Using native annual plant species to suppress weedy invasive species in post-fire habitats

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Abstract

Increasing fire frequencies and uncharacteristic severe fires have created a need for improved restoration methods across rangelands in western North America. Traditional restoration seed mixtures of perennial mid- to late-seral plant species may not be suitable for intensely burned sites that have been returned to an early-seral condition. Under such conditions, native annual plant species are likely to be more successful at competing with exotic annual plant species such as *Bromus tectorum* L. We used a field study in Colorado and Idaho, USA to test the hypothesis that native annual plant species are better suited to post-fire restoration efforts compared to perennial plant species that are commonly used in traditional seed mixtures. Replicated test plots at three post-fire sites were assigned one of four treatments (1) native annual seed mixture, (2) standard perennial seed mixture, (3) combination of annual and perennial, and (4) an unseeded control. Results suggest that there is potential for native annual plant species to be effective in the restoration of post-fire habitats.

Background and purpose

Wildland fires in western North America are becoming more frequent and are expected to increase in frequency with the current trend in climate change (Westerling et al. 2006). Fires have historically been a common element of western North American landscapes with fire return intervals of 60-100 years in some rangeland communities (Whisenant 1990) and decades-centuries in piñon-juniper communities (Floyd et al. 2004). However, ecosystems throughout the west have experienced displacement of native vegetation by exotic invasive annuals like *Bromus tectorum* L. (cheatgrass), which reduces fire return intervals to 3-5 years (Whisenant 1990). *Bromus tectorum* is potentially able to displace native vegetation after a fire due to its rapid growth during fall and spring (Harris 1967), its ability to germinate in a wide array of environmental conditions (Mack and Pyke 1983) and its ability to utilize soil resources before native plants (Melgoza et al. 1990). With more frequent fires and the increased potential for cheatgrass invasion, reseeding is an important practice during the initial post-fire period.

An immediate goal of post-fire seeding has been soil stabilization to prevent erosion and the loss of soil productivity (Robichaud et al. 2000). Fire rehabilitation projects have included species that are able to protect watersheds and provide forage but they have not taken into account the long-term effects on ecosystem dynamics (Richards et al. 1998). In the western U.S., exotics such as *Agropyron cristatum* (L.) Gaertn. (crested wheatgrass), *Agropyron fragile* [Roth] Candargy (Siberian wheatgrass), and *Medicago sativa* L. (alfalfa) have been used extensively to provide initial post-fire vegetative cover (Richards et al. 1998). However, this practice has resulted in exotic-dominated plant communities that have hindered native plant regeneration (Chambers et al. 1994; Walker 1997; Kruse et al. 2004). The use of native species in seed mixes has been increasing (Thompson et al. 2006; Dorner 2002) as land managers take into consideration changing social values (Johnson 1986), shifts in policies (Hoberg 1997), and advances in ecological knowledge (Roundy et al. 1995).

Typically, restoration seed mixtures have been comprised of late seral or climax species (Lesica and DeLuca 1996; Pellant and Monsen 1993; Beyers 2004). Restoration seed mixes like these can be insufficient for preventing weedy plant species from establishing and persisting on post-fire landscapes (Beyers 2004; Floyd et al. 2006). Planting perennial species in conditions where annuals typically would dominate may be tempting from a revegetation perspective, but may not be the best choice in post-fire restoration settings because later-seral species tend to perform poorly in early-seral soils (Kardol et al. 2006; Kulmatiski 2006). Young and Evans (1978) found that post-fire soils in sagebrush grasslands had accumulated relatively large amounts of soil nitrogen. Under high nitrogen conditions, annual plant species tend to perform better than perennial species (Baer et al. 2005; Paschke et al. 2000; Tilman 1987).

After intense disturbances, ruderal species, the majority of which are annuals, typically colonize first and dominate the first year or two after the disturbance before the widespread establishment of perennial species (Koniak and Everett 1982, Borgegard and Rydin 1989, Bazzaz 1996, Walker and Moral 2003, Ott et al. 2003, Keeley et al. 2006; Shinneman and Baker 2009). For example, Everett and Ward (1984) found that annuals can dominate early post-fire vegetation in Piñon-juniper ecosystems in eastern Nevada, even if they were sparse pre-fire.

Increasingly, exotic annual species, such as *B. tectorum*, have been colonizing and dominating post-fire habitats instead of native annuals (Young et al. 1969; Young and Evans 1978; Melgoza et al. 1990; Evangelista et al. 2004; Jessop and Anderson 2007). This could be due to a close proximity to an established exotic species population, close proximity to dispersal vectors such as roadways, the alteration of the historical fire regime (Keeley et al. 2005), or a lack of local native annual seed in the seed bank. Native annual seed in seed banks can be destroyed because of the increasing frequency and intensity of fires in the western U.S. (Westerling et al. 2006). To combat these issues, revegetation efforts may do well by establishing species that compete with *B. tectorum* during active growth, when soil and light resources are being used, (Booth et al. 2003), in addition to species that stabilize soils and are otherwise desirable.

Planting annuals has been indicated as a possible means of preventing or slowing *B. tectorum* invasion (Whisenant, 1990). Because annuals have similar growth forms and phenology as *B. tectorum*, they can be successful competitors for soil resources (Chambers et al. 2007), they can act as a cover crop in early growth stages to compete for light resources (Perry et al. 2009), and they can be the foundation for successional management and ecologically-based invasive plant management (Krueger-Mangold and Sheley, 2006). In addition, Whisenant (1990) stated that ruderal species may accelerate successional processes by (1) stabilizing the soil; (2) increasing soil organic matter; (3) enriching soil nutrients; and (4) excluding less desirable pioneer species through competition.

The objective of this project was to evaluate the effectiveness of native seed mixtures containing early-seral annual species for restoring native plant cover in post fire habitats. Because of their known important ecological roles, we hypothesized that native annual plant species would provide better initial plant cover, biomass, or both in post-burn sites than perennial species (H1) and that seeding with native annual species would lead to reduced exotic annual cover, biomass, or both (H2).

Study description and location

Sites

A field study was conducted at three sites (Table 1), one in Idaho, USA and two in Colorado, USA. The site in Idaho was located within the Craters of the Moon National Monument & Preserve (hereafter referred to as Craters) northeast of the city of Twin Falls. One Colorado study site was located south of the town of Dinosaur while the second Colorado study site was located north of the town of DeBeque. Each study site was selected in the fall of 2007 because it had recently burned (summer-fall of 2007), it was within close proximity to an existing population of *B. tectorum*, and was an area where land managers were concerned about post-fire invasion of *B. tectorum*. Each site had historically been subjected to grazing by livestock and wildlife. Study plots were established in the fall of 2007, and in the spring of 2008 a fence was installed at each site to prevent grazing of the study plots by livestock. A forth study site near the town of Castleford, ID in the Murphy Complex fire was established along with the other three sites. However, wind erosion of topsoil at the site resulted in soil scouring and deposition within the plots and a complete failure of the experimental seeding. Therefore, this fourth study site was dropped from the following analyses and reporting.

Table 1. Characteristics of the three field sites used in this study. Habitat, historic climate, and soil information are from: Soil Survey Staff, NRCS (2009).

Site	Fire	Habitat Type	Precip. (mm.)	Temp. (°C)	Soils
Craters, ID	Bear Den Butte	Basin big sagebrush/Bluebunch wheatgrass	35-40	7-10	Loamy-skeletal, mixed, superactive, mesic Calciargidic Argixerolls
Dinosaur, CO	Steuwe	Piñon-Juniper	25-30	6-8	Fine-loamy, mixed Borollic Haplargids
DeBeque, CO	Pyramid	*Piñon-Juniper*	25-30	8-11	Fine-loamy, mixed, mesic Ustollic Natrargids

Experimental Design

The study was a randomized complete block design with a 2 x 2 factorial treatment structure. The two factors were annual seed (with and without) and perennial seed (with and without), resulting in four treatments: (1) a native annual seed mixture, (2) a native perennial seed mixture, (3) a combination of the annual and perennial mixtures, and (4) an unseeded control (Table 2). The annual only and perennial only seed mixtures were seeded at a rate of 650 PLS m^{-2} and the combination mixture was seeded at 1300 PLS m^{-2}. The higher rate for the combination mixture was based on the assumption that annual species would drop out of the community within a few years. Each of the four sites contained seven blocks with four 2- x 2-m treatment plots randomly assigned in each block.

Table 2. Species seeded in native annual and native perennial mixes; both mixes were seeded at 650 pure live seeds (PLS) m^{-2}. The combination mix used all species listed at a combined rate of 1300 PLS m^{-2}.

Seed Mix	Scientific name	Common name	PLS m^{-2}
Native annual	*Amaranthus retroflexus* L.	Redroot amaranth	78
	Cleome serrulata Pursh.	Rocky Mountain bee-plant	65
	Coreopsis tinctoria Nutt.	Golden tickseed	78
	Helianthus annuus L.	Annual sunflower	65
	Verbena bracteata Cav. ex Lag. & Rodr.	Big bract verbena	65
	Aristida purpurea Nutt.	Purple three-awn	39
	Vulpia microstachys (Nutt.) Munro	Small fescue	130
	Vulpia octaflora (Walter) Rydb.	Six-weeks fescue	130
Native perennial	*Balsamorhiza sagitatta* (Pursh) Nutt.	Arrowleaf balsamroot	84.5
	Eriogonum umbellatum Torr.	Sulfur-flower buckwheat	97.5
	Oenothera pallida Lindl.	Pale evening primrose	52
	Sphaeralcea munroana (Douglas) Spach.	Munro's globemallow	84.5
	Achnatherum hymenoides (Roem. & Schult.) Barkworth	Indian ricegrass	65
	Elymus elymoides (Raf.) Swezey	squirreltail	58.5
	Elymus lanceolatus (Scribn. & J.G. Sm.) Gould	Thickspike wheatgrass	71.5
	Pascopyrum smithii (Rydb.) A. Löve	Western wheatgrass	58.5
	Pseudoroegneria spicata (Pursh.) A. Löve	Bluebunch wheatgrass	78

Plots were established at the Idaho site on 30 and 31 October 2007 and the Colorado plots were established on 13 and 14 November 2007. Treatment plots were prepared by raking with a leaf rake to remove debris followed by light raking with a garden rake to prepare the seedbed. Seeds were then hand broadcast onto the plots and lightly raked by hand to incorporate the seed. We were concerned that the distribution of *B. tectorum* seeds across each site would not be uniform and would not allow us to effectively test our hypotheses. Therefore, material that was removed from the plots with the initial raking was pooled at each site and to this material litter from interspersed unburned *B. tectorum* patches was collected and added. This site specific pooled material was mixed and then an equal volume was added to each plot in order to ensure more uniform *B. tectorum* propagule supply. After this material was added, each plot was rolled with a water-filled lawn roller. This was done to firm the seedbed and to reduce wind erosion of the seed and raked soil.

In order to effectively test the hypotheses, the moisture at each site had to be at least equal to the average annual precipitation levels during the initial years of the study. Therefore, precipitation levels were monitored using the High Plains Regional Climate Center (HPRCC, University of Nebraska, Lincoln, Nebraska, USA, http://www.hprcc.unl.edu) observation stations nearest each site. During fall 2007 to spring 2008, the Idaho sites had fallen below the 30-year average annual level of precipitation (HPRCC, station ID# 102260). To help offset this deficit; the equivalent of an additional 10 mm of precipitation (one time only) was added to each plot at the Idaho sites in May of 2008. Water applications were made by hand with garden watering cans. Additional watering was not necessary during the 2008 – 2011 growing seasons, because all four sites had received at least their average annual precipitation (HPRCC, Station ID #'s 102260, 101551, 056832, 050214).

Seedbank Analysis

After the study plots were located and marked soil cores were collected for a seedbank composition study. A 5 cm diameter bulb planter was used to collect two soil samples per plot to a depth of 5 cm, resulting in eight samples per block. The eight samples for each block were combined to be a representative composite sample of the individual blocks at each study site. These samples were used to determine post-fire seedbank composition. The soils were subjected to a cold stratification process by storing in a refrigerator for 16 weeks at 5 °C, before being transferred to the greenhouse at Colorado State University where they were maintained at 18 – 21 °C with supplemental lights that maintained a photoperiod of 16 hours. Half of each composite sample was spread onto a 2:1 mixture of Fafard™ Superfine Germination Mix potting soil and sand in a growth flat (26.7 cm x 53 cm) and placed onto heating pads set to 24.0°C to improve germination. Flats were watered as needed when samples were dry and randomized on a weekly basis. As plants germinated they were identified by species when possible, and counted to calculate seed density in the seedbank.

Sampling and Data Collection

Data collection occurred during May or June of 2008, 2009, 2010, and 2011 to capture as much of the ephemeral annual cover as possible during the spring. We measured percent cover by species in four 0.1875-m^2 subplots within each plot. Biomass was also measured during 2010 and 2011 by clipping all vegetation within the subplots by species and drying at 55°C for at least 72 h prior to weighing. Comparing measurements of total plant, exotic annual, and native perennial cover and biomass between treatments allowed us to test each of the hypotheses.

Statistical Analysis

Cover and biomass variables were transformed as necessary to attain approximate normality. Data were analyzed using a first-order autoregressive repeated measures randomized complete block mixed model with site as a random factor and annual seed, perennial seed, year and their interactions as fixed effects using SAS v.9.3 (SAS Institute, Cary, North Carolina, USA); the Kenward-Rogers denominator degrees of freedom method was used to account for unequal variances. For significant main effects, means comparisons were made with the studentized maximum modulous p-value adjustment and pairwise degrees of freedom were adjusted as appropriate for the pair. If the covariance associated with the random site effect was large, similar analyses were also conducted for each site individually. Due to inability of a transformation to achieve normality and lack of an appropriate non-parametric test, native annual biomass was not analyzed statistically. All analyses were performed at $\alpha=0.05$.

Key Findings and Relationship to Other Work

The Craters site had the lowest species richness and density of seeds post-fire and the seedbank did not contain any *B. tectorum* (Table 3). It is possible that the fire was intense enough that *B. tectorum* seeds may have been consumed or killed (Keeley and McGinnis 2007), as would any other seeds that were on or near the soil surface. The Dinosaur and Debeque sites, however, experienced low-severity ground fires. The seedbank samples from both of these sites contained viable *B. tectorum* seeds and had greater species richness and densities than the Craters seedbank. A study of varying fire severities on native grass seedbanks found that low severity fires resulted in significantly more establishment (Hunter and Omi 2006).

Table 3. Species germinated during seedbank study and the estimated densities (# m^{-2}) (±SE) of each species in the soil seedbank.

Species	Craters	Dinosaur	DeBeque
Bromus tectorum	0	805.9 (210.7)	18.3 (18.3)
Vulpia octoflora	0	128.2 (62.3)	36.6 (23.6)
Sisymbrium altissiumum	0	109.9 (76.3)	0
Plantago patagonica	0	18.3 (18.3)	0
Alyssum parviflorum	0	18.3 (18.3)	0
Oenothera pallida	0	0	18.3 (18.3)
Descurania pinnata	0	0	36.6 (23.6)
*Unknown forbs**	36.6 (23.6)	73.3 (54.9)	54.9 (38.1)

* Plants were too small to identify before they perished.

There was a significant interaction between annual seed treatment and year on total plant cover across all sites (P=0.001). Although there was no effect of seeding in 2008, 2010, or 2011, total cover was 16% lower in plots that were seeded with native annual species than those that were not (Fig. 1a). This was likely due to suppression of *B. tectorum* by seeded species as discussed below. There was no effect of annual seed treatment on total biomass, however perennial seeded plots had higher total biomass than plots that did not receive perennial seed (P=0.004) (Fig. 1b).

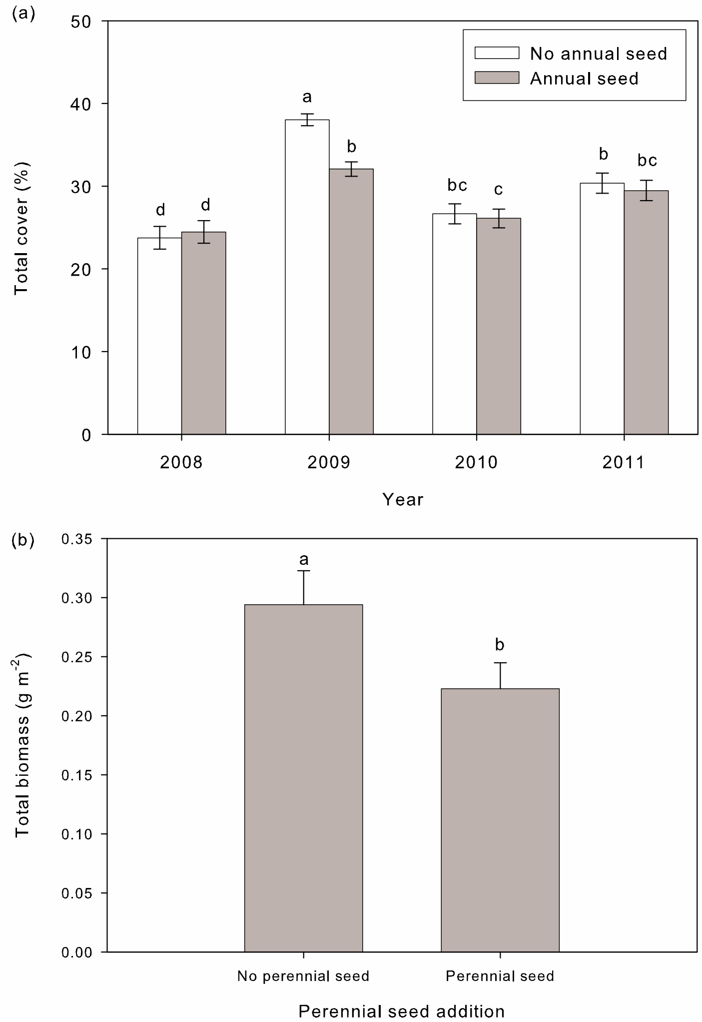
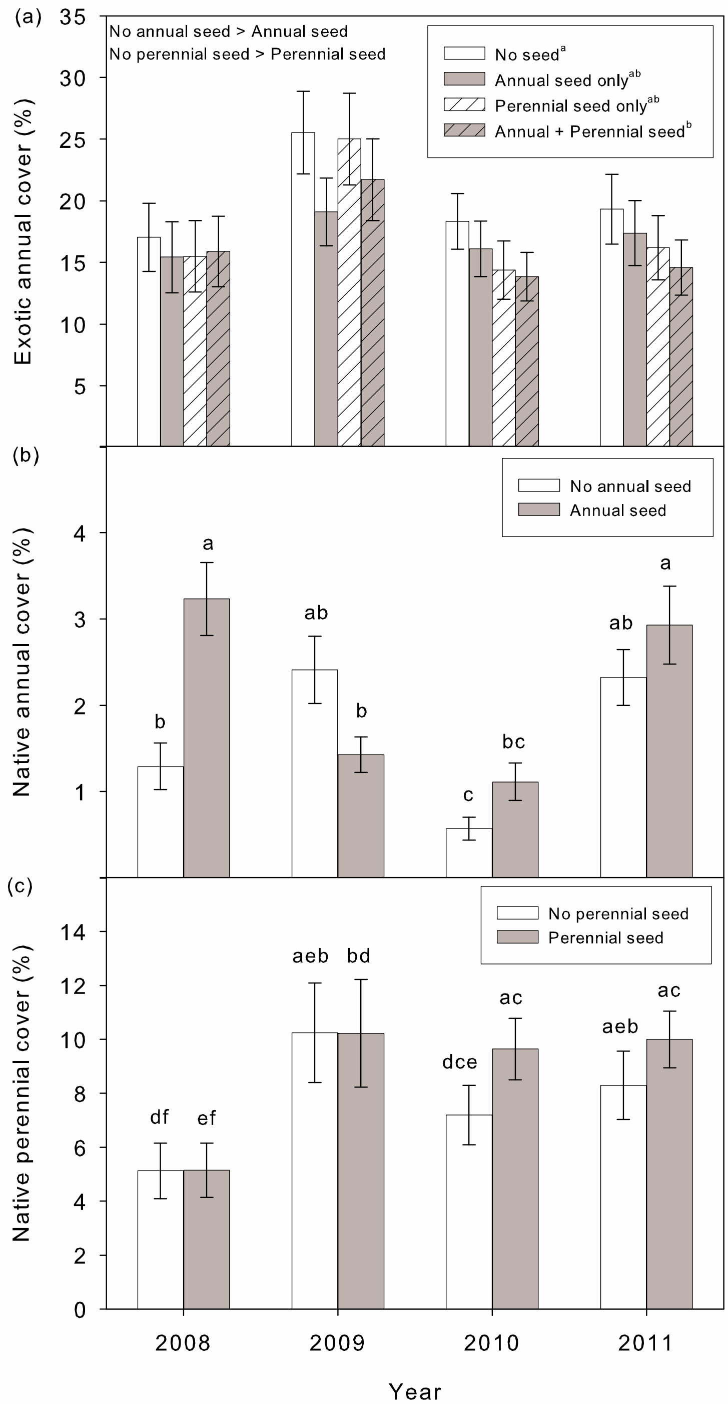


Figure 1. Effect of … r (%, ±SE) from 2008 to …) and non-seeded control plots (open bars) and (b) average total biomass (g m^{-2}, ±SE) in 2010 and 2011 in plots that were or were not seeded with native perennial species in 2007. Bars with different letters differ significantly at α=0.05 after adjustment for multiple comparisons.

Exotic annual cover, dominated by *B. tectorum*, showed significant responses to annual seed addition (P=0.046), perennial seed addition (P=0.035), and year (P<0.0001) (Fig. 2a). The effect was additive with exotic annual cover significantly lower in the combination treatment plots (seeded with both native annual and perennial species) than the non-seeded control plots. The annual only and perennial only seeded plots were intermediate and not significantly different from each other, the control, or combination treatments. There were no effects of seed treatments or year on exotic annual biomass.



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In 2008, native annual cover was significantly higher in plots seeded with native annuals relative to those that had not received annual seed (P=0.0002) (Fig. 2b). There was a similar non-significant trend in 2010 and 2011.

The perennial seed treatment x year interaction had a significant affect on native perennial cover (P=0.001). Although native perennial cover was similar across perennial seed treatments in 2008 and 2009, plots seeded with perennial species had higher native perennial cover in 2010 and 2011 than those without perennial seed addition (Fig. 2c). Similarly, native perennial biomass was significantly higher in the perennial seed treatment (P=0.002) (Fig. 3).

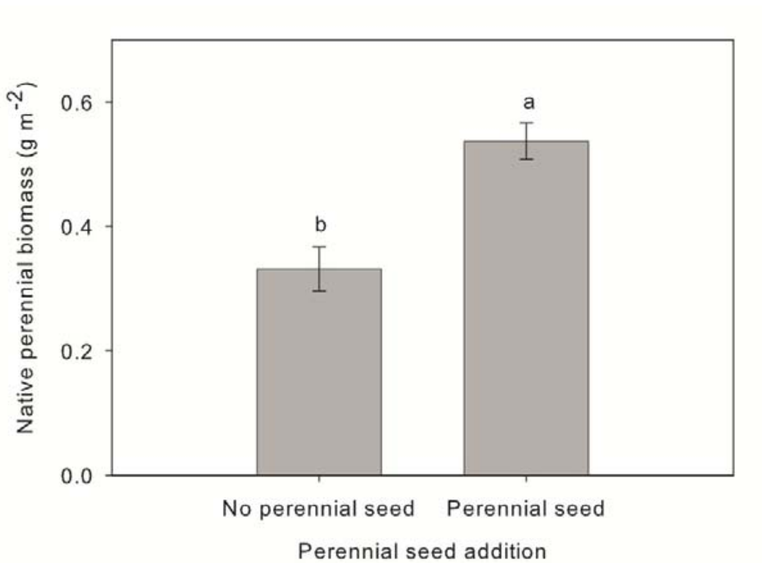

Figure 3. Average 2010 and 2011 native perennial biomass (g m^{-2}, ±SE) in treatments that were or were not seeded with native perennial species across all sites. Bars with different letters differ significantly at α=0.05.

The three study sites differed with regard to the extent of *B. tectorum* invasion based on the seedbank study and post-fire vegetation results. Dinosaur was further along in the invasion process with 25.2 (±0.7)% *B. tectorum* cover, while Craters was much more representative of an intact native plant community with only 1.1 (±0.2)% cover of *B. tectorum*.

Each site had unique environmental conditions (soils, vegetation, climate and fire effects), which likely resulted in distinct responses to the seeding treatments. The Craters site pre-burn vegetation was late-seral *Artemisia tridentata* Nutt. *ssp tridentata* (basin big sagebrush) – *Pseudoroegnaria spicata* (Pursh.) A. Löve (bluebunch wheatgrass) with a suite of other species characteristic of late-seral sagebrush steppe habitats. The Bear Den Butte fire that burned through this site was described as hot with severe behavior and spotting (Sammi 2007). nThe study site was located near an edge of the burn and was likely received seed rain from unburned surrounding vegetation. We also observed re-sprouting of the bunchgrasses and other perennial vegetation at this study site, which accounts for the strong presence of perennial vegetation in the first four years post-fire. Both Dinosaur (Steuwe fire) and DeBeque (Pyramid fire), were within the piñon-juniper habitat type (Soil Survey Staff, NRCS 2009) and experienced small ground fires ignited by lightning. However, the soils were different at the two sites (Table 1). The Dinosaur site had loamy soils with a clay component that exhibited a combination of Pinyon-juniper and sagebrush vegetation while the DeBeque site had very fine sandy loam soils that exhibited Pinyon-juniper vegetation with a strong herbaceous component.

Management Implications

Our results provide evidence that seeding with native species may help suppress exotic annual species and improve post-fire plant communities. We did not find that immediate post-fire seeding with native annual plant species provided improved initial plant cover as was hypothesized (H1). There was no effect of annual seed on plant cover in 2008, 2010, or 2011, and there was significantly less total cover associated with seeding native annual species in 2009. However, there was an overall significant decrease in exotic annual cover associated with the main effects of native annual seed (H2) and native perennial seed. The pattern was most pronounced in 2009 and responsible for the decrease in total cover observed in 2009. Importantly, our results also provide evidence that seeding both annual and perennial native species quickly after a fire can have a larger negative impact on exotic species than not seeding or seeding native annual or perennial species alone. Our results should be considered somewhat preliminary since the additive effect of annauls and perennials may have been confounded by increasing seed numbers in the combined treatment. However, since we did not observe differences in total plant cover between seeding treatments (data not shown) we suspect that differences in B. tectorum suppression between the seeding treatments were more likely due to species used in the seed mixes. Furthermore, because we only sampled these sites in the spring, it is possible that we were not able to capture the full spectrum of native annuals that may have emerged later in the growing season and perennial cover and biomass may have been underestimated by our study. During the second sampling year there were senesced skeletons of *Helianthus annuus* and *Cleome serrulata*, which were both seeded as part of the native annual seed treatments, that appeared to be from the previous growing season. These large native annual forbs may have contributed to the effects that we observed. Previous research has indicated that annual forb species may be effective competitors with *B. tectorum* for these resources (Young and Evans 1978; Pokorny et al 2005; Perry et al. 2009).

Including native annual species in post-fire seed mixes might be an effective management approach because of their tendency to grow in these early-seral conditions and for their ability to compete with exotic annuals at the phenological level (Chambers et al 2007). A major limitation of this management approach is the lack of native annual species that are commercially available from seed suppliers. Until there is a market for these species, it is not likely that a seed company will invest in producing them. However, due to the tendency of annuals to invest heavily in seed production (Smith et al 2010), commercially available native annual species might be easily produced relative to native perennials. Another advantage of using native annual species in post-fire reseeding is that they typically have broadly adapted genotypes with broad geographic ranges (Bazazz 1996). This means that local adaptations for a particular species' ecotype are less of a concern. Therefore, production and distribution of these species is generally compatible with their ecology. Furthermore, projects that have used ruderal annual species, especially forbs, in restoration efforts have shown superior establishment success (Smith et al 2010; Pywell et al. 2003).

While the idea of using native weedy species to combat exotic weeds is not a novel concept, we believe that the idea of using native annual species to combat exotic annuals in post-fire arid and semi-arid habitats represents a unique and promising management approach. This project has shown that the mixing native annuals and perennials in post fire seed mixes had significant effects on exotic annual (*B. tectorum*) cover. Based on these results, the addition of native annual plant species would be an easy modification to common perennial seed mixtures and may provide some competition for exotic annual plants during the few years post-fire. As indicated by Brown (2004), including multiple functional guilds in restoration seed mixtures may increase community competitiveness and provide a buffer against non-native plant invasions.

Future work needed

This study suggests that there should be more research on the use of native annuals in post-fire seed mixtures. This suggestion comes from our observation that including native annuals in a seed mix improves post-fire restoration success by reducing exotic annuals, especially *B. tectorum*. The number of native annual species that we used was limited by commercial availability because seed collecting was beyond the scope of our study. The results of our study suggest that there would be utility in testing additional native annual taxa that could be used in restoration. Our native annual seed mix contained only two native annual grasses due to limited commercial availability. Therefore, future work should explore the use of additional species of native annual grasses as well as forbs.

This study showed rather surprising results given the low level of establishment of our seeded species (Figures 1-3). We suspect that with greater establishment there would have been even greater restoration success. Future work looking at the use of native annuals should explore various seeding methods and rates for ensuring restoration success while minimizing expenditures on expensive native seed. We have recently initiated a follow-up study to explore the effects of seeding rates and seed mix diversity when using these and other species in restoration seed mixes. Give the context dependent nature of such studies, there is clearly need for many more investigations.

In our study we assumed that native annuals would provide benefits across a broad range of sites but this assumption needs further testing. Clearly, additional research is needed on the role of post-fire soil conditions in influencing the success of native annual seed treatments. Many of the results we observed varied across the three sites. A greater understanding of how best to match seed mixes to site conditions would be useful. Given that we only used three sites, we can only speculate as to why the sites may have differed in their response to seeding treatments. In order to get at such questions a study with much higher levels of site replication would be needed.

Deliverables

Table 4. Project deliverables, descriptions, delivery dates and status.

Deliverable	Description	Status	Delivery Dates
Annual reports	Summary of project progress	completed	August 07, 08, 09, 10 and 11
M.S. Thesis	Herron, C. M. 2010. Using native annual plants to suppress weedy invasive species in post-fire habitats. MS Thesis. Colorado State University, Department of Forest and Rangeland Stewardship. Fort Collins, CO. http://hdl.handle.net/10217/39332.	completed	July 2010
Refereed Publications	1) Initial study findings of plant community dynamics 2) Herron, C.M., J.L. Jonas and M.W. Paschke. Using native annual plants in the restoration of post-fire habitats. Journal of Wildland Fire	Incomplete - Initial findings were not publishable	
Final JFSP Report	Summary of project findings with management recommendations	This report	2011
Presentations at Conferences, Workshops and Field Tours	1) Herron, C.M. and M.W. Paschke. 2009. Using native annual plant species to suppress weedy invasives in post-fire habitats. Front Range Student Ecology Symposium, February 2009, Fort Collins, CO. 2) Herron, C. and M.W. Paschke. 2009. Using native annual plant species to suppress weedy invasive species in post-fire habitats. Workshop: Developing a Successful Native Plant Program. April 2009, Ontario, OR. Poster presentation. 3) Field Tour. May 7, 2009. Colorado Division of Wildlife, western Colorado habitat revegetation tour for managers and biologists. This 2-day tour visited the 2 Colorado study sites to see study plots and discuss results. 4) Paschke, M.W. 2009. Ecological restoration and soil ecology. Invited Presentation. Western chapter International Erosion Control Association, The Sustainable Erosion Control BMP Training Workshop, Oct. 25-27, 2009, Kings Beach, California. 5) Herron, C. and M.W. Paschke. 2009. Using native annual plant species to suppress weedy invasive species in post-fire habitats. 4th Internation Fire Ecology & Management Congress. Savannah Georgia. Nov. 30 - Dec. 4, 2009 6) Herron, C.M. and M.W. Paschke. 2010. Using native annual plant species to suppress weedy invasives in post-fire habitats. High Altitude Revegetation conference, March 2010, Fort Collins, CO. 7) Busby, R., M. Paschke, C. Herron, J. Rieder. 2010. Utilization of native annuals for restoration. Native Plant Materials Development, Production & Use in Habitat Restoration. The National Native Seed Conference. Snowbird, Utah, May 17 - 21, 2010		

Websites	Description of project and results on websites: 1) http://warnercnr.colostate.edu/rel-projects/	Completed and ongoing
	2) InsideNPS	March 2012*
	3) http://www.fws.gov/fire/ifcc/esr/Library/Library.htm	Spring 2012*
Interpretive Materials	Draft "common-language" project summary (for use in newsletters, websites, etc)	December 2011
	NPS Naturally Speaking newsletter	Spring 2012*
Interpretive Materials	NPS/NIFC Fire Education newsletters	Spring 2012*
Interpretive Materials	Talking points, pamphlets, etc for site-based interpreters	Spring 2012*

* These products will be timed for early fire season meetings and planning

While our original plan committed us to develop interpretive materials for a general National Park Service and land manager audience (as will be addressed above), we also have initiated work with two of the new JFSP Science Delivery Consortia – Great Basin and Southern Rockies to a) evaluate this project with similar work (for example, Beth Leger's work in the Great Basin) and b) identify additional opportunities for scientist-manager information exchange (such as webinars, field trips and BAER meetings as they are scheduled for 2012).

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