrass control and seeding

In the fall of 2014 and 2015, we applied *Imazapic* (Plateau) at 105 g ai/ha (6 oz/acre) to 24 m x 45 m plots (80 feet x 150 feet), with two replications and two control plot replications that did not receive herbicide application (Fig. 1), each year. Our two study sites were the Bedell Flat study site located 48 km (30 miles) north of Reno, Nevada and the Antelope study site located 210 km (130 miles) east of Reno, Nevada. There were eight plots total at each site. Both study sites burned in 1999 wildfires and the following seeding efforts failed (Fig. 2).

The Bedell Flat study site is dominated by cheatgrass with a sparse density of bottlebrush squirreltail (*Elymus ely-*

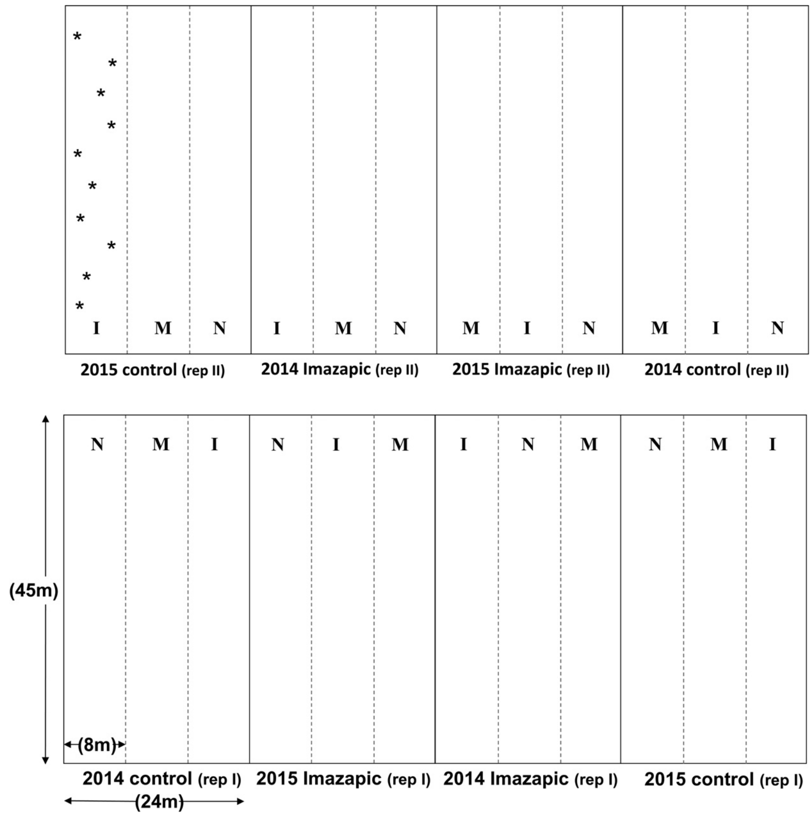

Figure 1. Schematic diagram of treated and control plots with seed mixes and randomized monitoring quadrats. I indicates introduced seed mix plots; N, native seed mix plots; M, introduced/native seed mix plots. The * represents an example of the randomized quadrats per plot.

Figure 2. Bedell Flat study site, August 2014, northern Nevada failed 1999 post wildfire seeding.

moides [Raf.] Swezey), Indian ricegrass (*Achnatherum hymenoides* [Roemer and Schultes] Barkworth), needle and thread grass (*Hesperostipa comata* [Trin. and Rupr.] Barkworth), bluegrass (*Poa secunda* J.S. Presl.), and Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle and A. Young). The site receives an average of 220 mm (8.7 inches) of annual precipitation (USDA-ARS unpublished data) and the soil is mapped as a Graufels series, mixed mesic, Torripsammetic Haploxeroll, and developed in granitic residuum with an elevation of 1,545 m (5,098 feet).[24] The Antelope study site is dominated by cheatgrass with a sparse bluegrass presence. The site receives an average annual precipitation of 178 mm (7 inches; USDA-ARS unpublished data) and the soils are mapped as Hessing Wholan series, mixed

Table 1
Seed mixes and seeding rates of perennial grasses for the Bedel Flat and Antelope study sites in northern Nevada

Site	Seed mix	Rate	Seeds/area
	Native mix		
Bedel Flat	'Anatone' bluebunch wheatgrass [*Pseudoroegneria spicata* (Pursh) A. Love ssp. *spicata*]	8 kg/ha (7 lb/acre)	257 seeds/m^2 (24 seeds/feet^2)
Antelope	Bottlebrush squirreltail (*Elymus elymoides* [*Raf.*] *Swezey*)	8 kg/ha (7 lb/acre)	220 seeds/m^2 (20 seeds/feet^2)
Bedel Flat Antelope	Sherman big blue grass (*Poa secunda* [*J. Presl*] *formerly Poa ampla*)	2.4 kg/ha (2 lb/acre)	300 seeds/m^2 (28 seeds/feet^2)
Bedel Flat Antelope	Sandberg bluegrass (*Poa secunda* [*J. Presl*] *formerly Poa sandbergii*)	2.4 kg/ha (2 lb/acre)	330 seeds/m^2 (31 seeds/feet^2)
	Introduced mix		
Bedel Flat Antelope	'Hycrest' crested wheatgrass (*Agropyron cristaum* L.)	4 kg/ha (3.5 lb/acre)	113 seeds/m^2 (10 seeds/feet^2)
Bedel Flat Antelope	Siberian wheatgrass (*Agropyron fragile* [Roth])	4 kg/ha (3.5 lb/acre)	105 seeds/m^2 (9 seeds/feet^2)
	Native/introduced mix		
Bedel Flat	'Anatone' bluebunch wheatgrass	4 kg/ha (3.5 lb/acre)	129 seeds/m^2 (12 seeds/feet^2)
Antelope	Bottlebrush squirreltail	4 kg/ha (3.5 lb/acre)	110 seeds/m^2 (10 seeds/feet^2)
Bedel Flat Antelope	Siberian wheatgrass	4 kg/ha (3.5 lb/acre)	105 seeds/m^2 (9 seeds/feet^2)
Bedel Flat	Sherman big bluegrass	2.4 kg/ha (2 lb/acre)	300 seeds/m^2 (28 seeds/feet^2)
Antelope	Sandberg bluegrass	2.4 kg/ha (2 lb/acre)	330 seeds/m^2 (31 seeds/feet^2)

xeric, and silty to sandy loam with an elevation of 1,620 m (5,346 feet).[24]

Treated plots were fallowed for 1 year after herbicide treatment, separated into thirds (i.e., 8 m x 45 m [26.2 feet x 150 feet]), and then seeded the following October with 3 separate seed mixes (native, introduced and native/introduced) using a Kincaid no-till drill (Kincaid Model 70, Kincaid Equipment, Haven, KS). Seeds were commercially acquired, and seed mixes and seeding rates at each study site included a native, introduced, and native/introduced seed mixes (Table 1). Each seed mix was also seeded on two replicated control plots for each year with the same dimensions that did not receive herbicide treatments (Fig. 1). Each plot received 10 randomly selected 1-m^2 (10.76 feet^2) quadrats that were monitored for 2 years (Fig. 1). Two years post seeding the seeded species plant densities and cheatgrass plant densities were recorded. Data were analyzed using SAS JMP[25] with treatment, year, and interaction as fixed effects and the site, site × treatment, and year × site × treatment as random effects.

Results and Discussion

The application of imazapic at both study sites was highly successful at decreasing cheatgrass densities (Fig. 3). Seed mix performances were significantly ($P \leq 0.05$) higher in herbicide treated plots than control plots for both sites for both years ($n = 40$; Fig. 4). Native, introduced, and native/introduced seed mixes were significantly ($P \leq 0.01$) more successful in the treated plots at the Bedell Flat site compared with the Antelope site in both years (Fig. 4). There were no significant differences in control plots between sites and years.

The Bedell Flat site recorded 7.9 (0.73/feet^2), 7.6 (0.70/feet^2), and 7.2 (0.67/feet^2) individual perennial grasses/m^2 in the native, introduced, and native/introduced treated plots in year 1, respectfully, compared with 1.1/m^2 (0.10/feet^2), 2.3/m^2 (0.21/feet^2), and 2.8/m^2 (0.26/feet^2) in year 1 at the Antelope site. In year 2, the Bedell Flat site recorded 7.9 (0.73/ft^2), 10.7 (0.99/ft^2) and 8.1 (0.75/ft^2) individual perennial grasses/m^2 in the native, introduced, and native/introduced seed mixes, respectfully, compared with 1.7/m^2 (0.16/ft^2), 4.2/m^2 (0.39/ft^2), and 3.4/m^2 (0.32/ft^2) at the Antelope site (Fig. 4). There was no significant difference in seed mix performance of herbicide treated plots at the Bedell Flat site in year 1, whereas in year 2 the introduced seed mix performed significantly ($P \leq 0.05$) better than the native and native/introduced seed mixes. The introduced seed mix was significantly ($P \leq 0.05$) more successful in year 2 than year 1 at the Bedell Flat site. The introduced and native/introduced seed mixes performed significantly ($P \leq 0.05$) higher in herbicide treated plots both years at the Antelope site (Fig. 4).

Amount and periodicity of precipitation plays a crucial role in the survivability and establishment of perennial bunchgrasses.[4,5,18,27,33] The Bedell Flat study site received 270 mm (10.6 inches) of precipitation in year 1 and 327 mm (12.9 inches) in year 2, both were above average years. The Antelope study site received 223 mm (8.8 inches) of precipitation in year 1 and 216 mm (8.5 inches) in year 2, which was also above average for both years (USDA-ARS unpublished data).

Figure 3. Effective cheatgrass control using a pre-emergent herbicide, *Imazapic*, at the Antelope study site, June 2015, northern Nevada.

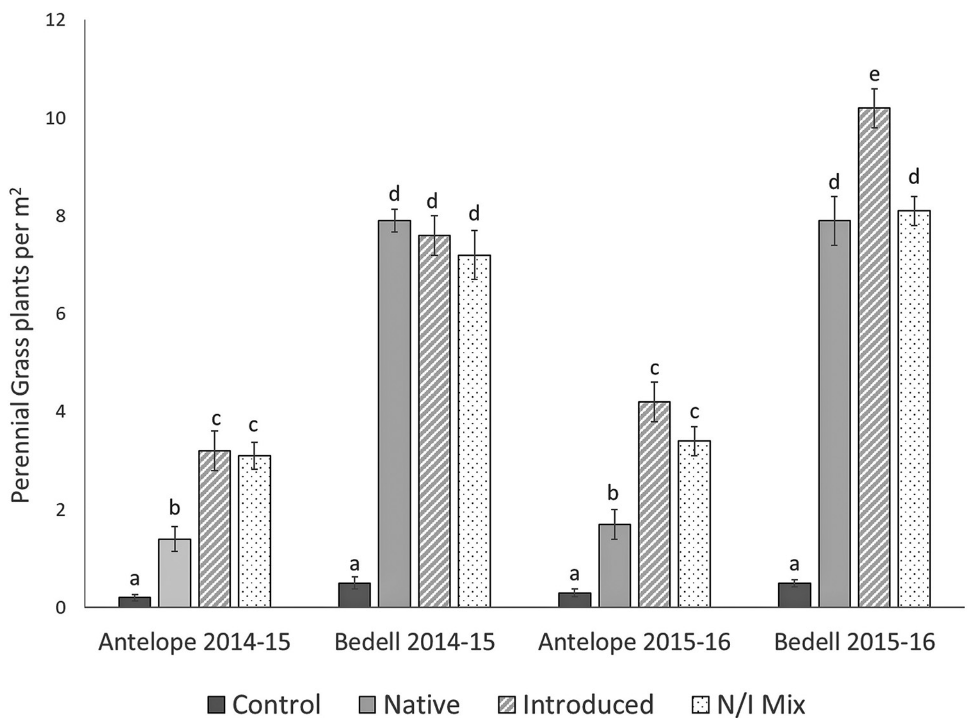

Figure 4. Perennial grass establishment for each treatment and year at our Antelope and Bedell Flat study sites in northern Nevada. Corresponding letters represent no significant difference ($P < 0.05$). N/I is Native/Introduced mix.

Cheatgrass densities were significantly ($P \leq 0.05$) higher in the control plots at both sites for both years compared with herbicide/seed mix treated plots (Table 2). The Antelope site had significantly ($P \leq 0.05$) more above-ground cheatgrass densities in the control plots compared with the Bedell Flat site for both years (Table 2). There were no significant differences in cheatgrass above-ground densities among the three seed mixes at the Bedell Flat site, while at the Antelope site the introduced and native/introduced seed mixes had significantly ($P \leq 0.05$) less cheatgrass than the native seed mix plots (Table 2). Even though it is well reported that increased densities of perennial bunchgrasses reduce cheatgrass dominance, our study quantifies this reduction.

Restoration or rehabilitation of degraded big sagebrush communities in arid environments, especially those receiving ≤ 254 mm (10 inches) of annual precipitation, are very limited

Figure 5. Native seed mix plot 5 years post seeding, June 2020, Bedell Flat study site, northern Nevada.

Table 2
Cheatgrass (*Bromus* tectorum) densities after seed mix treatments at Bedell Flat and Antelope study sites in northern Nevada

		Cheatgrass (*Bromus tectorum*) plants/m^2			
Year	Site	Control	Native mix	Introduced mix	N/I mix
2014-15	Antelope	667 (a)	359 (b)	243 (c)	139 (c)
2014-15	Bedell Flat	161 (a)	25 (b)	18 (b)	22 (b)
2015-16	Antelope	640 (a)	338 (b)	140 (c)	160 (c)
2015-16	Bedell Flat	257 (a)	27 (b)	12 (b)	15 (b)

Note. Corresponding letters represent no significant difference ($P < 0.05$). N/I indicates native/introduced mix.

due to the lack of adequate precipitation.[5,10,26] Near complete control of cheatgrass is necessary if desirable perennial grasses are to be successfully seeded and established.[5,6,10,17,20,27,28] The use of pre-emergent herbicides to aid in the establishment of perennial grasses is an effective cheatgrass control practice.[5,6,29] The use of the pre-emergent herbicide, *Imazapic*, decreased cheatgrass densities >95% during the fallow year and before sowing seed the following fall during our study, which significantly reduced the cheatgrass competition for seedlings of seeded species. This level of cheatgrass control is essential as cheatgrass outcompetes perennial seedlings at the seedling stage for limited moisture and nutrients as well as contributing to significant rangeland seeding failures.[5,9,17,30-32]

Restoring or rehabilitating degraded Great Basin rangelands by re-establishing perennial grasses is extremely difficult because annuals such as cheatgrass maintain dominance on disturbed sites by exhibiting high growth rates and seed production.[1,19,33-35] At our Bedell Flat study site, over the 2-year period of our study, the level of perennial grass seedling germination, emergence, and establishment significantly reduced cheatgrass densities by as much as 95% in the introduced seed mix in year 2 with a low cheatgrass suppression level of 85% in the native seed mix plot in year 1. The native/introduced seed mix reduced cheatgrass by 86% in year 1 and 94% in year 2 (Table 2). The Antelope site, which is more arid, experienced less perennial grass establishment and therefore was less successful at suppressing cheatgrass. The native seed mix only reduced above-ground cheatgrass densities 47% in each of the 2 years of our study, and native/introduced seed mix reduced above-ground cheatgrass densities by 79% in year 1 and 75% in year 2. The introduced seed mix reduced above-ground cheatgrass densities by 64% and 78% in year 1 and 2, respectfully (Table 2).

We started experimenting with native/introduced seed mixes nearly 3 decades ago to hedge our bets on above and below average precipitation years,[36-40] and others have also reported on this approach to restore or rehabilitate degraded rangelands.[7,41-45] Climate patterns throughout the Great Basin are highly variable and erratic,[46] and this erratic unpredictable pattern has significant impact on germination, emergence, and seedling establishment of seeded and nonseeded plant species.[5,47,48] The two sites in our study received less than average precipitation >60% of the time over the 30+ years we have actively been recording precipitation (USDA-ARS unpublished data). Therefore, our study was designed to use introduced plant material that has been reported to be more successful in reseeding efforts if our sites received submarginal precipitation.[1,17,33,43,49,50] Throughout our study the native seed mix performed very well at the Bedell Flat site (Fig. 5), while performing far less at the more arid Antelope site. As previously mentioned, perennial grasses have a difficult time establishing when annual precipitation is ≤254 mm (10 inches), and especially true for native perennial grasses.[5,10,26,45] Managers should be aware of such limitations when seeding arid rangelands. Prior research has reported that 2.5 to 3.0 individual perennial grasses/m² (0.23-0.28/feet²) is a desired density to maintain perennial vegetation and prevent cheatgrass dominance,[27,51] which we achieved at the Bedell Flat site for all mixes for both years. This level of density was not achieved with the native mix at the Antelope site and struggled to meet the desired density levels with the introduced and native/introduced seed mixes. Our data suggests that to actively suppress cheatgrass densities and reduce its' dominance, >4 individual perennial grasses/m² (0.37/feet²) are necessary to achieve this goal.

The use of introduced perennial grasses in restoration/rehabilitation efforts continues to be a focus of considerable debate. A wide range of concerns exists ranging from introduced perennial grasses significantly inhibiting the return of native species back to the site to the use of more adapted introduced perennial grasses that are essential in protecting watersheds, soil resources, and reducing cheatgrass dominance and further site degradation on the other edge of the spectrum.[4,33,49,52-56] Success and failure of establishing perennial grasses in restoration or rehabilitation practices is highly dependent on proper seed and seed mix selections and rates, seeding methodologies, and favorable precipitation.[5,20,27,56,57] A first step in restoring or rehabilitating degraded rangelands throughout the Great Basin is providing resource managers with effective weed control practices and proper seeding methodologies to combat such aggressive annual weeds as cheatgrass, therefore reducing cheatgrass densities and associated fuels that add further risk to watersheds, soil properties, grazing resources, and wildlife habitats.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests. The authors certify that they have no financial interest in the subject matter discussed in the manuscript. C. D. C., D. N. H., and R. R. B. are employees of USDA Agricultural Research Service and were associated with management decisions regarding the topic of this manuscript

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