Restoring native grasslands along the coast of northern California: interim results suggest sawdust will help

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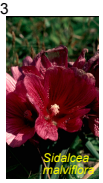
Abstract Previous research showed that adding sugar to soil and fencing out herbivores partly reversed the invasion of introduced, annual grasses into a coastal grassland in northern California. This study is testing if sawdust can be as effective as sugar and if treatments show similar results at other sites. Two fencing treatments (fenced or unfenced) have been crossed with 3 soil treatments (none, sawdust, or sugar) at each of 3 sites. In May-June 2008, we measured the cover of each plant species in areas where natives and introduced species are mixed, and the survival of native grasses planted into areas where introduced, annual grasses strongly dominate. Cover of introduced species was significantly lower in plots treated with sugar than in control plots at the 2 sites treated for 14 months; effect of sawdust was less than that of sugar but not significantly so. Soil treatments did not affect cover at the site treated for 6 months, and fencing did not affect cover at any site. After 5 months, 73% of the planted native grasses had survived; there were no effects of soil treatments and no consistent effects of fencing on survival. Based on these interim results, we recommend sawdust as an inexpensive and minimally intrusive way to restore coastal prairie in California where natives still make up > 20% of plant cover.



Introduction

Introduced species of plants now dominate most of the grasslands in California. One of the most widespread changes has been from communities of native, perennial grasses and native forbs to introduced, annual grasses. A previous study was able to partly reverse this change by a) adding sugar to the soil to promote the immobilization of nutrients by microbes and b) fencing out mammals (deer, rabbits and rodents, all natives) to decrease herbivory and burrowing. *To see if these results can be turned into prescriptions for restoring native grasslands in the region, we are now testing 1) if sawdust, which is less expensive, can be used in place of sugar; and 2) if results are general, i.e., if applying the treatments at other sites in grasslands along the coast of northern California will produce similar results.*

Methods

We are conducting 2 experiments at each of 3 sites (Fig. 1), one in remnant areas where native grasses (all perennials, including some non-grass graminoids) and forbs are mixed with introduced grasses (almost all annuals) and forbs, and one in heavily invaded areas where introduced, annual grasses make up > 90% of plant cover. In each experiment, 2 fencing treatments (unfenced or fenced against deer and rabbits, but not rodents, which is impractical on a large scale) are crossed with 3 soil treatments (none, sawdust [2 kg m^{-2} y^{-1}], or sugar [1 kg m^{-2} y^{-1}]).

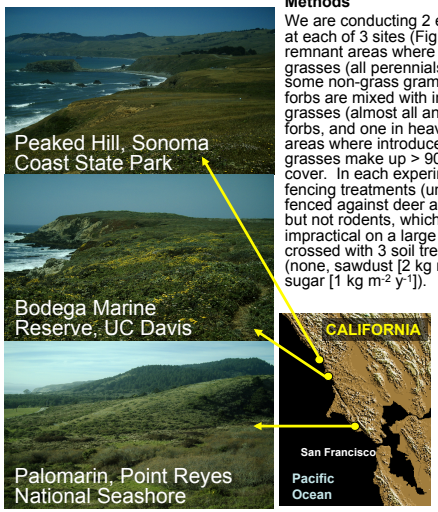


Fig. 1. Study sites.

In remnant grassland, there are 10 blocks of 6 4 x 4 m plots per site. Treatments began in April 2007 at Bodega Marine Reserve and Peaked Hill, and in December 2007 at Palomarin. Cover of each plant species in each plot is being measured each May to June.

In heavily invaded grassland, there are 8 blocks of 6 1 x 5.25 m plots per site. Seeds of 3-4 species of native grasses were collected from each site and grown for 3-4 months; 10-13 plugs of each species from a site were then planted 25 cm apart in each plot at the site. Treatments began in December 2007-January 2008; natives were planted in January-February 2008. Survival of planted natives is being recorded each June.

Here we present results for 2008, using ANOVAs and post hoc Bonferroni tests for effects of block, soil treatment, and fencing on percent cover and survival.

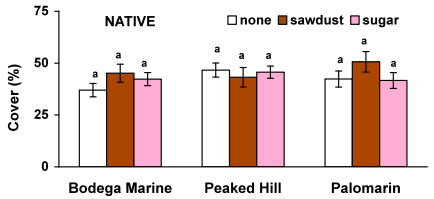


Fig. 2. Effect of soil treatments on the total cover (mean ± SE) of introduced and native plants. For introduced plants, *P* (ANOVA) < 0.001 (BMR), = 0.004 (PH), and = 0.6 (PM). For native plants, *P* = 0.06 (BMR), 0.6(PH), and 0.1(PM). Letters above bars show which treatments differed within a site (*P* [Bonferroni] = 0.05).

Results

In remnant areas, total cover of introduced species was lower in plots with sawdust or sugar than in plots with none at both sites treated for 2 growing seasons (Fig. 2: Bodega Marine Reserve and Peaked Hill); effect of sawdust was less than that of sugar but not significantly so. Total cover of native species was marginally higher in plots with sawdust or sugar at one site. There was no effect of soil treatments on the total cover of introduced or native plants at the site treated for one season (Palomarin), and no effect of fencing on total cover (data not shown; each *P* [ANOVA] > 0.2) at any site.

Soil treatments affected specific subgroups of introduced and native species. At Bodega Marine Reserve, negative effect of sawdust and sugar on introduced species was due solely to effect on annual grasses, and positive effect of sawdust and sugar on native species was due mainly to effect on perennial forbs (Table 1). Fencing did affect some subgroups of species. Cover of native perennial forbs was higher in fenced than in unfenced plots, while cover of introduced and native grasses was lower.

Table 1. Cover (%; mean (SE)) of subgroups of species at Bodega Marine Reserve.

	Unfenced			Fenced			ANOVA					
	none	sawdust	sugar	none	sawdust	sugar	soil		fence		soil x fence	
							$F_{2,45}$	*P*	$F_{1,45}$	*P*	$F_{2,45}$	*P*
INTRODUCED												
annual forb	1.4 (0.7)	0.8 (0.3)	1.4 (0.7)	1.1 (0.5)	1.3 (0.5)	1.3 (0.5)	0.08	0.93	0.10	0.75	0.32	0.72
perennial forb	17.3 (3.4)	15.5 (2.8)	12.3 (3.0)	16.6 (5.9)	15.3 (3.7)	21.6 (6.7)	0.01	0.99	0.05	0.82	0.86	0.43
annual grass	50.4 (4.9)	41.8 (3.9)	41.9 (4.7)	49.1 (7.1)	36.4 (3.9)	31.0 (5.0)	7.39	**0.002**	4.17	*0.047*	0.96	0.39
NATIVE												
annual forb	7.9 (3.8)	6.8 (2.6)	4.6 (2.2)	5.9 (2.9)	7.7 (4.4)	5.9 (2.4)	0.51	0.60	0.19	0.67	0.54	0.58
perennial forb	6.5 (1.6)	9.2 (2.0)	12.0 (2.6)	11.8 (3.3)	17.7 (2.6)	17.9 (5.3)	2.63	*0.08*	7.82	**0.008**	0.53	0.59
perennial grass	22.3 (2.1)	29.4 (2.5)	23.9 (2.9)	19.6 (2.8)	19.5 (2.3)	22.3 (2.1)	1.12	0.33	8.24	**0.006**	0.72	0.49

In heavily invaded areas, 73% of planted natives survived, even through rainfall during March–May 2008 was the lowest ever recorded for this season in the region. Survival was lower in fenced than in unfenced plots at Bodega Marine Reserve but the reverse was true at Peaked Hill (Fig. 3). Survival did not differ between soil treatments at any site (each *P* [ANOVA] > 0.15), and survival and effects of treatments did not differ greatly between species at any site (data not shown).

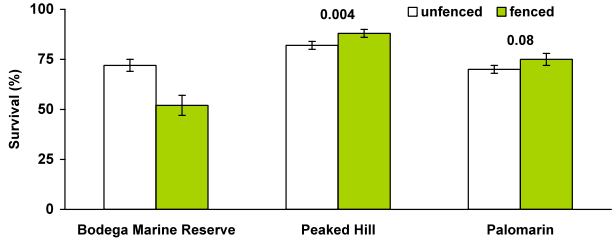


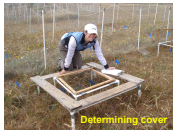
Fig. 3. Effect of fencing on the survival (mean ± SE) of native grasses. Numbers above bars show *P* (ANOVA) for effect of fencing.

Discussion

Results in remnant areas so far suggest that *1) sawdust is effective but may be less so than sugar* at decreasing the abundance of introduced, annual grasses, and that *2) soil treatments may be generally effective* in the region. Lack of effects at one site may be due to its having been treated for only one growing season, and the relatively weak positive effect of soil treatments on natives may reflect the cascade of effects expected following carbon addition, with introduced species responding to reduction in nutrient availability and natives then responding to competitive release from introduced plants. Measurements in 2009 will test both these possibilities. However, *3) fencing may not be effective* at reversing the change from native grassland plants to introduced, annual grasses. Its effectiveness in the previous study might have been due to use of fences that excluded rodents as well as larger herbivores.

Initial results in heavily invaded areas suggest that *1) native grasses survive well* through the first rainy season when planted as 3- to 4-month-old plugs. However, there is *2) no indication yet that either soil or fencing treatments generally promote survival*.

Based on these results, we recommend the application of sawdust as an inexpensive and minimally intrusive way to restore coastal prairie where natives still comprise > 20% of cover.



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