Control of barbed goatgrass (*Aegilops triuncialis*) in serpentine grasslands

Paul A. Aigner and Rhett J. Woerly, University of California Davis, Donald and Sylvia McLaughlin Reserve, Lower Lake, CA

Serpentine grasslands are known for being relatively free of the invasive species that typify other California grasslands. Recently the special status of serpentine grasslands as strongholds of native plant diversity has been threatened by the spread of barbed goatgrass (*Aegilops triuncialis*), a Eurasian annual that is unique in its tolerance of serpentine soils (Plate 1). Carefully timed prescribed fire, especially applied over two consecutive years, has been shown to reduce goatgrass while benefitting many native species (DiTomaso et al. 2001). At the McLaughlin Reserve in the inner North Coast Range of California, we found prescribed fire cannot be applied for two consecutive years, because the low productivity of serpentine grasslands prevents adequate fuel build up in the second year. Some serpentine grasslands are so unproductive that fire will not carry at all.

Motivated by the need for a follow up/alternative treatment to fire, we evaluated nine treatments for their effectiveness controlling barbed goatgrass and for restoring native species cover and diversity: two grass-specific herbicides —fluazifop [Fusilade II] and clethodim [Envoy +]—applied before goatgrass flowering (early-season), at flower initiation (mid-season), and at early seed development (late-season), a broad-spectrum herbicide (glyphosate) applied late-season, mowing , and hand pulling.

Methods

In fall of 2007 we established a grid of 100, 2m x 2m plots with 2-m wide buffers between plots in a serpentine grassland with high cover of barbed goatgrass but few other non-native species (Plates 2, 3). We counted goatgrass tillers within a 0.25-m^2 frame in the center of each plot, and stratified the experiment into 10 blocks based on tiller density. The nine treatments and a non-treatment control were assigned randomly within each block. Treatments were applied in spring 2008 and 2009. In early March 2008, 2009, and 2010 (prior to the application of treatments in 2008 and 2009) we measured the frequency of barbed goatgrass, native forbs, native bunchgrasses (almost exclusively *Nassella pulchra* and *Poa secunda*), and other annual grasses (*Bromus hordeaceus* and *Vulpia microstachys*) in 25, 27-mm diameter circular subplots within each plot. In early May 2010, we made visual estimates of cover of all species within a 1-m^2 frame at the center of each plot.

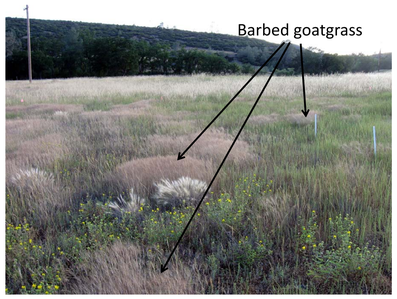

Plate 1. Barbed goatgrass invasion front in a serpentine grassland at the McLaughlin Reserve

Plate 2. Experimental plots in summer 2009, after the first season of treatment

Early-season herbicide treatments were applied in mid-March, three to four weeks before flower initiation. Mid-season herbicide treatments were applied in early May as inflorescences were beginning to extend from the sheath. Late-season herbicide treatments were applied at the end of May, when all goatgrass had flowered, and most were showing signs of early seed development (a small, soft, green embryo was apparent). Mowing occurred at the peak of flowering in late May before any seed development was evident, and was done with gas-powered string trimmers at a height of approximately 2 cm . Hand pulling occurred in mid-May.

Herbicides were applied using a spray to wet technique with a backpack sprayer using the recommended spot-spray rate for Fusilade II, the near-maximum spot-spray rate for Envoy +, and a 1.6% solution for Roundup (Table 1, Plate 4). Envoy and Fusilade were mixed with 0.33 oz/gal of a modified vegetable oil/silicone surfactant (Syl-tac).

Table 1. Application rates used for herbicide treatments.

Herbicide	Mix concentration oz concentrate/gallon	Approximate per-acre rate oz concentrate/acre
Envoy +	0.8	64-80
Fusilade II	0.75	60-75
Roundup Pro	2.1	168-210

References

DiTomaso, J.M., K.L. Heise, G.B. Kyser, A.M. Merenlender, and R.J. Keiffer. 2001. Carefully timed burning can control barb goatgrass. California Agriculture 55(6): 47-53.

Plate 3. Control plot , summer 2009.

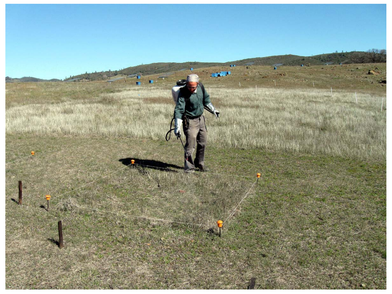

Plate 4. Early-season herbicide application, March 2009.

Effects on goatgrass

After two years of treatment , all treatments except for Roundup and early-season Envoy resulted in reduced goatgrass frequency relative to controls (Fig. 1). Mid-season Fusilade, hand pulling, and early-season Fusilade showed the best performance, reducing goatgrass frequency by 66%, 62% , and 52% respectively from the pre-treatment frequency of about 0.7. Early-season Envoy and Roundup produced no significant reduction relative to controls. Early-season application of Envoy resulted in damage to goatgrass, followed by partial recovery. Late-season application of all herbicides failed to prevent at least some viable seed production.

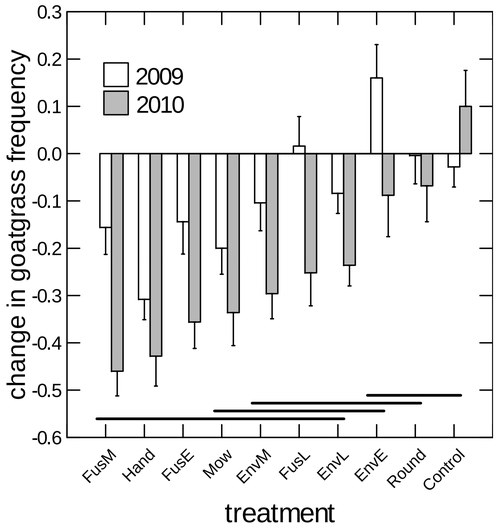

Figure 1. Change in barbed goatgrass frequency after one and two years of treatment. Error bars represent SEM. Solid lines below the bars group treatments that are not significantly different in 2010 by Tukey's HSD test at α=0.05. Abbreviations: EnvE, Envoy early season; EnvM, Envoy mid season; EnvL, Envoy late season; FusE, Fusilade early season; FusM, Fusilade mid season; FusL, Fusilade late season; Hand, hand pull; Round, Roundup.

Effects on native grasses

Both grass-specific herbicides caused damage to native perennial grasses, but virtually all of these grasses recovered, even after the second year of application. Late-season Envoy resulted in an increase in total bunchgrass frequency relative to controls (data not shown), whereas all other treatments produced changes that were statistically indistinguishable from controls. There was no suggestion that bunchgrass frequency was reduced by any treatment, with the possible exception of early-season Envoy. Individually, neither *N. pulchra* nor *P. secunda* was negatively affected by treatments (Fig. 2, Plate 5), except that *N. pulchra* was completely eliminated by Roundup (*P. secunda* escaped this effect because it was dormant during the late-season herbicide applications). The native annual grass, *V. microstachys,* also was not negatively impacted by any of the treatments (Fig. 2). For *V. microstachys*, hand pulling produced a benefit relative to early-application of Envoy, but neither treatment differed from controls.

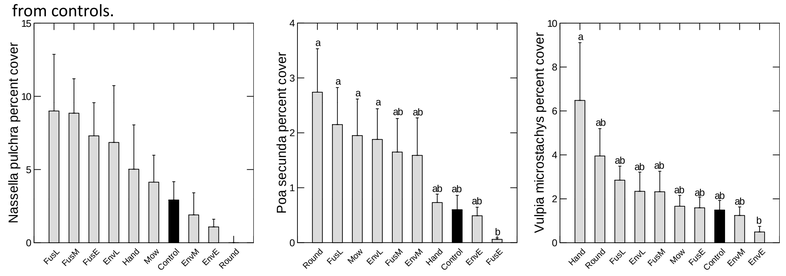

Figure 2. Percent cover of three native grasses after two years of treatment. Error bars represent SEM. Letters above the bars group treatments that are not significantly different by Tukey's HSD test at α=0.05. Abbreviations: EnvE, Envoy early season; EnvM, Envoy mid season; EnvL, Envoy late season; FusE, Fusilade early season; FusM, Fusilade mid season; FusL, Fusilade late season; Hand, hand pull; Round, Roundup.

Effects on native forbs

Native forbs were especially diverse in the study area, with 51 species recorded across all plots, and a median of 13 species per plot. As a group, native forbs increased in frequency dramatically on hand-pulled, early-season Fusilade, and early-season Envoy plots (Fig. 3A). All other treatments showed a trend toward increasing native forb frequency, but none differed statistically from controls. Of the eight forb species with an average cover across all plots of >1%, two showed increases with early-season application of grass specific herbicides (Fig. 3B&C). *Navarretia jepsonii*, a serpentine endemic annual, had higher cover on early-season Fusilade plots compared to controls, mowing, and all of the late-season herbicide plots (Fusilade, Envoy, and Roundup). *N. jepsonnii* may have been negatively affected by Roundup, as it was still actively growing at the time of application. *Holocarpha virgata*, a summer annual, had higher cover on early-season Fusilade and Envoy plots relative to controls.

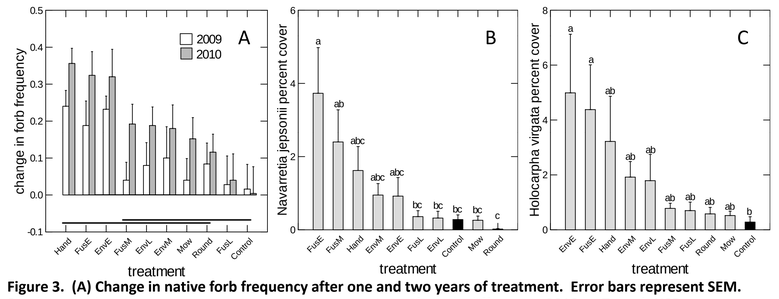

Figure 3. (A) Change in native forb frequency after one and two years of treatment. Error bars represent SEM. Solid lines below the bars group treatments that are not significantly different in 2010 by Tukey's HSD test at α=0.05. (B & C) Percent cover of two native forbs after two years of treatment. Error bars represents SEM. Letters above the bars group treatments that are not significantly different by Tukey's HSD test at α=0.05. Abbreviations: EnvE, Envoy early season; EnvM, Envoy mid season; EnvL, Envoy late season; FusE, Fusilade early season; FusM, Fusilade mid season; FusL, Fusilade late season; Hand, hand pull; Round, Roundup.

Effects on other non-natives

Besides goatgrass, the only non-native species recorded in the plots were the annual grass, *Bromus hordeaceus*, and the annual forb, *Lactuca serriola*, and both species were a minor component of the community with an average of 0.4% and 0.06% cover, respectively. *B. hordeaceus* increased on hand-pulled plots , late-season Envoy plots, and Roundup plots relative to plots that were treated early with grass-specific herbicide (data not shown). *B. hordeaceus* was susceptible to all three herbicides, but sets seed in April and May, so it was unaffected by the late season applications.

Plate 5. Late season Envoy plot after two years of treatment showing persistence of *N. pulchra*.

Plate 6. Early-season Fusilade plot in early summer 2009 showing growth of *N. jepsonii* and *H. virgata*.

Conclusions

- **Fusilade applied early or mid-season and Envoy applied mid-season controls barbed goatgrass, while sparing native perennial grasses and forbs. Early-season Envoy failed to control goatgrass.**
- **Application of grass-specific herbicides early in the season provides the most benefit to native forbs (probably because of their early release from competition), but may set back native grasses, which benefit more from applications later in the season when they have set seed or are nearer to dormancy. Early-season application can also provide control of other non-native annual grasses, such as *B. hordeaceus*, that mature earlier than goatgrass.**
- **Mowing provides acceptable goatgrass control, but less benefit to native forbs.**
- **Late-season application of Roundup failed to control goatgrass, eliminated *N. pulchra*, and reduced the cover of some native forbs that were still actively growing at the time of application.**
- **For all treatments, significant goatgrass cover remains after two years of treatment. Outside of this study, our experience suggests that five to six years of hand pulling is necessary to deplete the seed bank. To avoid selection for herbicide resistance, a multi-year treatment program should begin with prescribed fire and alternate herbicide use with mowing.**