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This progress report describes the first and second year's results of Project 07-2-2-06.

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Management of fuel loading in the shrub-steppe: Responses six and seven years after treatments

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Abstract

Our objective was to determine if our strategy to reduce *Bromus tectorum* cover and thus fire risk is sustainable after implementation. Our primary task was to test the hypothesis that the bunchgrass, *Elymus wawawaiensis*, established in 2003 will show an increasing degree of *B. tectorum* control over three years. Here we discuss results for the first two years. Six years after plots that were burned, treated with Plateau herbicide at a rate of 4 or 8 oz/acre, and then drill-seed with *E. wawawaiensis* had significantly ($p = 0.0016$) less *B. tectorum* cover ($14.4 \pm 4.17\%$) than plots that were only burned (37.9 ± 3.65 %). In 2009, the effect remained with significantly ($p = 0.0003$) less *B. tectorum* cover ($19.1 \pm 3.95\%$) in treated plots than in plots that were only burned ($47.0 \pm 3.42\%$). We tested the hypothesis that native species cover and richness and cover of aliens in Plateau only plots will not be different from controls 6 and 7 years after treatment application. Cover of native species in Plateau only plots was not significantly different from that in control plots in 2008 ($p = 0.155$) or 2009 ($p = 0.167$). Cover of alien species in Plateau only plots was not significantly different from that in control plots in 2008 ($p = 0.061$) or 2009 (0.074). Native species richness in Plateau only plots was not significantly different from that in control plots in 2008 ($p = 0.142$) or 2009 ($p = 0.106$). The number of *E. wawawaiensis* plants in twelve monitored plots increased from 694 in 2004 to 946 in 2008 and 1022 in 2009. We found a strong reduction in *B. tectorum* cover with increasing density of *E. wawawaiensis.*

Introduction

Land management in the West is complicated by fires associated with invasive species such as *Bromus tectorum* (cheatgrass) (Whisenant 1990). It is possible to reduce cover of *B. tectorum* and thus fire risk (Link et al. 2006a) by instituting prescribed fire management strategies, applying herbicide, and drill seeding native perennial grass species in the shrub-steppe (Link et al. 2005a). We found the best strategy was to conduct a prescribed burn in the fall, apply Plateau herbicide at a rate of 4 or 8 oz/acre, and then drill-seed *Elymus wawawaiensis* (Snake River wheatgrass). Land managers at the Columbia, McNary, and Umatilla National Wildlife Refuges are now applying Plateau at levels similar to those determined in our experiments (4 and 8 oz $acre^{-1}$). They wish to know how long the effect of Plateau will remain and if drill-seeded grasses will be sufficient to reduce *B. tectorum* cover. Also, they are interested in determining if the increase in native species richness is sustainable after application of Plateau.

Seeding *E. wawawaiensis* at about 7 lbs $acre^{-1}$ resulted in about 0.55 plants m^{-2} (Link et al. 2005a). We were not able to detect the effect of the newly established bunchgrasses on plant community composition or cover in 2004. It takes a longer time to recognize the competitive effect of bunchgrasses on *B. tectorum* cover. To obtain better value from the experiment started in 2002 (Link et al. 2005a) it was necessary to document responses to treatments for a longer period of time. This is relevant to the Task Statement in the AFP, “Re-measurement of past JFSP study sites or experimental plots”.

The competitive effect of bunchgrasses on *B. tectorum* cover was observed in an adjacent field from our study area. After 18 years (since 1986), drilled *E. wawawaiensis* bunchgrasses (2.77 plants m^{-2}) reduced *B. tectorum* cover to 2.8% (Fig. 1) compared with about 25% in adjacent untreated fields. It should be noted that *B. tectorum* cover is highly variable year-to-year ranging from about 52% in 2003 to about 25% in 2004 in untreated plots (Link et al. 2005a).

Figure 1. Eighteen years (since 1986) after drill seeding the large bunchgrass, *E. wawawaiensis,* results in near elimination of *B. tectorum*, an increase in bare soil and soil cryptogam cover, and a reduction of fire risk at the Columbia National Wildlife Refuge.

While we know *B. tectorum* cover was greatly reduced after 18 years, we do not know how long it took to achieve this level of control. There have been few attempts to address this question. Seven years after seeding a number of perennial bunchgrasses and rhizomatous grass species effects on *B. tectorum* biomass were variable (Robertson et al. 1966). *Agropyron inerme* reduced *B. tectorum* biomass by 40% while *Elymus elymoides* reduced *B. tectorum* biomass by 88% (Robertson et al. 1966). There is little information on how long it takes for *E. wawawaiensis* to dominate a site (Monsen et al. 2004). Monson et al. (2004) also notes that there are many perennial species that can compete with and invade areas dominated by *B. tectorum.* It will be important to land managers to know how long it will likely take to achieve a significant reduction in *B. tectorum* cover and fire risk through planting competitive bunchgrasses. Our primary task was to test the hypothesis that bunchgrasses established in 2003 will show an increasing degree of *B. tectorum* control over three years. Here, we define the effect for the first of three years. If there is no increasing control of *B. tectorum* over the three years of observations then managers can suggest that a higher rate of seeding is needed to establish significant control. If the current experiment shows increasing and significant control then managers can be assured that fire risk will be reduced in a predictable amount of time.

Another result of our application of Plateau at 8 oz acre^{-1} was a 58% increase in native species richness over controls and a decrease in cover of alien species two years after application (Link et al. 2005a). Little is known on how long communities treated with Plateau herbicide will continue to show effects. Beran et al. (1999) showed increases in native wildflower density two years after imazapic (Plateau) application. Similarly, (Beran et al. 2000) showed increases in *Andropogon gerardii* yields two years after applying imazapic. Long-term effects of herbicides have been noted 11 years after application (Miller et al. 1999). We tested the hypothesis that native species richness and cover in Plateau plots will not be different from controls 6 years after treatment application. We also tested the hypothesis that alien species cover in Plateau plots will not be different from controls 6 years after treatment application. We asked these questions to see if increases in native species and reductions in alien species cover are maintained up to 6 years after Plateau application. If this is true, then part of the hypothesized reduction in *B. tectorum* cover associated with *E. wawawaiensis* may be attributed to the effect of Plateau alone. If native species richness increases are maintained and *B. tectorum* and other invasive species cover is significantly reduced over the three-year observation period then the simple use of Plateau without drill seeding bunchgrasses may be sufficient to reduce fire risk.

Our objective was to determine if our strategy to reduce *B. tectorum* cover and thus fire risk is sustainable after implementation. We monitored species composition and cover in 6 plots without Plateau application, but with and without drill seeded bunchgrasses and in 6 plots where Plateau had been applied at 4 and 8 oz acre^{-1} with and without drill seeded bunchgrasses. All plots are split-plots. Our primary task was to test the hypothesis that bunchgrasses established in 2003 will show an increasing degree of *B. tectorum* control over three years. In addition we monitored the survivorship, phenology, and size of established bunchgrasses. We documented presence and density of new *E. wawawaiensis* arising from self-seeding. We tested the hypothesis that native species richness and cover plus cover of alien species in Plateau plots without drill seeded *E. wawawaiensis* will not be different from controls 6 to 8 years after treatment application. This report documents the first and second year's results.

Materials and Methods

The Columbia National Wildlife Refuge is located in the Columbia Basin of eastern Washington. It includes more than 23,000 acres (9,308 ha) north and west of Othello in Grant and Adams counties, and lies in the rain shadow of the Cascade Mountains. Precipitation averages 8" (203 mm) per year, with most rain falling between October and April. Snowfall is quite variable with winter high temperatures usually near freezing. Lightning during the summer is a frequent cause of wildfire.

Cover was dominated by *Artemisia tridentata* (big sage), Sandberg's bluegrass, and *Pseudoroegneria spicata* (bluebunch wheatgrass) when cattle and sheep were introduced in the 1800's. The area was severely overgrazed and soon dominated by cheatgrass. The Columbia Basin Irrigation Project brought water to the area in the 1950's, and the refuge area was set aside due to rockiness, shallow soils, and depression areas that filled with water from a rising water table and seepage from reservoirs and canals. Grazing was halted more than 20 years ago and fire is the most prominent disturbance to upland areas. In untreated areas cheatgrass remains the dominant cover, with variable amounts of annual and perennial forbs. All areas have Sandberg's bluegrass.

Plots were established in early 2002 (Link et al. 2005a). The study area was then burned in October 2002. Plots were located throughout the study area and herbicide treatments randomly applied to the plots after the burn. Each plot was then split and *E. wawawaiensis* was drill seeded in half the plot. Observations were taken in 2002, 2003, and 2004.

Measurements were taken in 2008 and 2009. Species richness was determined in each plot by identifying all vascular plant species. This was done by inspection in the spring and summer. Cover was determined using a tape (Bonham 1989; Elmore et al. 2003; Link et al. 2005b) and identifying the first observed (tallest) cover type at each 0.25 m hash mark on the tape. A second layer was identified under the canopy of *E. wawawaiensis.* All drill-seeded grasses and their progeny were counted, flowering status (in flower or not) recorded, and measured for height in each plot. A meter stick was used to measure height.

A plot is the experimental unit for herbicide application. A split-plot is an experimental unit for drill seeding. All observations within a split-plot were averaged or summed for analysis. Statistical analyses were done using JMP version 5, software (SAS Institute 2002). Percent cover data were transformed by:

$$arcSin\sqrt{\frac{\%cover}{100}},$$

before statistical analysis (Steele and Torrie 1960). Species richness count data are likely to have a Poisson distribution, thus were transformed with the natural log for analysis (MacNally and Fleishman 2004). Untransformed species richness count data are presented to facilitate interpretation. Statistical significance is set at the $\alpha = 0.05$ level.

Results and discussion

Plant cover

Six (2008) and seven (2009) years after plots that were burned, treated with Plateau herbicide at a rate of 4 or 8 oz/acre, and then drill-seeded with *E. wawawaiensis* had significantly less *B. tectorum* cover than control plots that were only burned (Fig. 2). Cover of *E. wawawaiensis* was $9.52 \pm 2.16\%$ in 2008 and $11.19 \pm 3.07\%$ in 2009, which are significantly ($p < 0.05$) greater than zero. Addition of Plateau alone did not result in a significant decrease in *B. tectorum* cover compared with the controls that were only burned in 2008 or 2009 (Fig. 2). *Bromus tectorum* cover significantly ($p < 0.0001$) increased $8.95 \pm 1.84\%$ from 2008 to 2009 when all treatments were combined ($n = 24$) demonstrating natural yearly variation in *B. tectorum* cover. There was no significant effect of Plateau herbicide on native species cover (Fig. 3) in 2008 ($p = 0.147$) or 2009 ($p = 0.167$). There was no significant effect of Plateau herbicide on alien species cover (Fig. 4) in 2008 ($p = 0.061$) or 2009 ($p = 0.074$).

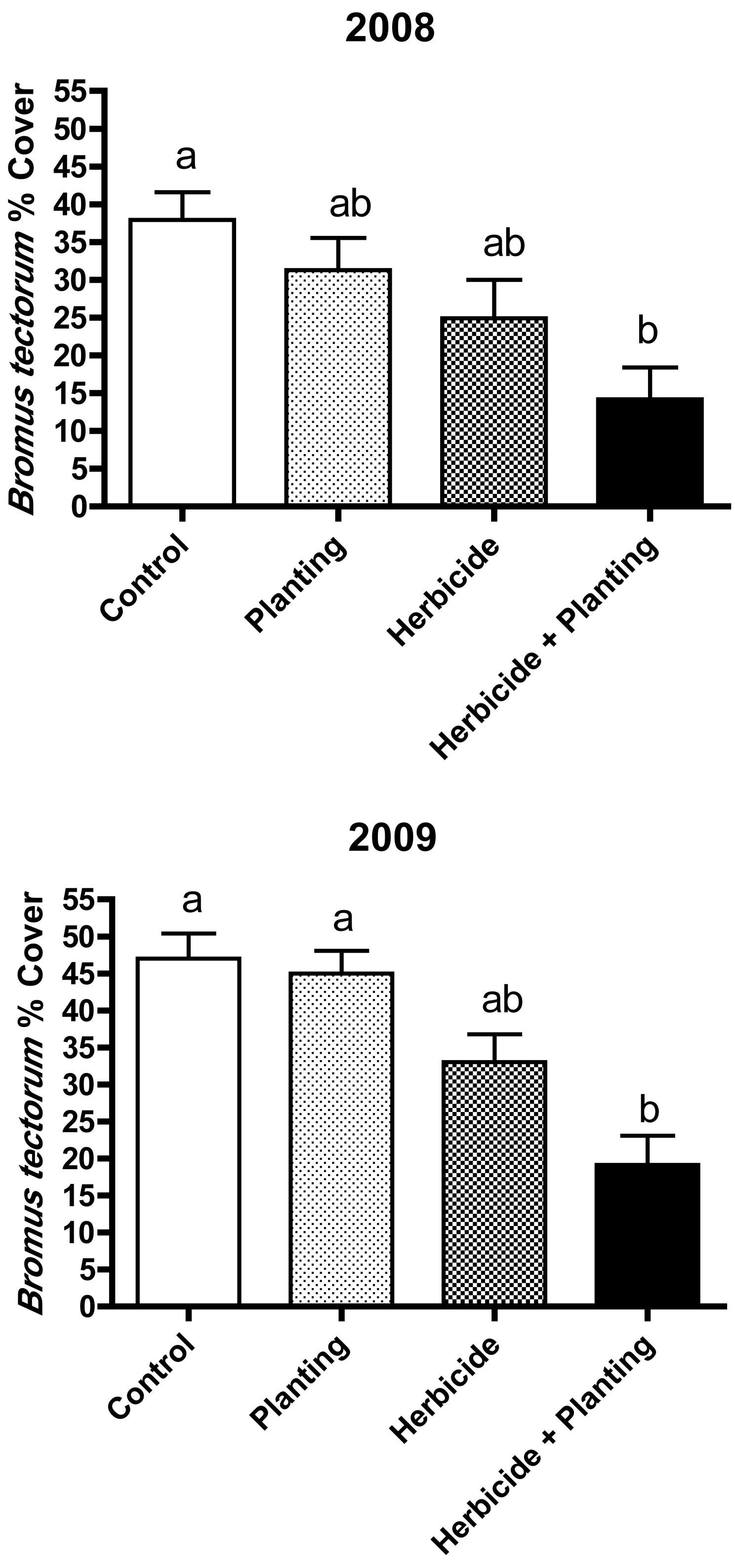


Figure 2. Effect of treatments on *Bromus tectorum* cover (mean ± 1 sem) in 2008 and 2009. Differing letters indicate significant differences.

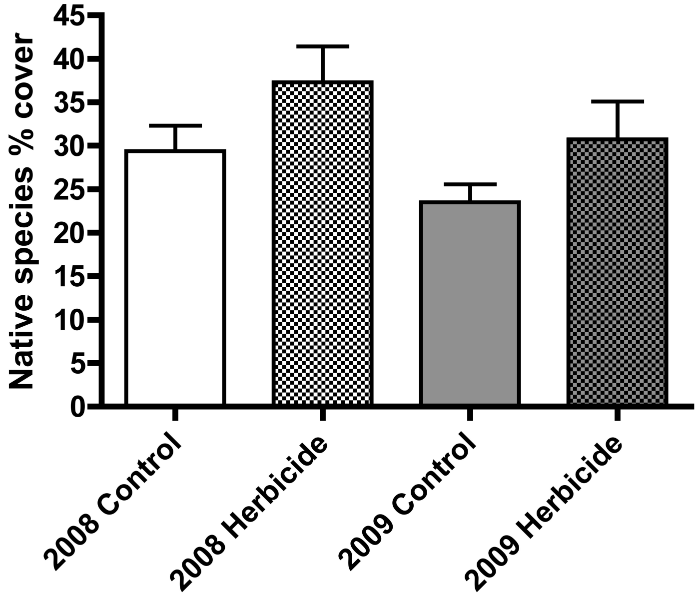


Figure 3. Effect of Plateau herbicide treatment on native species cover (mean ± 1 sem) in 2008 and 2009. There was no significant effect within years.

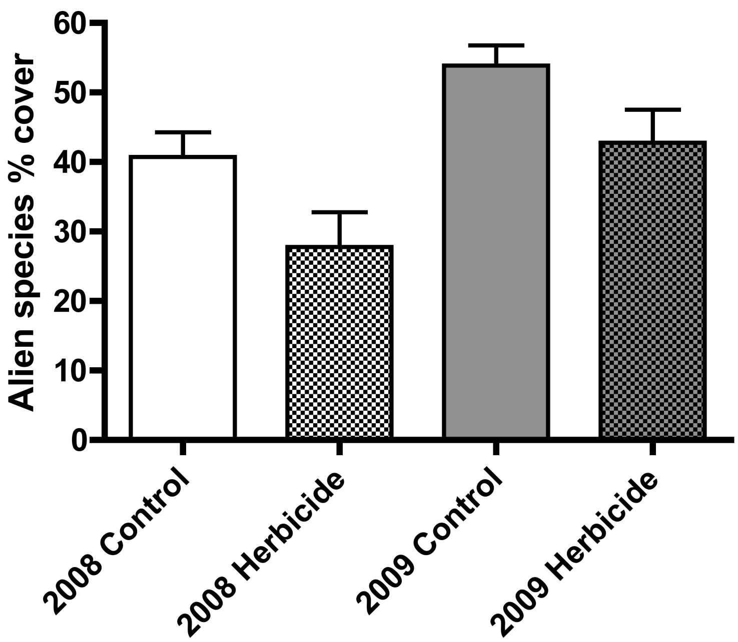
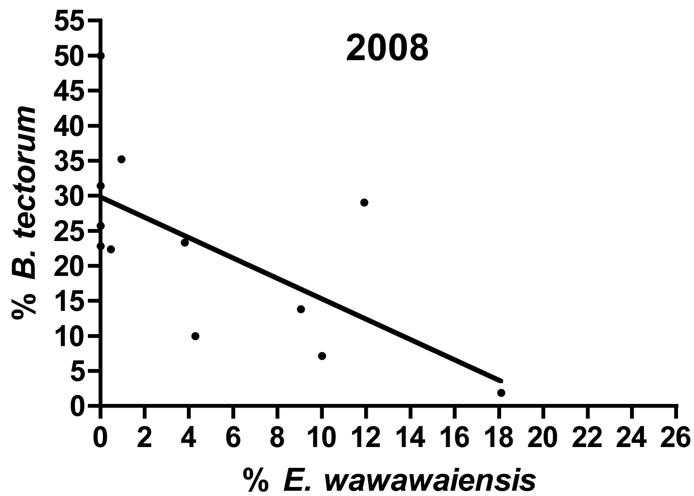


Figure 4. Effect of Plateau herbicide treatment on alien species cover (mean ± 1 sem) in 2008 and 2009. There was no significant effect within years.

When cover of *B. tectorum* was related to cover of *E. wawawaiensis* using all 12 plots (with and without Plateau, but all seeded) a significant ($p = 0.0201$, $r^2 = 0.43$) and linearly decreasing relationship (% *B. tectorum* = 29.8 ± 3.97 – (1.45 ± 0.526) * % *E. wawawaiensis*) resulted in 2008 (Fig. 5). A similar and significant ($p = 0.0026$, $r^2 = 0.61$) response (% *B. tectorum* = 41.3 ± 3.77 – (1.62 ± 0.406) * % *E. wawawaiensis*) was found in 2009 (Fig. 5).



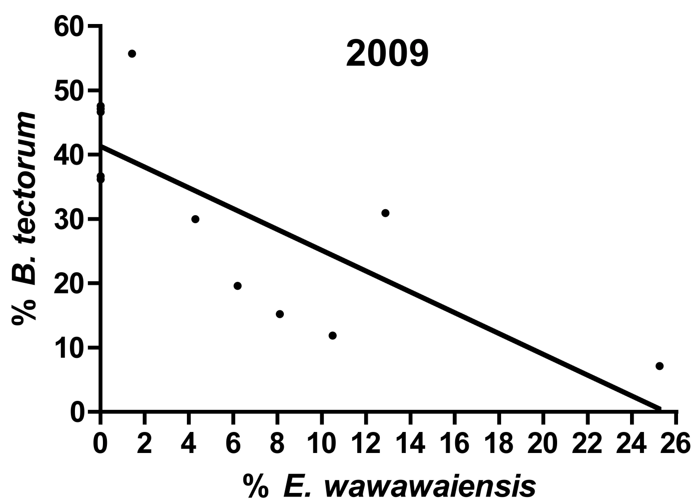


Figure 5. Relationship between cover of *Bromus tectorum* and *Elymus wawawaiensis* six (2008) and seven (2009) years after seeding.

<u>Native species richness</u>

Native species richness in Plateau treated plots (without drill-seeded bunchgrasses) was not significantly different than in control plots in 2008 or 2009 (Table 2) in contrast to the significant increase in native species richness with Plateau treatment in the second year after application (2004).

Table 2. Native species richness in Plateau treated and control plots (n = 12). Observations in 2002 were made before Plateau treatments were applied to the study plots. Observations after 2002 were after fire and Plateau treatment application.

Year	Control (± 1 sem)	Plateau (± 1 sem)	p
2002	7.917 ± 0.3	8.583 ± 0.79	0.524
2003	11.08 ± 0.523	11.67 ± 0.573	0.468
2004	10.67 ± 0.441	15.25 ± 0.783	0.0003
2008	11.17 ± 0.543	12.33 ± 0.477	0.142
2009	12.08 ± 0.570	13.42 ± 0.529	0.106

Survivorship, phenology, and size of established bunchgrasses

All seeded plots with Plateau continued to have significant populations of *E. wawawaiensis* in 2009. There was no significant (p = 0.1556) linear increase in the population over time (Fig. 3). While there has been no statistically significant population increase five of six plots had numerical increases in plants from 2004 to 2009 ranging from 1 to 192 plants $plot^{-1}$ while one plot lost plants going from 139 in 2004 to 66 in 2008 and back up to 77 in 2009.

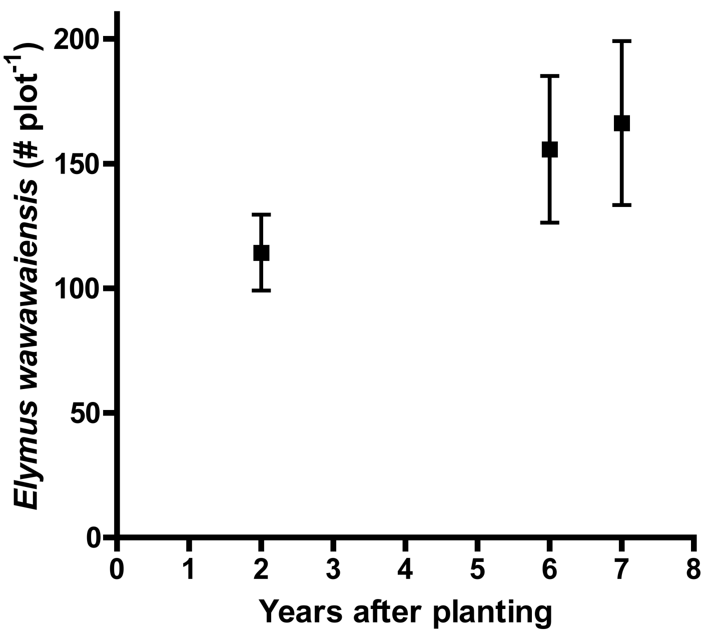


Figure 3. The mean number of *E. wawawaiensis* bunchgrasses per plot. The error bars are one standard error of the mean (n = 6).

All plots had population increases from 2008 to 2009 ranging from 1 to 35 plants. The increases in some of plots suggest that either the original seed had germination delays over years or that there was significant recruitment of new individuals from new seed. There were no individual bunches found outside the drill-rows suggesting delayed germination or that the drill row disturbance strongly favors incorporation and germination of new seed. The population is dynamic with recruitment in most plots and a significant number of senescent plants (6.35 ± 1.32 %) distributed across all plots.

Seeded plots that were not treated with Plateau had very low populations. In 2004 there was an average of 1.3 ± 1.1 plants per plot, but this mean is not significantly different from zero. By 2008 and 2009 there were significant, yet very small populations of 2.0 ± 0.6 and 4 ± 0.6 respectively, again suggesting delayed germination or that the drill row disturbance favors incorporation and germination of new seed.

Combining counts of all *E. wawawaiensis* plants in all 12 plots revealed 694 plants in 2004, 946 plants in 2008, and 1022 plants in 2009. A more detailed assessment of recruitment and mortality of *E. wawawaiensis* plants would require counts in the more of the other seeded plots.

The percent of plants in flower has not changed significantly (p = 0.0823) since 2004 (Fig. 4). The number of flowering culms on individual bunches, while not counted, varied from one to numerous. It is likely that the plants are producing enough seed to account for the number of observed new plants.

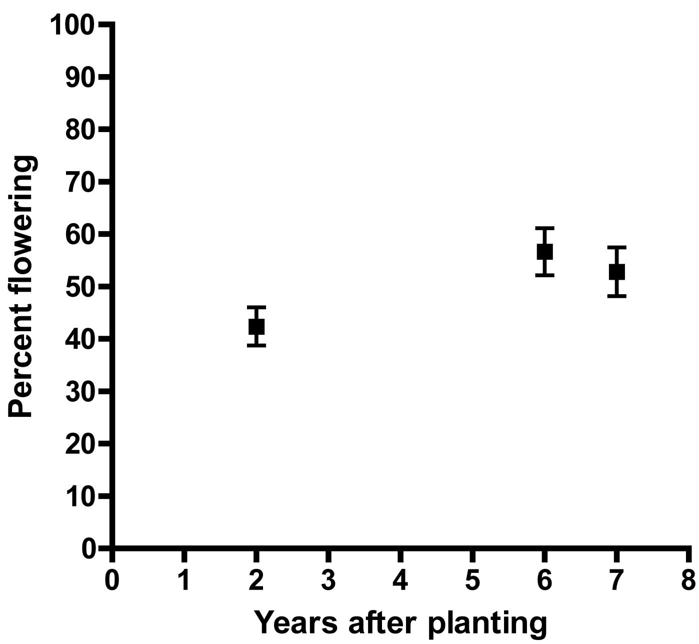


Figure 4. The mean percent of *E. wawawaiensis* in flower. The error bars are one standard error of the mean (n = 6).

The greatest height of bunches was compared across years for those plants in flower and those not in flower. The greatest height of plants in flower was not significantly (p = 0.832) different among years (Fig. 5). The greatest height of plants not in flower was significantly (0.0116) greater in 2009 than in 2004 (Fig. 5) although the effect is small. This small difference may be associated with differences in water status or growing degrees days in the two years that the smaller plants may be sensitive to, compared with those in flower.

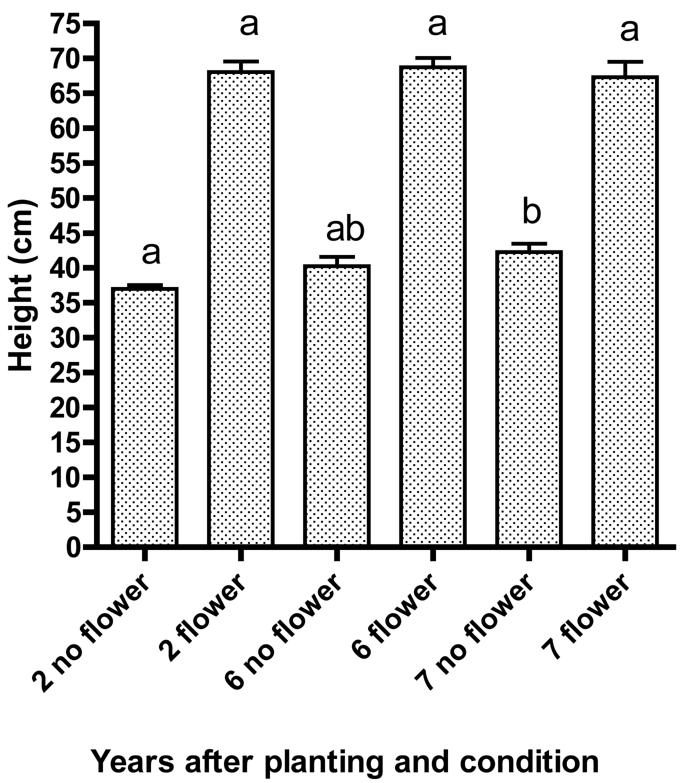


Figure 5. Greatest height of plants in flower and those not in flower, in years after planting. Means within the same class with the same letters are not significantly different. The error bars are one standard error of the mean (n = 6).

<u>Density of *E. wawawaiensis* and *B. tectorum* cover</u>

Bromus tectorum cover decreases with increasing density of *E. wawawaiensis* (Fig. 6). The highest *B. tectorum* cover occurred in plots without *E. wawawaiensis.* This observation and that associated with *E. wawawaiensis* density of 1.23 ± 0.24 plants m^{-2} were gathered in 2009. The plots with *E. wawawaiensis* were seven years old. The highest density *E. wawawaiensis* and lowest cover of *B. tectorum* were observed in 2004 in the adjacent field that had been planted in 1986 after a fire. Using the relationship between fire risk and *B. tectorum* cover derived by Link et al. (2006a) and assuming the relationship is similar for differing locations we conclude that fire risk is near 85% when *B. tectorum* cover is near 38%, near 50% with *B. tectorum* cover near 14%, and predicted to be near 25% with less than 5% *B. tectorum* cover.

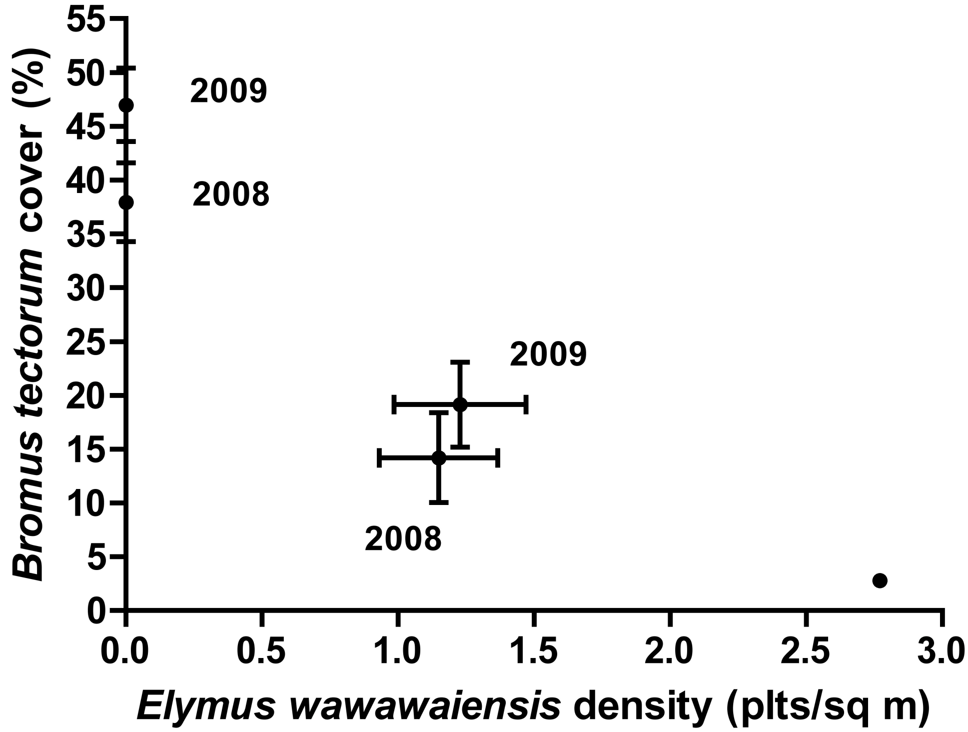


Figure 6. Relation between planted bunchgrass density and *B. tectorum* cover.

<u>Management Implications and Conclusion</u>

We conclude that *B. tectorum* cover can be significantly and sustainably reduced by burning and applying Plateau herbicide at 4 or 8 oz acre^{-1} in the fall and then drill seeding *E. wawawaiensis* in the late winter. Burning and applying Plateau without drill seeding *E. wawawaiensis* had no strong effect on native and alien species cover or native species richness. Seven years after treatment application the density of drill seeded *E. wawawaiensis* was 1.23 ± 0.24 plants m^{-2}. Doubling the seeding rate may increase density enough to further reduce *B. tectorum* cover to be closer to the minimal value of 2.8% achieved with *E. wawawaiensis* density was 2.77 plants m^{-2}. If we demonstrate over three years continued increases in *E. wawawaiensis* cover and density with decreases in *B. tectorum* cover then the we can conclude that experimental system has not yet come to steady state.

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