FINAL REPORT
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Stabilization of Plant Communities After Integrated Picloram and Fire Treatments
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Table of Contents

List of Tables

List of Figures

Summary

Prescribed fire alone, herbicide alone, and various timing combinations of prescribed burning and herbicide were applied to weed infested bunchgrass communities in western Montana. All burns were conducted in early spring while most species were still winter dormant or were just emerging from winter dormancy. The herbicide applications include spring and fall timings. Canopy cover of every species was determined in the growing season before treatments were begun and for up to three growing seasons after treatment initiation. Primary target weeds were spotted knapweed, dalmatian toadflax, St. Johnswort, and leafy spurge. Weed suppression was assessed along with the response of perennial grasses and exotic annual brome species. Shifts in community composition were compared among treatments and also to habitat type definition plots to determine similarity to the potential natural communities for each of four study sites.

Burning alone did not affect target weed abundance during the period of response measurement. Nor did burning in combination with spraying alter the high level of weed control obtained by spraying alone. Burning did not effect overall species composition nor similarity to the potential natural communities at three of the study sites. The burning did alter community level response at one site which was dominated by mature rough fescue bunches and the burned plots at this site showed retrogression relative to the habitat type definition. At two sites the canopy cover of rough fescue or combined native bunchgrasses were reduced in the growing season following the spring burn. However these burn influences were all limited to the growing season immediately after the burn.

Spraying made the plots more similar to the potential natural communities at three sites that had remnant bunchgrass indicator species. Progression towards the potential natural community was not obtained by burning alone or addition of a burn along with spraying. Plots which lacked habitat type indicator bunchgrasses, or were co-dominated by introduced rhizomatous grasses, exhibited post treatment floristic trajectories that will not lead to a composition similar to the potential natural communities.

Several annual brome grass species, primarily cheatgrass, increased in abundance at one of the four study sites. This rather degraded site was lacking in remnant perennial grasses. The spring burns used in this study did not affect cheatgrass abundance.

Introduction

Public land managers are increasing the use of prescribed fire to reduce excessive fuel loads, and to restore plant communities to a composition and structure more similar to that of the pre-European settlement. However, many managers believe that the disturbance caused by prescribed fire may contribute to greater abundance and spread of certain exotic weed species that increase following other canopy and soil surface disturbance factors. Other managers are intrigued with the idea that they may be able to control weeds with fire by stimulating fire-adapted native species and injuring the weed species.

Many northwest grassland, Ponderosa pine, and drier Douglas-fir communities are infested with weedy introduced species. Herbicides and prescribed fire are two of the most effective tools for changing the composition and structure of vegetation over large enough areas to implement ecosystem restoration goals. However, there is very little scientific documentation of how these two management tools might interact to effect noxious weed abundance. Fire and herbicides as a means of weed control have been studied only in a limited number of cases. There were no studies that specifically looked at the use of fire and herbicides together in northwestern forest or bunch grass communities. Nor do the available publications give conclusive results as to whether fire causes a change in weed abundance, or whether fire and herbicides would be an effective management tool in bunchgrass and drier forest habitat types.

There are two primary goals in this project:

1. To assess the change in abundance of particular invasive weed species to the use of combinations of herbicide spraying and prescribed burning as well as these treatments methods alone.

2. To assess the impact of using various combinations of prescribed fire and herbicides on the native grassland plant community composition and its similarity to the potential natural community.

Methods

Site Descriptions

Initially three study sites were chosen and baseline vegetation composition measured in the summer of 2000. An additional site was added in 2001.

1. Blue Mountain (Missoula Ranger District, Lolo National Forest) is a spotted knapweed (*Centaurea maculosa*) infested site having an initial (2000) canopy cover of 13%. The habitat type is rough fescue / bluebunch wheatgrass (Mueggler and Stewart 1980).

2. Henry Creek (Plains Ranger District, Lolo National Forest) is infested with St. Johnswort having 8% initial canopy cover. The habitat type is bluebunch wheatgrass / Sandberg bluegrass, but bluebunch wheatgrass is lacking on the site.

3. The Missoula North Hills site (City of Missoula) was chosen to represent a leafy spurge (*Euphorbia esula*) infestation and baseline composition determined in 2001. Average canopy cover of leafy spurge was 42% in 2001 prior to initiation of treatments. The natural vegetation of the site has been severely degraded. Spotted knapweed (4.8%), sulfur cinquefoil (4.7%), and dalmatian toadflax (2.0%) were common on the site in addition to the dominant leafy spurge. The habitat type is most likely bluebunch wheatgrass/Sandberg bluegrass, although bluebunch wheatgrass (2.5% canopy cover) is not abundant and was not present in the microplots sampled on every plot. Sandberg bluegrass was the most abundant grass at 7.2% canopy cover in 2001.

4. The National Bison Range near Moiese Montana (U. S. Fish and Wildlife Service) was chosen as a dalmatian toadflax (*Linaria dalmatica*) infested site, but St. Johnswort is more abundant (6% initial canopy cover) than dalmatian toadflax (2% initial canopy cover). The habitat type is rough fescue / Idaho fescue.

Experimental Design

Thirty-five monitoring plots were established each site. Each 66 x 66 foot plot covers 1/20th of an acre and encloses 6 transects of 5 microplots each, for a total of 30 microplots. The microplots are 10 x 20 inches. Plot corners are marked with rebar and locations of microplots are marked with painted nails so the same sample points can be re-sampled each year. Some markers were sabotaged at Blue Mountain, so additional markers have been buried on site to assure that plots can be relocated in the event of future disruption on the surface. Due to the unique nature of wildlife management at the National Bison Range, an electrified fence was built around the array of plots to prevent trampling and browsing of the study site by large ungulates.

Plots are arranged in five blocks based on proximity and similarity of pre-treatment species composition. Each block at Blue Mountain, Henry Creek, and North Hills has seven treatments. A spring burn planned for the Bison Range site in 2001 could not be implemented so the treatment schedule differs from that of the first two sites. The Bison Range site has six treatments per block, with an additional five plots that had received a spray only treatment in fall 2000.

Treatment Schedules

Tordon 22K herbicide was used at all sites. Rates were 1 pt/ac at the Blue Mountain spotted knapweed site, 1 qt/ac qt the Henry Creek St. Johnswort site, 1 qt/ac plus Preference non-ionic surfactant at 0.125% v/v at the Bison Range dalmatian toadflax site, and 2 qt/ac at the North Hills leafy spurge site. The higher rate of Tordon was used for leafy spurge in the North Hills on all three spray dates because this weed did not green up in the fall of 2001 nor the fall of 2002. Total volumes (herbicide plus water) were ~15 gallons per acre. TeeJet 8001 nozzles were used on the steep North Hills and Bison Range sites while 8002 nozzles were used at Blue Mountain and Henry Creek. The sprayer was a research type carbon dioxide powered backpack sprayer with a six nozzle boom spaced for a ten foot spray swath. Most plant species were still winter dormant at the time of burning except for some green up of rough fescue at the Bison range site. The treatment schedule dates are summarized in Table 1. Tables 2, 3, and 4 provide the sequence of treatments and sampling for 2000-2003 or 2001-2004 for North Hills.

Table 1. Treatment schedule dates.

Treatment Name	Sprayed	Burned
Blue Mt. Spotted Knapweed Site		
Treatment Name	**Sprayed**	**Burned**
Check	None	None
Spray Only	Oct 16-17,2000	None
Burn Only	None	April 17, 2001
Spray, Grow, Burn	Oct 16-17, 2000	April 12, 2002
Burn, Grow, Spray	Oct 25, 2001	April 17, 2001
Spray, Burn	Oct 16-17, 2000	April 17, 2001
Burn & Spray	May 25, 2001	April 17, 2001
Henry Cr. St. Johnswort Site		
Check	None	None
Spray Only	Oct 18-19, 2000	None
Burn Only	None	April 5, 2001
Spray, Grow, Burn	Oct 18-19, 2000	April 9, 2002
Burn, Grow, Spray	Oct 26, 2001	April 5, 2001
Spray, Burn	Oct 18-19, 2000	April 5, 2001
Burn & Spray	May 30, 2001	April 5, 2001
North Hills Leafy Spurge Site		
Check	None	None
Spray Only	Nov 2, 2001	None
Burn Only	None	April 4, 2002
Spray, Grow, Burn	Nov 2, 2001	March 19, 2003
Burn, Grow, Spray	Oct 25, 2002	April 4, 2002
Spray, Burn	Nov 2, 2001	April 4, 2002
Burn & Spray	June 7, 2002	April 4, 2002
Check		
Bison Range Dalmatian Toadflax Site		
Check	None	None
Spray Fall 2000 Only	Oct 23, 2000	None
Spray Spring 2002 Only	June 17, 2002	None
Burn Only	None	April 5, 2002
Spray, Grow, Burn	Oct 23, 2000	April 5, 2002
Burn & Spray	June 17, 2002	April 5, 2002

Table 2. Treatment schedule and sampling for Blue Mt. spotted knapweed and Henry Cr. St. Johnswort sites.

	2000		2001			2002		2003
Treatment	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Summer
Check	Sampled			Sampled			Sampled	Sampled
Spray Only	Sampled	Spray		Sampled			Sampled	Sampled
Burn Only	Sampled		Burn	Sampled			Sampled	Sampled
Spray, Grow, Burn	Sampled	Spray		Sampled		Burn	Sampled	Sampled
Burn, Grow, Spray	Sampled		Burn	Sampled	Spray		Sampled	Sampled
Spray, Burn	Sampled	Spray	Burn	Sampled			Sampled	Sampled
Burn & Spray	Sampled		Burn & Spray	Sampled			Sampled	Sampled

Table 3. Treatment schedule and sampling for North Hills leafy spurge site.

	2001		2002			2003		2004
Treatment	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Summer
Check	Sampled			Sampled			Sampled	Sampled
Spray Only	Sampled	Spray		Sampled			Sampled	Sampled
Burn Only	Sampled		Burn	Sampled			Sampled	Sampled
Spray, Grow, Burn	Sampled	Spray		Sampled		Burn	Sampled	Sampled
Burn, Grow, Spray	Sampled		Burn	Sampled	Spray		Sampled	Sampled
Spray, Burn	Sampled	Spray	Burn	Sampled			Sampled	Sampled
Burn & Spray	Sampled		Burn & Spray	Sampled			Sampled	Sampled

Table 4. Treatment schedule and sampling completed for Bison Range dalmatian toadflax site.

	2000		2001			2002		2003
Treatment	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Summer
Check	Sampled			Sampled			Sampled	Sampled
Spray Fall 2000 Only	Sampled	Spray		Sampled			Sampled	Sampled
Spray Spring 2002 Only	Sampled			Sampled		Spray	Sampled	Sampled
Burn Only	Sampled			Sampled		Burn	Sampled	Sampled
Spray, Grow, Burn	Sampled	Spray		Sampled		Burn	Sampled	Sampled
Burn & Spray	Sampled			Sampled		Burn & Spray	Sampled	Sampled

Sampling Methods

Daubenmire (1968) techniques as modified by Hann and Jensen (1987) for the ECODATA Cover Microplot Method were used to estimate canopy cover of every species observed in the sample microplots. Canopy cover classes were trace (<1%), present (1-5%), 1 (5-15%), ….., 9 (85-95%), and full (>95%).

Fuel loads were determined by clipping and weighting five composited 10 x 20 inch microplots on each plot. There were five fuel classes: target weeds, other forbs, cheatgrass, other grasses, and litter. The plots were then sampled after the burns to allow calculation of fuel consumption.

Data Analyses

Plant community data was ordinated by global non-metric multidimensional scaling (Kruskal & Wish 1978). Floristic trajectories and similarity to the species composition of the Mueggler and Stewart (1980) habitat type definition plots were illustrated with the NMS ordination graphics. Multivariate differences in species composition of treatment groups were tested by blocked multi-response permutation procedures (Mielke 1991, McCune et al. 2002). Ordinations and multi-response permutation procedures were calculated using PC-ORD 4.0 (McCune and Mefford 1999).

Response of individual species and life forms were tested by analysis of variance (block and treatment factors) for the baseline pre-treatment year measurements. Then analysis of covariance with the baseline summer (pre-treatment) values for the species or life form as the covariate was conducted for the years after initiation of treatments. If the analysis of covariance was significant ($p<.05$) pairwise comparisons were made for treatment pairs of interest, not all possible pairwise comparisons. Significance levels of pairwise comparisons were based on the conservative Bonferroni adjustment. In a few pairwise cases the unadjusted least significant differences were calculated. Although the post baseline year significance tests were based on means adjusted by the covariate term, all tabled and graphed means are for the observed values. The analyses of covariance and pairwise comparisons were performed using SPSS 13.5

Results

Fuel Consumption

The Blue Mountain spotted knapweed plots were first burned 4/17/2001 and the Henry Creek St. Johnswort plots were first burned 4/05/2001 (Table 5).

Table 5. Spring 2001 average fuel loads (lbs/acre) and consumption for Blue Mt. spotted knapweed and Henry Cr. St. Johnswort sites.

SITE/Type	PRE BURN	POST BURN	CONSUMED	% CONSUMED
BLUE MT.				
All Fuels	2,760	943	1,818	66
Cheatgrasses	24	0	24	99
Other grass	804	163	642	80
Weeds	561	101	459	82
Other forbs	29	16	13	45
Litter	1,342	662	680	51
HENRY CR.				
All Fuels	1,175	651	524	45
Cheatgrasses	136	9	127	93
Other grass	495	212	283	57
Weeds	221	157	64	29
Other forbs	82	37	45	55
Litter	241	235	5	2

The final Blue Mountain burn 4/12/2002 and the final Henry Creek burns were 4/09/2002 (Table 6).

Table 6. Spring 2002 average fuel loads (lbs/acre) and consumption for Blue Mt. spotted knapweed and Henry Cr. St. Johnswort sites.

SITE/Type	PRE BURN	POST BURN	CONSUMED	% CONSUMED
BLUE MT.				
All Fuels	2,110	900	1,211	57
Cheatgrasses	20	0	20	100
Other grass	834	179	655	78
Weeds	94	1	92	99
Other forbs	0	0		
Litter	1,162	719	443	38
HENRY CR.				
All Fuels	983	381	602	61
Cheatgrasses	95	18	77	81
Other grass	272	15	257	94
Weeds	44	50		
Other forbs	18	0	18	100
Litter	554	298	256	46

The North hills leafy spurge site was burned April 4, 2002 and March 19, 2003 (Tables 7 & 8).

Table 7. Spring 2002 average fuel loads (lbs/acre) and consumption for the North Hills leafy spurge site.				
SITE/Type	**PRE BURN**	**POST BURN**	**CONSUMED**	**% CONSUMED**
NORTH HILLS				
All Fuels	1,921	204	1,717	89
Cheatgrasses	21	0	21	100
Other grass	207	2	205	99
Weeds	765	5	761	99
Other forbs	22	1	21	96
Litter	906	196	710	78

Table 8. Spring 2003 average fuel loads (lbs/acre) and consumption for the North Hills leafy spurge site.				
SITE/Type	**PRE BURN**	**POST BURN**	**CONSUMED**	**% CONSUMED**
NORTH HILLS				
All Fuels	1,525	368	1,157	76
Cheatgrasses	11	0	11	100
Other grass	226	46	180	80
Weeds	537	43	494	92
Other forbs	0			
Litter	751	279	472	63

The Bison Range dalmatian toadflax site was burned only on 4/05/2002 (Table 9).

Table 9. Spring 2002 average fuel loads (lbs/acre) and consumption for the Bison Range dalmatian toadflax site.				
SITE/Type	PRE BURN	POST BURN	CONSUMED	% CONSUMED
BISON RANGE				
All Fuels	3,775	1,778	1,998	53
Cheatgrasses	14	0	14	100
Other grass	868	18	850	98
Weeds	116	9	107	92
Other forbs	18	23		
Litter	2,761	1,728	1,033	37

Blue Mountain Spotted Knapweed Site Vegetation

Blocks 3, 4, and 5 at the Blue Mountain site were inadvertently over-sprayed with Tordon by a helicopter in early spring 2003. Accordingly we analyzed all five blocks at Blue Mountain for 2000 through 2002, then just blocks 1 and 2 for 2000 through 2004.

Individual Species and Life Form Reponses

Spotted knapweed canopy cover is graphed in Figure 1 from 2000 through 2002 for the seven treatments to all five blocks. The spotted knapweed (CENMAC) canopy cover among the planned treatment plots did differ significantly in the summer of 2000 when sampled before the treatments were begun but in the years after initiation of treatments there were highly (p<.001) differences (Table 10).

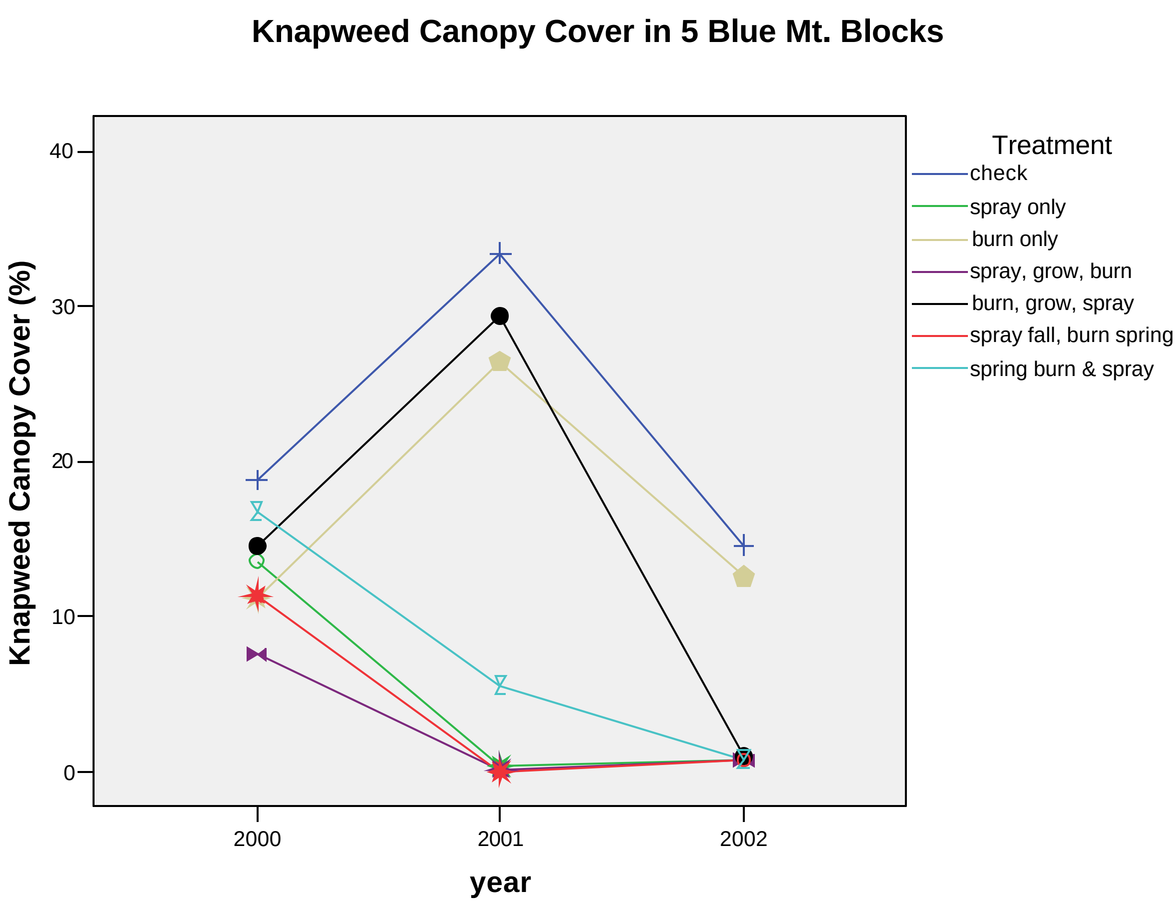


Figure 1. Spotted knapweed canopy cover in all five blocks at Blue Mt. from 2000 through 2002.

Table 10. Average spotted knapweed canopy cover at Blue Mountain for all five blocks from 2000 through 2002.

Treatment	CENMAC 2000	CENMAC 2001	CENMAC 2002
Check	18.8	33.4	14.6
Spray fall 2000 only	13.6	<0.4	<0.8
Burn spring 2001 only	11.2	26.4	12.6
Spray fall 2000, grow, burn spring 2002	7.6	<0.2	<0.8
Burn spring 2001, grow, spray fall 2001	14.6	29.4	<1.0
Spray fall 2000, burn spring 2001	11.4	0.0	<0.8
Burn & spray spring 2001	16.8	5.6	<0.8
p. treatment effects ANOVA or ANCOVAR	.189	<.001	<.001

p based on estimated marginal means of log (X+1) as corrected by pre-spray year covariate but tabled means are observed values

Knapweed regrowth was nearly eliminated in 2001 on all three sets of plots that had been sprayed in fall 2000 (Table 11). Knapweed canopy cover in burn and spray spring 2001 plots was also significantly reduced relative to check plots but although the May 25, 2001 spraying prevented further growth some knapweed (5.6%) canopy cover was still present at the time of the summer 2001 sampling. However the two treatment sets with burning as the only treatment received through the spring of 2001 did not differ in knapweed canopy cover relative to the check plots in 2001. Spray fall 2000 only plots and spray fall 2000, burn spring 2001 did not differ in 2001; knapweed was nearly eliminated in both treatment sets. In 2002 all five treatments that included spraying continued to have very little knapweed compared to check plots. Burning alone did lead to a difference in knapweed abundance in 2002 as was the case in 2001. Nor did plots with burning in combination with spraying differ in 2002 knapweed canopy cover from the high level of control obtained by spraying alone.

Table 11. Bonferroni adjusted pairwise comparisons of spotted knapweed canopy cover in treatments (n=5) of interest at all five Blue Mt. blocks from 2001 through 2002.

Year	Treatment One Canopy Cover	Treatment Two Canopy Cover	p.
2001	Check	Spray fall 2000 only	
	33.4	<0.4	<.001
		Spray fall 2000, grow, burn spring 2002	
		<0.2	<.001
		Spray fall 2000, burn spring 2001	
		0.0	<.001
2001	Check	Burn spring 2001 only	
	33.4	26.4	ns
		Burn spring 2001, grow, spray fall 2001	
		29.4	ns
		Burn & spray spring 2001	
		5.6	<.001
2001	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	<0.4	0.0	ns
2002	Check	Spray fall 2000 only	
	14.6	<0.8	<.001
		Spray fall 2000, grow, burn spring 2002	
		<0.8	<.001
		Spray fall 2000, burn spring 2001	
		<0.8	<.001
		Burn spring 2001, grow, spray fall 2001	
		<1.0	<.001
		Burn & spray spring 2001	
		<0.8	<.001
2002	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	<0.8	<0.8	ns
		Spray fall 2000, grow, burn spring 2002	
		<0.8	ns

ns=p>.05

p calculated as LSD based on estimated marginal means log (X+1) as corrected by pre-spray year covariate but tabled means are observed values

The canopy cover of spotted knapweed in just blocks 1 and 2 for 2000 through 2003 is graphed in Figure 2 and the initial analyses of variance and covariance are presented in Table 12. As with all five Blue Mountain blocks the treatment plot sets did not differ (p=.507) in the 2000 baseline year sample, but treatment responses were significant in all three years following the start of treatments. Pairwise comparisons were calculated using least significant differences as there were only two plots per treatment (Table 13). The pattern of responses was similar to that for all five blocks. Spraying significantly (p =.05) reduced the knapweed canopy cover to less than 1% canopy cover in the growing season after spraying with this near total suppression of knapweed regrowth continuing through 2003. Canopy cover of knapweed in the treatments/years plot sets that had only been burned did not differ from the check. Over the years of response measurement burning in combination with spraying did not improve the very high level of suppression obtained from spraying.

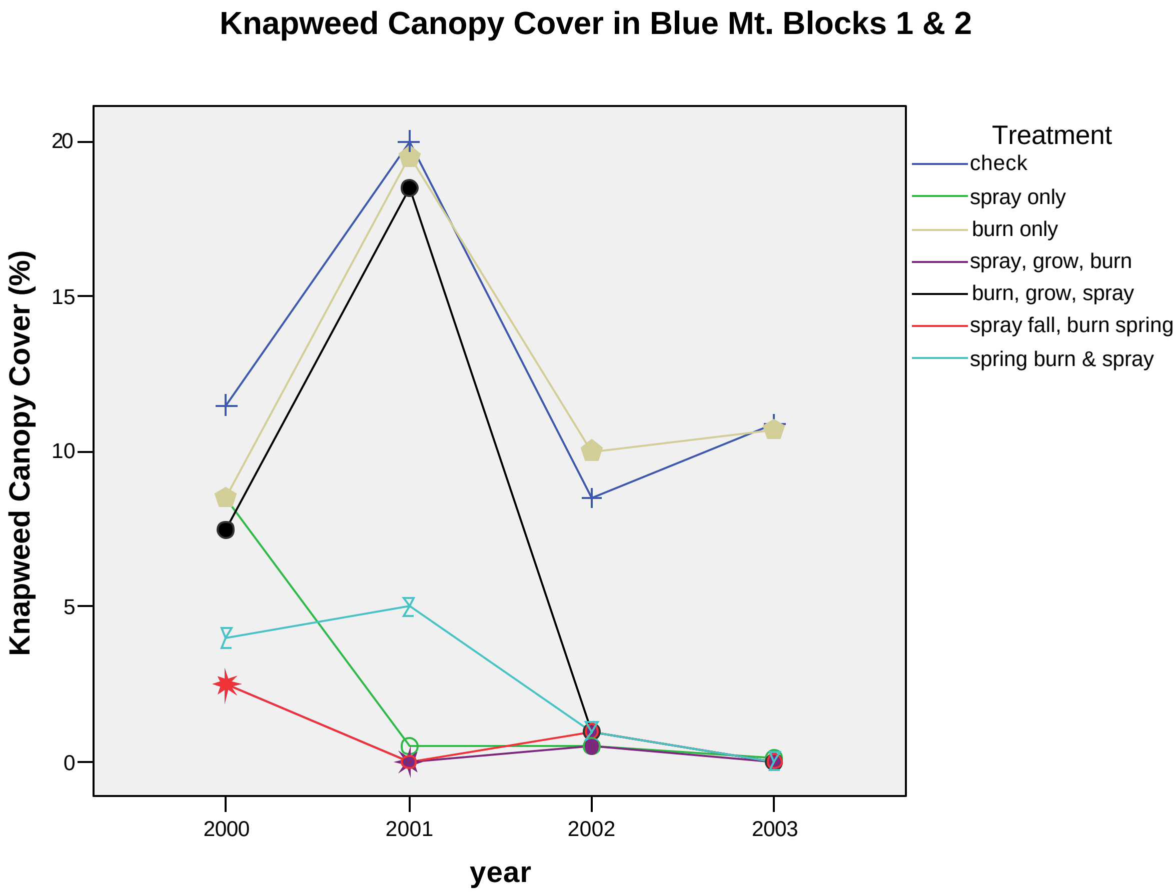


Figure 2. Spotted knapweed canopy cover in blocks 1 and 2 at Blue Mt. from 2000 through 2003.

Table 12. Average spotted knapweed canopy cover at Blue Mountain for blocks 1 & 2 from 2000 through 2003.

Treatment	CENMAC 2000	CENMAC 2001	CENMAC 2002	CENMAC 2003
Check	11.50	20.00	8.50	10.90
Spray fall 2000 only	8.50	<0.50	<0.50	0.12
Burn spring 2001 only	8.50	19.50	10.00	10.70
Spray fall 2000, grow, burn spring 2002	2.50	0.00	<0.50	0.03
Burn spring 2001, grow, spray fall 2001	7.50	18.50	<1.00	0.03
Spray fall 2000, burn spring 2001	2.50	0.00	<1.00	0.03
Burn & spray spring 2001	4.00	5.00	<1.00	0.02
p. treatment effects ANOVA or ANCOVAR	.507	<.001	.007	<.001

p based on estimated marginal means of log (X+1) as corrected by pre-spray year covariate but tabled means are observed values

Table 13. LSD pairwise comparisons of spotted knapweed canopy cover in treatments (n=2) of interest at Blue Mt. blocks 1 & 2 for 2001 through 2003.

Year	Treatment One Canopy Cover	Treatment Two Canopy Cover	p.
2001	Check	Spray fall 2000 only	
	20.00	<0.50	<.001
		Spray fall 2000, grow, burn spring 2002	
		0.00	.001
		Spray fall 2000, burn spring 2001	
		0.00	.001
2001	Check	Burn spring 2001 only	
	20.00	19.50	ns
		Burn spring 2001, grow, spray fall 2001	
		18.50	ns
		Burn & spray spring 2001	
		5.00	.036
2001	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	<0.50	0.00	ns
2002	Check	Spray fall 2000 only	
	8.50	<0.50	.002
		Spray fall 2000, grow, bum spring 2002	
		<0.50	.007
		Spray fall 2000, burn spring 2001	
		<1.00	.021
		Burn spring 2001, grow, spray fall 2001	
		<1.00	.004
		Burn & spray spring 2001	
		<1.00	.016
2002	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	<0.50	<1.00	ns
		Spray fall 2000, grow, burn spring 2002	
		<0.50	ns
2003	Check	Spray fall 2000 only	
	10.90	0.12	<.001
		Spray fall 2000, grow, burn spring 2002	
		0.03	<.001
		Spray fall 2000, burn spring 2001	
		0.03	<.001
		Burn spring 2001, grow, spray fall 2001	
		0.03	<.001
		Burn & spray spring 2001	
		0.02	<.001
2003	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	0.12	0.03	ns
		Spray fall 2000, grow, burn spring 2002	
		0.03	ns

ns=p>.05

p calculated as LSD based on estimated marginal means of log (X+1) as corrected by pre-spray year covariate but tabled means are observed values

Perennial grass canopy cover for all five blocks at Blue Mt. is graphed for 2000 through 2002 in Figure 3 and the treatment means are summarized in Table 14. The yearly covariate analyses indicated very highly significant differences in both growing seasons following initiation of fall spraying (Table 14). Although the trend in 2001 was for perennial grass canopy cover to increase, relative to the check the plots, in plots that had been sprayed the preceding fall this first year post spray response was only significant (p=.08) for the spray fall 2000 only treatment plots (Table 15). Plots that were burned did not differ significantly from check plots and the spray fall 2000 versus spray fall 2000, burn spring 2001 comparison was also not significant. By 2002 treatments sets that were two growing seasons post spray had significantly (p=.066) more perennial grass than the check plots except for the spray fall 2000, grow, burn spring 2002 treatments. Burning in spring of either 2001 0r 2002 in combination with fall 2000 spraying did not result in a grass response that differed from the spray fall 2000 only treatment.

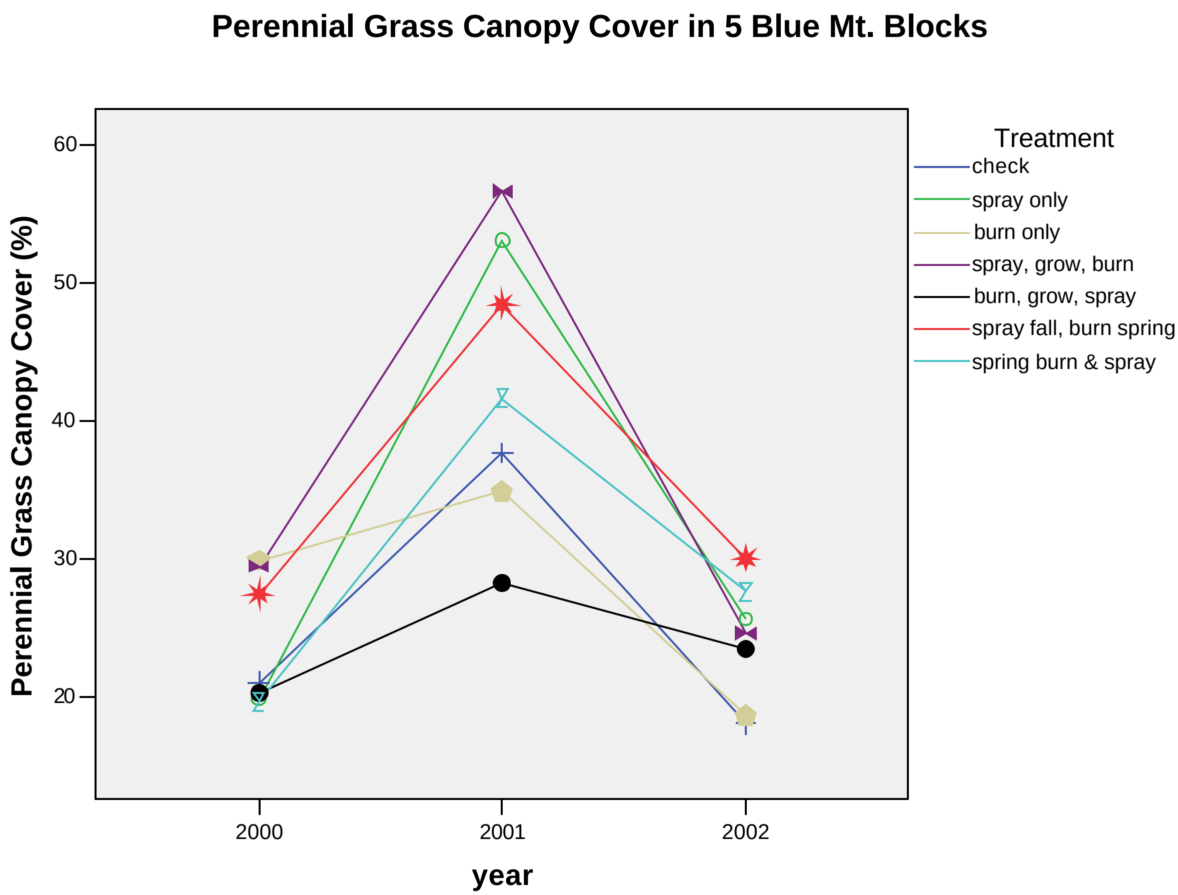


Figure 3. Perennial grass canopy cover in all five blocks at Blue Mt. from 2000 through 2002.

Table 14. Average perennial grass canopy cover at Blue Mountain for all five blocks from 2000 through 2002.

Treatment	All Per. Grasses 2000	All Per. Grasses 2001	All Per. Grasses 2002
Check	21	38	18
Spray fall 2000 only	20	53	26
Burn spring 2001 only	30	35	19
Spray fall 2000, grow, burn spring 2002	29	57	25
Burn spring 2001, grow, spray fall 2001	20	28	23
Spray fall 2000, burn spring 2001	27	48	30
Burn & spray spring 2001	20	42	28
p. treatment effects ANOVA or ANCOVAR	.058	<.001	<.001

p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Table 15. Bonferroni adjusted pairwise comparisons of perennial grass canopy cover in treatments (n=5) of interest at all five Blue Mt. blocks from 2001 through 2002.

Year	Treatment One Canopy Cover	Treatment Two Canopy Cover	p.
2001	Check	Spray fall 2000 only	
	38	53	.080
		Spray fall 2000, grow, burn spring 2002	
		57	.214
		Spray fall 2000, burn spring 2001	
		48	ns
2001	Check	Burn spring 2001 only	
	38	35	ns
		Burn spring 2001, grow, spray fall 2001	
		28	ns
		Burn & spray spring 2001	
		42	ns
2001	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	53	48	ns
2002	Check	Spray fall 2000 only	
	18	26	.066
		Spray fall 2000, grow, burn spring 2002	
		25	ns
		Spray fall 2000, burn spring 2001	
		30	.008
		Burn spring 2001, grow, spray fall 2001	
		23	ns
		Burn & spray spring 2001	
		28	.008
2002	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	26	30	ns
		Spray fall 2000, grow, burn spring 2002	
		25	ns

ns=p>>.05

p calculated as LSD based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Perennial grass canopy cover for blocks 1 and 2 at Blue Mt. is graphed for 2000 through 2003 in Figure 4 and the treatment means are summarized in Table 16. The trend was for relative treatment difference to increase in each growing seasons following start of treatments but the sample size was two plots per treatments and the separations in response were not significant (p,.05) until 2003 (Table 16). A less conservative least significance differences (LSD) test of relevant pairwise comparisons is presented in Table 17. Sprayed plots did exhibit an increase in grass cover during the first growing season after the fall 2000 herbicide applications. However there was a trend (p=.20) for the spring 2001 burning to retard bunchgrass development relative to check plots in the growing season immediately after the burn. Herbicide spraying may have compensated for burning that spring as the grass cover was nearly identical for check vs. burn and spray spring 2001 contrast, and the spray fall 2000 only vs. spray fall 2000, burn spring 2001 contrast. In 2002 all treatment sets that were two growing seasons post spray tended (p=.20) to have more grass than the check plots except for the set (spray fall 2000, grow, burn spring 2002) that was still in the first growing season immediately after burning. The 2002 comparison of spray fall 2000 only vs. spray fall 2000, grow, burn spring 2002 also suggested that burning was reducing bunchgrass development in the growing season immediately following the burn (p.<.079). By the 2003 growing season the grass release on sprayed plots relative to check plots was significant (p=.039 to .017) for all treatment sets that included spraying. There was no significant (p>.20) evidence that burning was influencing response in the second growing season post burn.

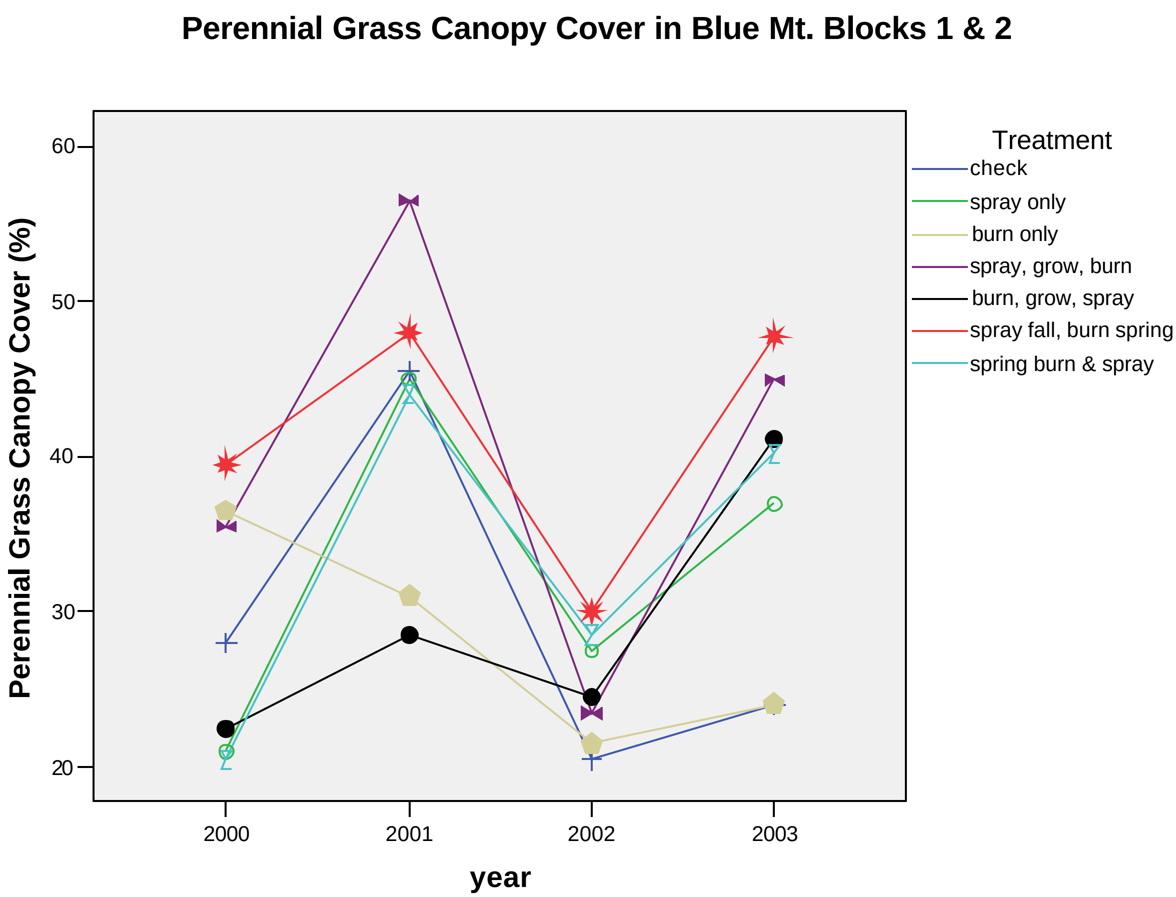


Figure 4. Perennial grass canopy cover at Blue Mountain for blocks 1 & 2 from 2000 through 2003.

Table 16. Average perennial grass canopy cover at Blue Mountain for blocks 1 & 2 from 2000 through 2003.

Treatment	All Per. Grasses 2000	All Per. Grasses 2001	All Per. Grasses 2002	All Per. Grasses 2003
Check	28	46	21	24
Spray fall 2000 only	21	45	28	37
Burn spring 2001 only	37	31	22	24
Spray fall 2000, grow, burn spring 2002	36	57	24	45
Burn spring 2001, grow, spray fall 2001	23	29	25	41
Spray fall 2000, burn spring 2001	40	48	30	48
Burn & spray spring 2001	21	44	29	40
p. treatment effects ANOVA or ANCOVAR	.241	.194	.072	.028

p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Table 17. LSD pairwise comparisons of perennial grass canopy cover in treatments (n=2) of interest at Blue Mt. blocks 1 & 2 for 2001 through 2003.

Year	Treatment One Canopy Cover	Treatment Two Canopy Cover	p.
2001	Check	Spray fall 2000 only	
	46	45	ns
		Spray fall 2000, grow, burn spring 2002	
		57	ns
		Spray fall 2000, burn spring 2001	
		48	ns
2001	Check	Burn spring 2001 only	
	46	31	.142
		Burn spring 2001, grow, spray fall 2001	
		29	.152
		Burn & spray spring 2001	
		44	ns
2001	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	45	48	ns
2002	Check	Spray fall 2000 only	
	21	28	.029
		Spray fall 2000, grow, burn spring 2002	
		24	ns
		Spray fall 2000, burn spring 2001	
		30	.073
		Burn spring 2001, grow, spray fall 2001	
		25	.119
		Burn & spray spring 2001	
		29	.020
2002	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	28	30	ns
		Spray fall 2000, grow, burn spring 2002	
		24	.079
2003	Check	Spray fall 2000 only	
	24	37	.039
		Spray fall 2000, grow, burn spring 2002	
		45	.022
		Spray fall 2000, burn spring 2001	
		48	.022
		Burn spring 2001, grow, spray fall 2001	
		41	.017
		Burn & spray spring 2001	
		40	.020
2003	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	37	48	ns
		Spray fall 2000, grow, burn spring 2002	
		45	ns

ns=p>.20

p calculated as LSD based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Canopy cover of annual bromes did not differ significantly in the years following initiation of treatments at Blue Mt. for either the five or two block data sets. The yearly treatment set means are graphed in Figures 5 and 6 and tabled in Tables 18 and 19.

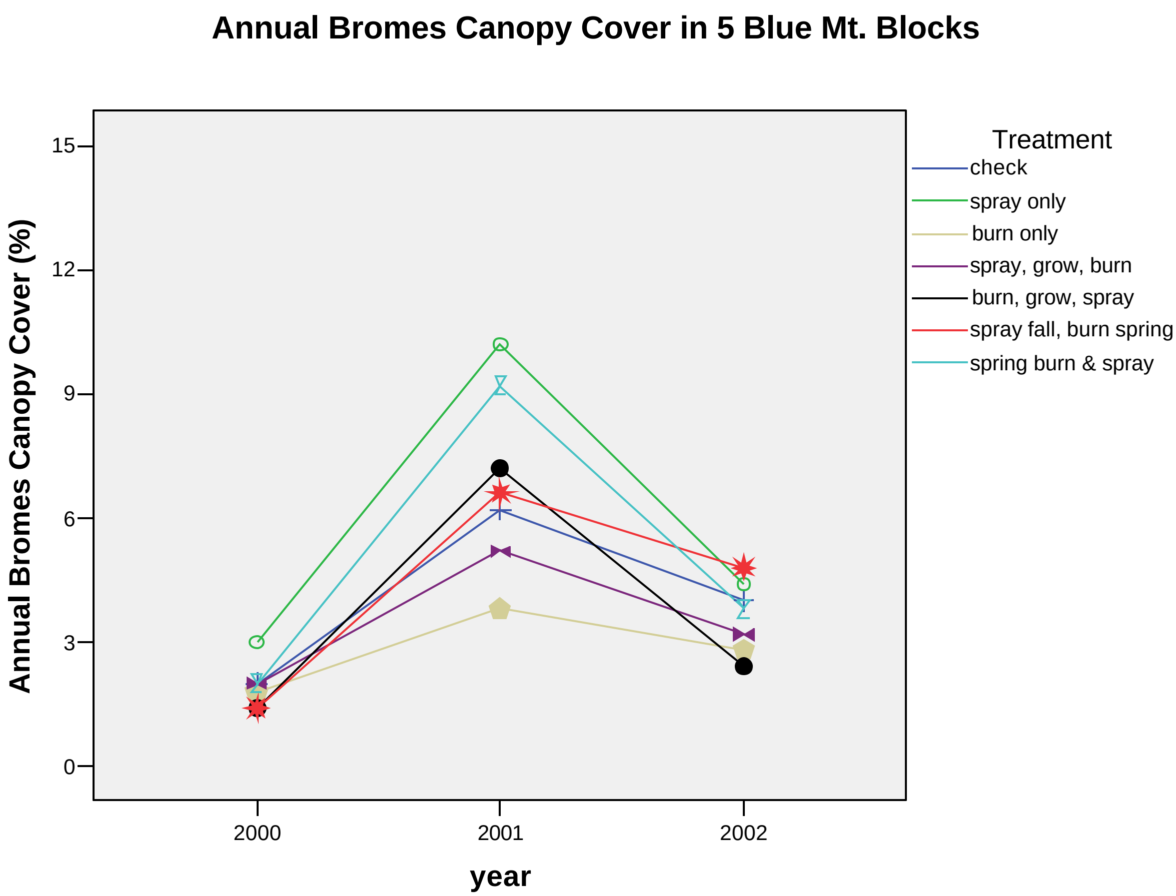


Figure 5. Canopy cover of annual bromes at Blue Mountain for all 5 blocks from 2000 through 2002.

Table 18. Average canopy cover of annual bromes at Blue Mountain for all 5 blocks from 2000 through 2002.

Treatment	A. BROME 2000	A. BROME 2001	A. BROME 2002
Check	2.00	6.20	4.00
Spray fall 2000 only	3.00	10.20	4.40
Burn spring 2001 only	1.80	3.80	2.80
Spray fall 2000, grow, burn spring 2002	2.00	5.20	3.20
Burn spring 2001, grow, spray fall 2001	1.40	7.20	2.40
Spray fall 2000, burn spring 2001	1.40	6.60	4.80
Burn & spray spring 2001	2.00	9.20	3.80
p. treatment effects ANOVA or ANCOVAR	.028[†]	.133	.126

p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values
[†]In the pre-spray year (2000) the spray only plots had more annual brome canopy than both the burn spring 2001, grow, spray fall 2001 plots and the spray fall 2000, burn spring 2001 plots (both p=.031), but these two pairwise comparisons were not of interest.

Annual Bromes Canopy Cover in Blue Mt. Blocks 1 & 2

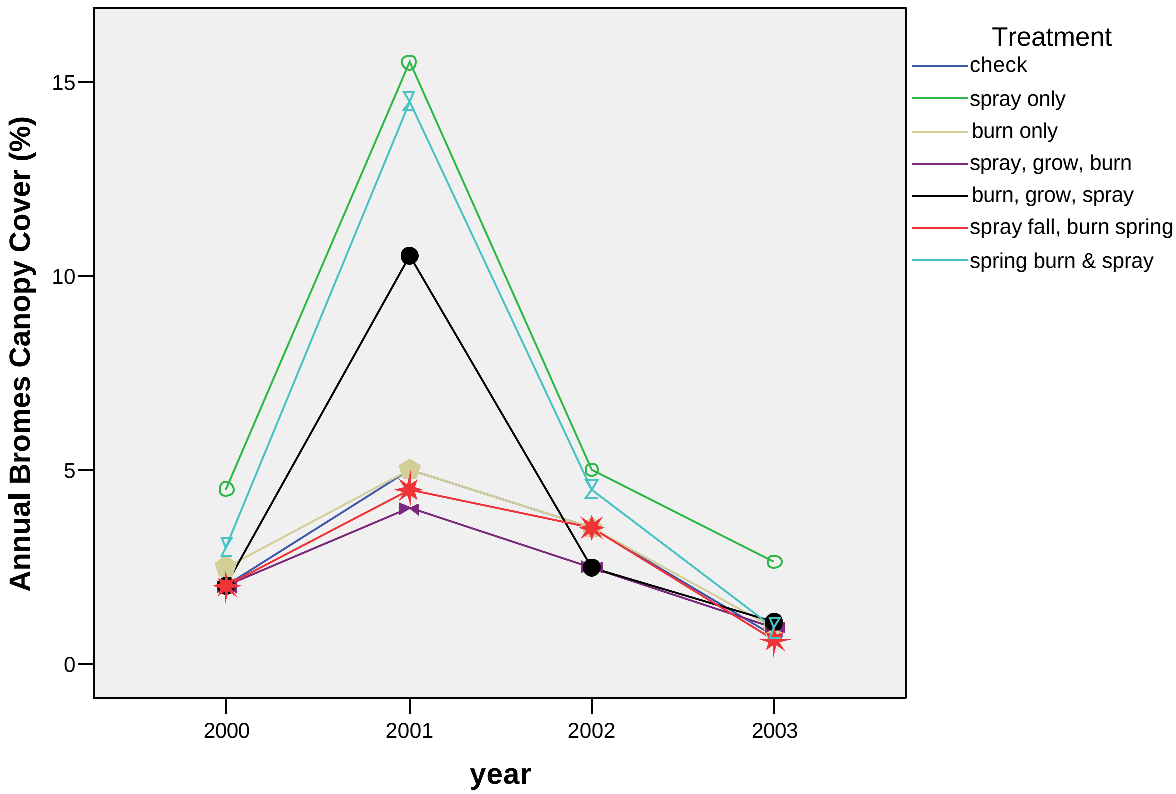


Figure 6. Canopy cover of annual bromes at Blue Mountain for blocks 1 & 2 from 2000 through 2003.

Table 19. Average canopy cover of annual bromes at Blue Mountain for blocks 1 & 2 from 2000 through 2003.

Treatment	A. BROME 2000	A. BROME 2001	A. BROME 2002	A. BROME 2003
Check	2.00	5.00	3.50	0.75
Spray fall 2000 only	4.50	15.50	5.00	2.63
Burn spring 2001 only	2.50	5.00	3.50	0.92
Spray fall 2000, grow, burn spring 2002	2.00	4.00	2.50	0.94
Burn spring 2001, grow, spray fall 2001	2.00	10.50	2.50	1.07
Spray fall 2000, burn spring 2001	2.00	4.50	3.50	0.61
Burn & spray spring 2001	3.00	14.50	4.50	0.93
p. treatment effects ANOVA or ANCOVAR	0.063	0.430	0.180	0.139

p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Community Level Comparisons of Treatments

Community composition at Blue Mt. did not vary among treatment sets in 2000 before treatments were initiated (p>.05). However in the first growing season after treatments there were very highly significant difference (p=.001) at the whole community level when considering all seven treatment sets and the shift was considerable (Table 20). The effect size was .26, and effect size of ~.3 for a plant community implies an considerable difference in species present and/or species proportional canopy cover. As the contrast of all seven treatments was significant in 2001 we examined subsets of the treatments. The composition of spray fall 2000 only vs. check differed greatly (effect size .38, p=.02). The burn only plots composition was almost identical to that of the check plots. Combining burning in spring 2001 with spraying in fall 2000 did result in a community composition that was different from that of just spraying in fall 2000 (p>.05).

Table 20. Treatment group community similarity comparisons at Blue Mt. spotted knapweed site in 2001.

Treatments Compared	p	Effect Size
All seven in 2000 (pre-treatment)	.066	.03
All seven in 2001	<.001	.26
Spray fall 2000 only vs. check in 2001	.020	.38
Burn spring 2001 only vs. check in 2001	.315	.02
Spray fall 2000 only vs. spray fall 2000, burn spring 2001 in 2001	.066	.10

Analyses were by Blocked Multi-Response Permutation Procedures.

In 2002 the community composition of all five treatment sets that included spraying differed significantly from the check plots and the effect sizes were considerable (.23 to .27) (Table 21). The comparison of burn only with check indicated no shift had occurred. Comparing all five treatments that included spraying showed that these communities were quite similar (effect size .03, p=102) thus indicate that inclusion of a burn did not lead to any overall difference from the spraying effect.

Table 21. Treatment group community similarity comparisons at Blue Mt. spotted knapweed site in 2002.

Treatments Compared	p	Effect Size
All seven in 2000 (pre-treatment)	.066	.03
All seven in 2002	<.001	.19
Spray fall 2000 only vs. check in 2002	.021	.27
Spray fall 2000, grow, burn spring 2002 vs. check in 2002	.021	.27
Burn spring 2001, grow, spray fall 2001 vs. check in 2002	.021	.27
Spray fall 2000, burn spring 2001 vs. check in 2002	.021	.23
Burn & spray spring 2001 vs. check in 2002	.019	.27
Burn only vs. check in 2002	.877	-.07
All five treatments with spraying as of 2002	.102	.03

Analyses were by Blocked Multi-Response Permutation Procedures.

For 2003 only blocks 1 & 2 treatments could be compared for community composition at Blue Mt. and the composition did not vary amount the treatment plots although the analyses has limited power due to the small sample size (Table 22).

Table 22. Treatment group community similarity comparisons at Blue Mt. spotted knapweed site for blocks 1 & 2 only in 2003.

Treatments Compared	p	Effect Size
All seven in 2000 (pre-treatment)	.831	-.08
All seven in 2003	.184	.09

Analyses were by Blocked Multi-Response Permutation Procedures.

Ordination With Habitat Type Definition

As with the multi response permutation procedure analysis of community composition the Blue Mountain plots in the summer of 2000, prior to treatment initiation, did not form any similar grouping by planned treatment groups (Figure 7). Table 23 contains the treatments codes for the ordination graphics. The ordination also reveals that the entire set of Blue Mountain plots is quite dissimilar from the Mueggler and Stewart definition plots for the rough fescue/bluebunch wheatgrass habitat type. In 2003 the block 1 and 2 plots at Blue Mountain that had been sprayed had become more similar to the habitat type definition while the check and burn only plots were least similar (Figure 8). The plots in blocks 3 to 5 did not improve in similarity to the habitat type definition (not graphed).

Table 23. Treatment codes for ordination of plots at Blue Mountain site.

Code	Treatment
1	Check
2	Spray fall 2000 only
3	Burn spring 2001 only
4	Spray fall 2000, grow, burn spring 2002
5	Burn spring 2001, grow, spray fall 2001
6	Spray fall 2000, burn spring 2001
7	Burn & spray spring 2001
8	Mueggler & Stewart rough fescue / bluebunch wheatgrass habitat type

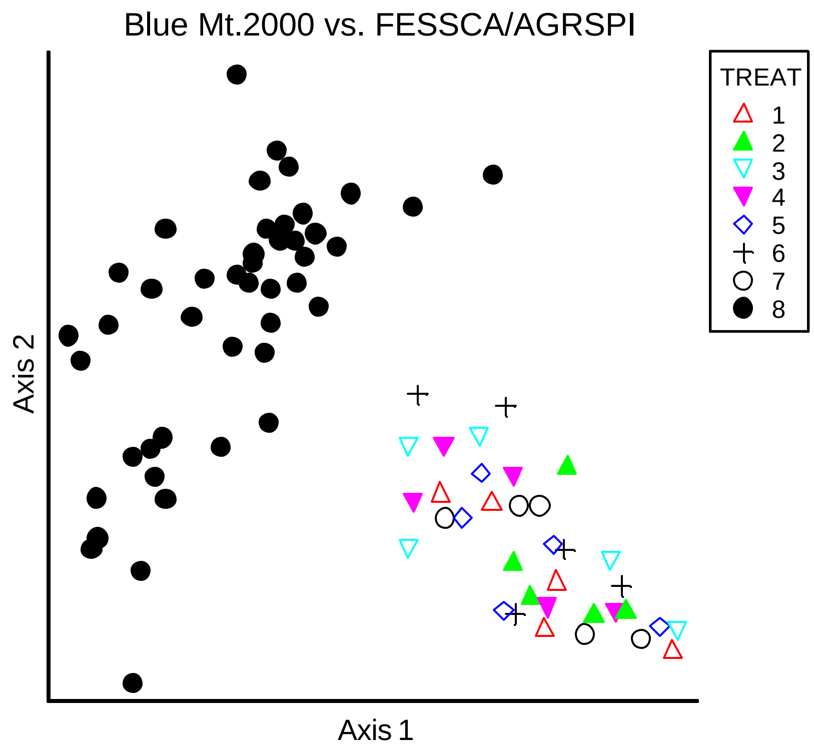


Figure 7. Ordination of pretreatment Blue Mt. plots with Mueggler & Stewa rt rough fescue/bluebunch wheatgrass definition plots (stress 15).

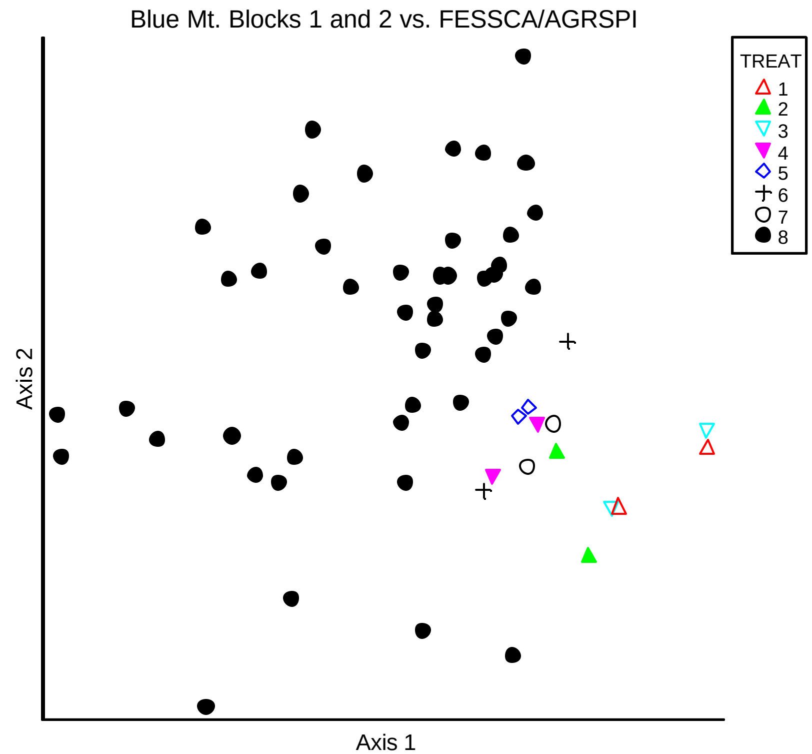


Figure 8. Ordination of 2003 Blue Mt. Blocks 1 & 2 plots with Mueggler & Stewart rough fescue/bluebunch wheatgrass definition plots (stress 19).

Henry Creek Saint Johnswort Site Vegetation

Individual Species and Life Form Reponses

St. Johnswort canopy cover is graphed in Figure 9 from 2000 through 2003 for the seven treatments at Henry Creek.

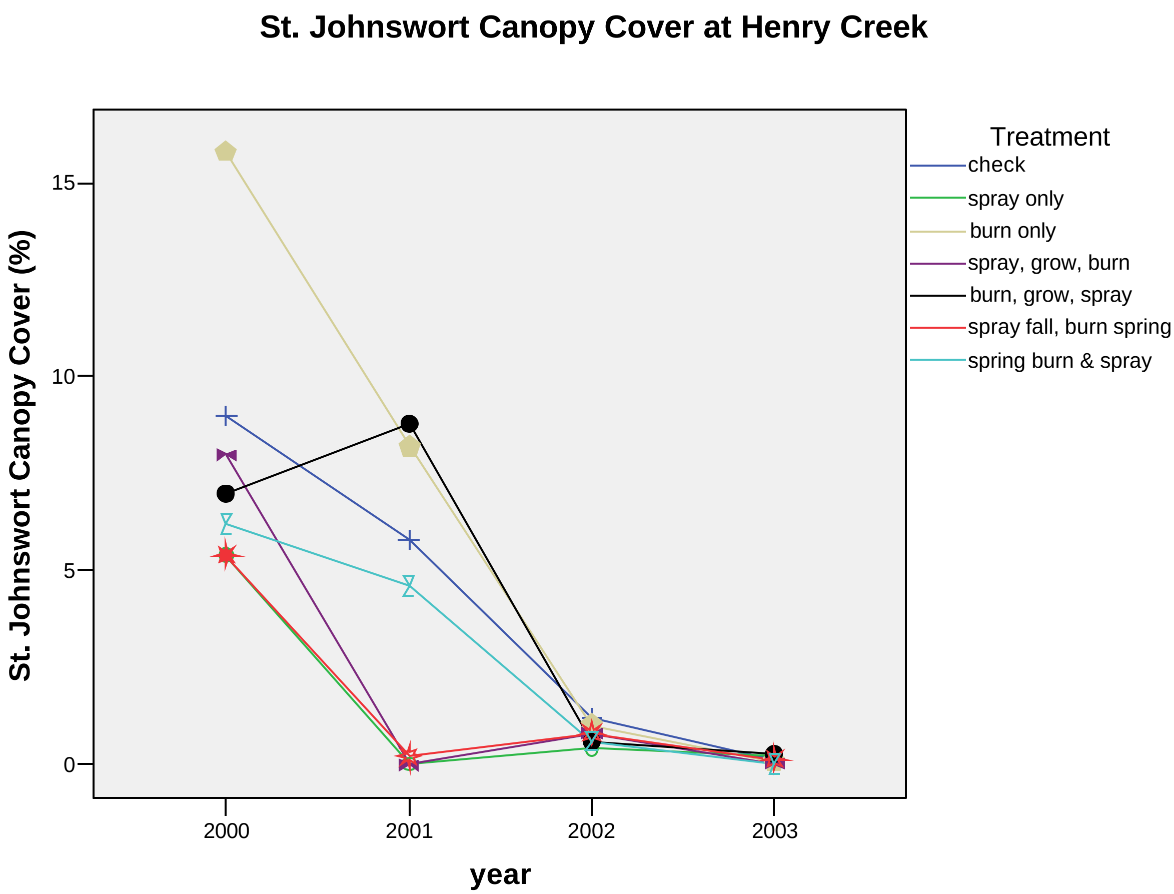


Figure 9. St. Johnswort canopy cover at Henry Creek from 2000 through 2003.

The St. Johnswort (HYPPER) canopy cover among the planned treatment plots did differ significantly in the summer of 2000 when sampled before the treatments were begun (Table 24). In 2001, the first growing season after initiation of treatments, there were highly ($p<.001$) differences in that St. Johnswort regrowth was essentially eliminated in the three treatment sets that had included fall 2000 spraying but the check plot canopy cover was 5.8% (Table 25). The St. Johnswort canopy cover on the three treatments sets that were burned in the spring of 2001 but had not been sprayed the preceding fall did not differ from the check plots ($p>.05$). St. Johnswort regrowth in 2001 was essentially elimitated on both the spray fall 2000 only and the spray fall 2000, burn spring 2001 treatment sets. Treatment differences in 2002 and 2003 were not detectable ($p>.05$) (Table 24). St. Johnswort abundance on check plots began to decline in

2001 and did not recover through the remaining years of measurement. In 2002 the canopy cover of St. Johnswort was reduced to about 1% or less in all treatments including the check plots. The site wide collapse of the St. Johnswort population as of 2002 may have been caused by the Chrysolina beetles which were active at Henry Creek, as well as cumulative drought effects. St. Johnswort did not recover in 2003.

Table 24. Average St. Johnswort canopy cover at Henry Creek.

Treatment	HYPPER 2000	HYPPER 2001	HYPPER 2002	HYPPER 2003
Check	9.000	5.800	1.200	0.128
Spray fall 2000 only	5.400	0.000	<0.400	0.202
Burn spring 2001 only	15.800	8.200	<1.000	0.054
Spray fall 2000, grow, burn spring 2002	8.000	0.000	<0.800	0.032
Burn spring 2001, grow, spray fall 2001	7.000	8.800	<0.600	0.278
Spray fall 2000, burn spring 2001	5.400	<0.200	<0.800	0.132
Burn & spray spring 2001	6.200	4.600	<0.600	0.004
p. treatment effects ANOVA or ANCOVAR	0.111	<.001	0.334	0.481

p based on estimated marginal means of log (X+1) as corrected by pre-spray year covariate but tabled means are observed values

Table 25. Bonferroni adjusted pairwise comparisons of St. Johnswort canopy cover in treatments (n=5) of interest at Henry Creek.

Year	Treatment One Canopy Cover	Treatment Two Canopy Cover	p.
2001	Check	Spray fall 2000 only	
	5.8	0.000	<.001
		Spray fall 2000, grow, burn spring 2002	
		0.000	<.001
		Spray fall 2000, burn spring 2001	
		<0.200	.001
2001	Check	Burn spring 2001 only	
	5.8	8.200	ns
		Burn spring 2001, grow, spray fall 2001	
		8.800	ns
		Burn & spray spring 2001	
		4.600	ns
2001	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	0.000	<0.200	ns

ns=p>.05

p calculated on estimated marginal means log (X+1) as corrected by pre-spray year covariate but tabled means are observed values

Perennial grass canopy cover at Henry Creek is graphed in Figure 10. Perennial grass canopy cover did not differ among the planned treatments in the summer of 2000 (Table 26). In the summers subsequent to initiation of treatments significant differences were indicated by the overall analysis of covariance. Although an increase in perennial grasses would be expected in the growing season after spraying the pairwise comparisons for 2001 indicated that the perennial grass response did not differ significantly (p>>.05) between any of the treatments of interest (Table 27). The only significant pairwise difference (p=.048) in 2001 was between the lower perennial grass cover (14%) in the burn spring 2001 only treatment and the higher cover (26%) in the spray fall 2000, grow, burn spring 2002 plots (Bonferroni contrast not tabled). By summer 2002 all four treatment sets that were more than one full growing season post spray had significantly (p=.05) more perennial grass than the check plots. The 2002 perennial grass cover on the plots that had been burned as well as sprayed did not differ from the cover on the spray fall 2000 only plots. In 2003 the overall analysis of covariance was significant (p=.022, Table 26). However although the trend was for the treatments sets that included spraying to have more perennial grasses than the check and burn only plots the conservative Bonferroni test did not indicate any significant (p>.05) pairwise comparisons. The treatments sets in 2003 that were most recently sprayed (burn spring 2001, grow, spray fall 2001 (p=.058); burn & spray spring 2001 (p=.065)) did have the most perennial grass relative to the check and burn only plots while the treatment sets that had included spraying back in fall 2000 had intermediate levels of perennial grass cover (Figure 10, Tables 26 & 27).

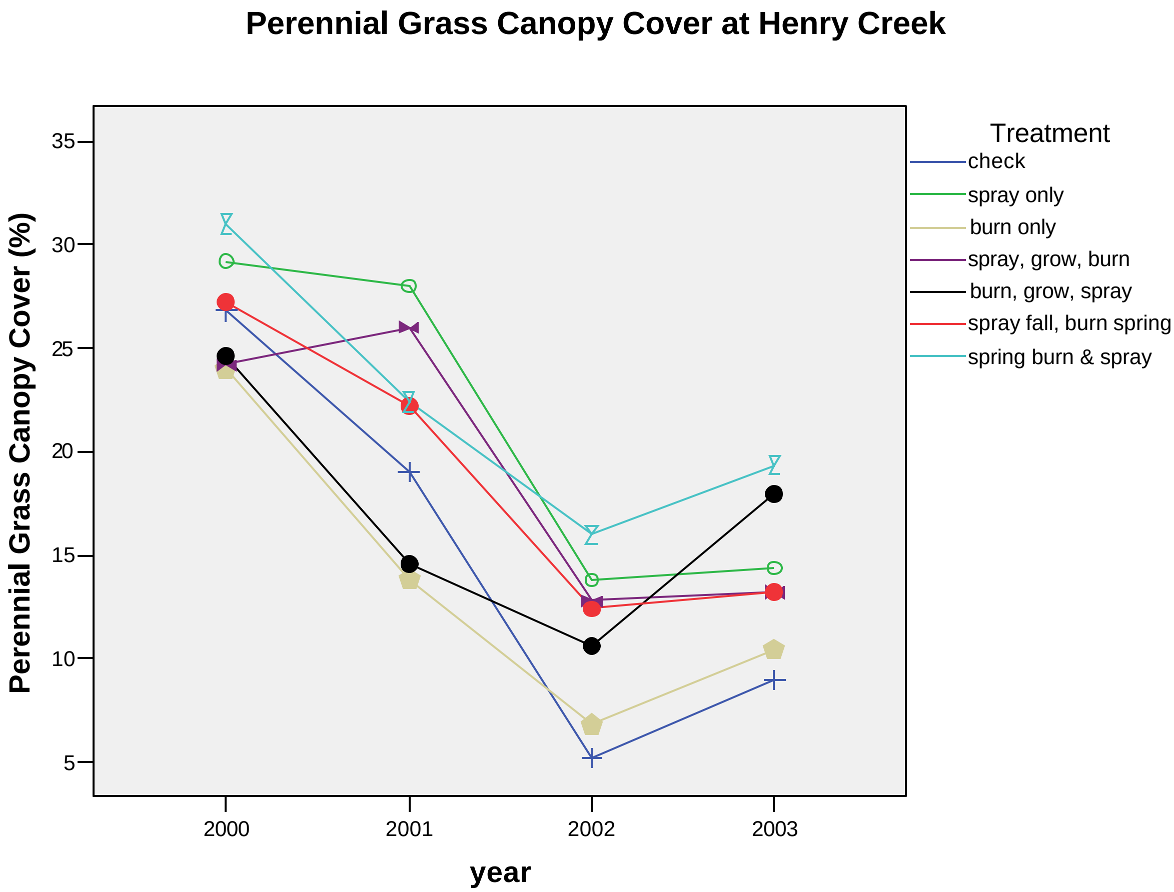


Figure 10. Perennial grass canopy cover at Henry Creek from 2000 through 2003.

Table 26. Average perennial grass canopy cover at Henry Creek.

Treatment	Per. Grasses 2000	Per. Grasses 2001	Per. Grasses 2002	Per. Grasses 2003
Check	27	19	5	9
Spray fall 2000 only	29	28	14	14
Burn spring 2001 only	24	14	7	10
Spray fall 2000, grow, burn spring 2002	24	26	13	13
Burn spring 2001, grow, spray fall 2001	25	15	11	18
Spray fall 2000, burn spring 2001	27	22	12	13
Burn & spray spring 2001	31	22	16	19
p. treatment effects ANOVA or ANCOVAR	0.505	0.008	0.001	0.022

Table 27. Bonferroni pairwise comparisons of perennial grass canopy cover in treatments (n=5) of interest at Henry Creek.

Year	Treatment One Canopy Cover	Treatment Two Canopy Cover	p.
2001	Check	Spray fall 2000 only	
	19	28	ns
		Spray fall 2000, grow, burn spring 2002	
		26	ns
		Spray fall 2000, burn spring 2001	
		22	ns
2001	Check	Burn spring 2001 only	
	19	14	ns
		Burn spring 2001, grow, spray fall 2001	
		15	ns
		Burn & spray spring 2001	
		22	ns
2001	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	28	22	ns
2002	Check	Spray fall 2000 only	
	5	14	.014
		Spray fall 2000, grow, burn spring 2002	
		13	.018
		Spray fall 2000, burn spring 2001	
		12	.047
		Burn spring 2001, grow, spray fall 2001	
		11	ns
		Burn & spray spring 2001	
		16	.002
2002	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	14	12	ns
		Spray fall 2000, grow, burn spring 2002	
		13	ns
2003	Check	Spray fall 2000 only	
	9	14	ns
		Spray fall 2000, grow, burn spring 2002	
		13	ns
		Spray fall 2000, burn spring 2001	
		13	ns
		Burn spring 2001, grow, spray fall 2001	
		18	.058
		Burn & spray spring 2001	
		19	.065
2003	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	14	13	ns
		Spray fall 2000, grow, burn spring 2002	
		13	ns

ns=p>>.05

p calculated on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Combined canopy covers of annual brome grasses at Henry Creek are graphed in Figure 11 for 2000 through 2003. The annual bromes canopy cover did not vary significantly before initiation of treatments, but very highly significant (p=.001) differences among treatments were measured in the subsequent years (Table 28). The 2001 annual bromes canopy cover more than doubled relative to check plots in the two treatment sets that were just sprayed in fall of 2000 (Table 29). The 2001 increase relative to check plots (14.2%) was less on spray fall 2000, burn spring 2001 plots (25.4%) and not significant. The 2001 increase of annual bromes on spray fall 2000, burn spring 2001 plots (25.2%) was also less than on spray fall 2000 only plots (25.4%) but this difference also was not significant. Otherwise there was no indication that including burning had affected the 2001 annual bromes response in comparison with the check plots. In 2002 the five treatment sets which included spraying had 2.5 to 5.5 times more annual bromes than the check plots although the Bonferroni tests were not significant (p>.05) for two of the treatment sets. Including a burn with spraying in fall 2000 did not produce 2002 annual brome canopy cover responses that differed significantly from the spray fall 2000 only treatment. In 2003 the five treatment sets which included spraying had 3 to 6 times more annual bromes than the check plots although the Bonferroni tests were not significant (p>>.05) for three of the treatment sets. As was the case in 2002 the treatments two sets including a burn with spraying in fall 2000 did not produce 2003 annual brome canopy cover responses that differed significantly from the spray fall 2000 only treatment. Check and burn only plots had almost identical annual bromes canopy cover over the period of measurements (Figure 11).

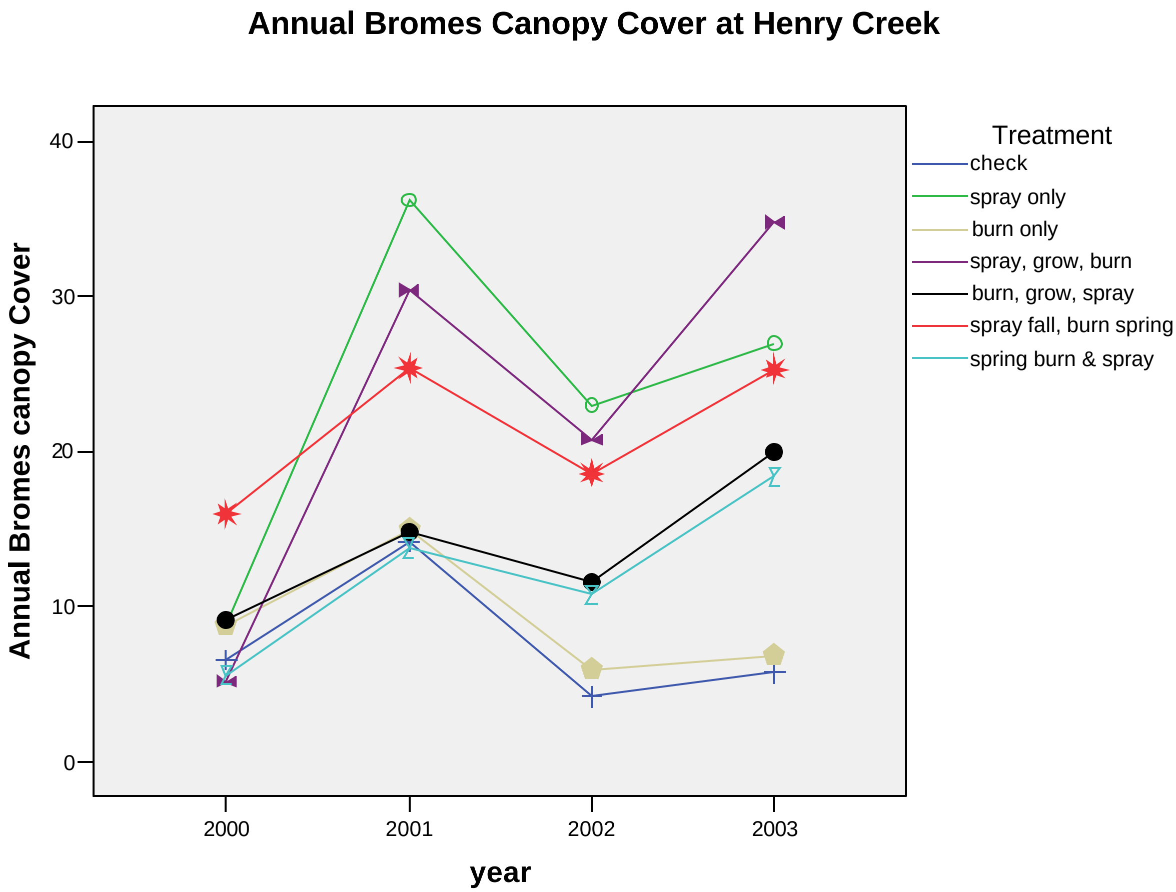


Figure 11. Annual bromes canopy cover at Henry Creek from 2000 through 2003.

Table 28. Average canopy cover of annual bromes at Henry Creek.

Treatment	A. BROME 2000	A. BROME 2001	A. BROME 2002	A. BROME 2003
check	6.6	14.2	4.2	5.8
Spray fall 2000 only	8.8	36.2	23.0	27.0
Burn spring 2001 only	8.8	15.0	6.0	6.9
Spray fall 2000, grow, burn spring 2002	5.2	30.4	20.8	34.8
Burn spring 2001, grow, spray fall 2001	9.2	14.8	11.6	20.0
Spray fall 2000, burn spring 2001	16.0	25.4	18.6	25.3
Burn & spray spring 2001	5.6	13.8	10.8	18.4
p. treatment effects ANOVA or ANCOVAR	0.853	0.001	<0.001	0.001

p based on estimated marginal means of log (X+1) as corrected by pre-spray year covariate but tabled means are observed values

Table 29. Bonferroni pairwise comparisons of annual bromes canopy cover in treatments (n=5) of interest at Henry Creek.

Year	Treatment One Canopy Cover	Treatment Two Canopy Cover	p.
2001	Check	Spray fall 2000 only	
	14.2	36.2	.045
		Spray fall 2000, grow, burn spring 2002	
		30.4	.031
		Spray fall 2000, burn spring 2001	
		25.4	ns
2001	Check	Burn spring 2001 only	
	14.2	15.0	ns
		Burn spring 2001, grow, spray fall 2001	
		14.8	ns
		Burn & spray spring 2001	
		13.8	ns
2001	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	36.2	25.4	ns
2002	Check	Spray fall 2000 only	
	4.2	23.0	<.001
		Spray fall 2000, grow, burn spring 2002	
		20.8	<.001
		Spray fall 2000, burn spring 2001	
		18.6	.005
		Burn spring 2001, grow, spray fall 2001	
		11.6	ns
		Burn & spray spring 2001	
		10.8	.089
2002	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	23.0	18.6	ns
		Spray fall 2000, grow, burn spring 2002	
		20.8	ns
2003	Check	Spray fall 2000 only	
	5.8	27.0	.040
		Spray fall 2000, grow, burn spring 2002	
		34.8	.006
		Spray fall 2000, burn spring 2001	
		25.3	ns
		Burn spring 2001, grow, spray fall 2001	
		20.0	ns
		Burn & spray spring 2001	
		18.4	ns
2003	Spray fall 2000 only	Spray fall 2000, burn spring 2001	
	27.0	25.3	ns
		Spray fall 2000, grow, burn spring 2002	
		34.8	ns

ns=p>>.05

p calculated on estimated marginal means of log (X+1) as corrected by pre-spray year covariate but tabled means are observed values

Community Level Comparisons of Treatments

Community composition at Blue Mt. did not vary among treatment sets in 2000 before treatments were initiated (p=.487). However, in the first growing season after treatments there were very highly significant differences among the seven treatments (p<.001) although the overall effect size was only moderate (.18) (Table 30). The spray fall 2000 only communities differed did greatly from the composition of the check plots (p=.017, effect size .36). Burning in the spring of 2001 did not alter the 2001 composition relative to the check plots, and following spraying in fall 2000 with spring 2001 burning did not result in a 2001 community composition that was any different than just spraying.

Table 30. Treatment group community similarity comparisons at Henry Cr. St. Johnswort site in 2001.

Treatments Compared	p	Effect Size
All seven in 2000 (pre-treatment)	.487	.00
All seven in 2001	<.001	.18
Spray fall 2000 only vs. check in 2001	.017	.36
Burn spring 2001 only vs. check in 2001	.580	-.01
Spray fall 2000 only vs. spray fall 2000, burn spring 2001 in 2001	.144	.08
Analyses were by Blocked Multi-Response Permutation Procedures.		

Community composition differences were also present among the seven treatment sets in 2002 (Table 31). The composition of all five treatments sets that included spraying differed significantly (all p<.02) from the check plots with the effect size ranging from .25 to as large as .42. However, within the five treatments that included spraying there was almost no difference in composition (effect size .02, p=.299) indicating that burning was not having much impact on the plant community. Similarly indicating a lack a burn effect the contrast of burn spring 2001 vs. check in 2002 had a non-significant effect size of only .04.

Table 31. Treatment group community similarity comparisons at Henry Cr. St. Johnswort site in 2002.

Treatments Compared	p	Effect Size
All seven in 2000 (pre-treatment)	.487	.00
All seven in 2002	<.001	.18
Spray fall 2000 only vs. check in 2002	.016	.42
Spray fall 2000, grow, burn spring 2002 vs. check in 2002	.017	.41
Burn spring 2001, grow, spray fall 2001 vs. check in 2002	.019	.30
Spray fall 2000, burn spring 2001 vs. check in 2002	.016	.37
Burn & spray spring 2001 vs. check in 2002	.015	.25
Burn spring 2001 only vs. check in 2002	.124	.04
All five treatments with spraying as of 2002	.299	.02
Analyses were by Blocked Multi-Response Permutation Procedures.		

The pattern of composition difference among treatments in 2003 was identical to that of 2002 (Table 32). Spraying was associated with shifts in species composition and abundance relative to check plots but there was no detectable burn effect at the community level.

Table 32. Treatment group community similarity comparisons at Henry Cr. St. Johnswort site in 2003.

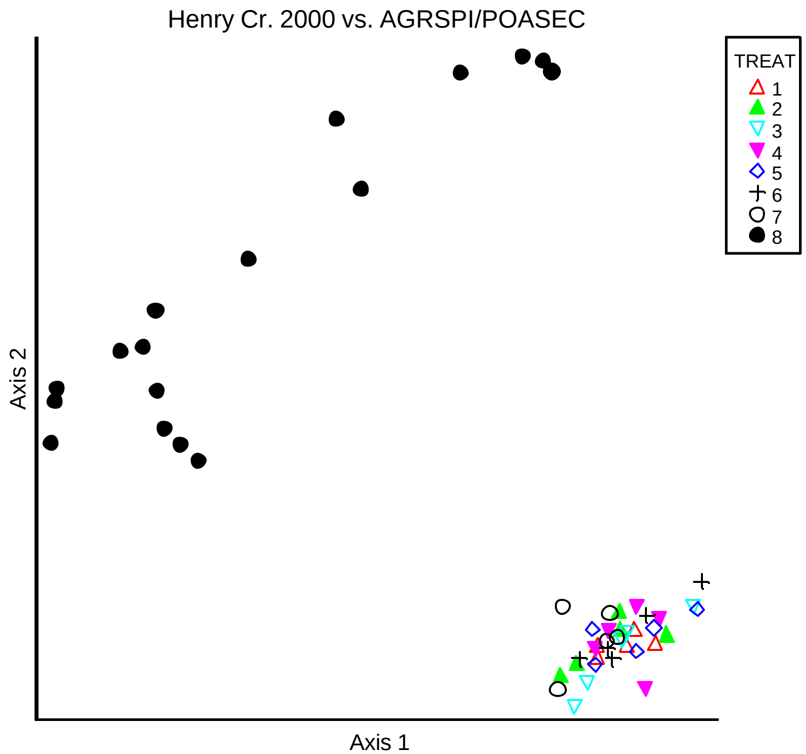
Treatments Compared	p	Effect Size
All seven in 2000 (pre-treatment)	.487	.00
All seven in 2003	.002	.19
Spray fall 2000only vs. check in 2003	.019	.41
Spray fall 2000, grow, burn spring 2002 vs. check in 2003	.018	.37
Burn spring 2001, grow, spray fall 2001 vs. check in 2003	.035	.25
Spray fall 2000, burn spring 2001 vs. check in 2003	.016	.36
Burn & spray spring 2001 vs. check in 2003	.024	.32
Burn only vs. check in 2003	.350	.02
All five treatments with spraying as of 2003	.525	-.01

Analyses were by Blocked Multi-Response Permutation Procedures.

Ordination With Habitat Type Definition

As with the multi response permutation procedure analysis of community composition the Henry Creek plots in the summer of 2000, prior to treatment initiation, did not form any similar grouping by planned treatment groups (Figure 12). Table 33 contains the treatments codes for the ordination graphics. The ordination also reveals that the entire set of Henry Creek plots is quite dissimilar from the Mueggler and Stewart definition plots for the bluebunch wheatgrass/Sandberg bluegrass habitat type. Although Sandberg bluegrass is quite prevalent at Henry Creek the site has very little bluebunch wheatgrass. Average bluebunch wheatgrass canopy cover in 2000 was 0.3% and it was sampled only in four plots. The Mueggler and Stewart plots averaged 32% bluebunch wheatgrass, with a range of 1% to 65%. The Mueggler and Stewart bluebunch wheatgrass / Sandberg bluegrass h.t. plots with low bluebunch wheatgrass abundance are in the needle and thread grass (*Stipa comata*) phase. Needle and thread grass was not found at Henry Creek. This phase is located mostly east of the continental divide. At the conclusion of community measurements in 2003 the Henry Creek plots were still highly dissimilar from the bluebunch wheatgrass / Sandberg bluegrass h.t. definition plots (Figure 13). The Henry Creek plots did form generally like groups based on their treatment history with the check and burn only plots being similar and distinct from the five sets of plots were the treatments had included spraying.

Table 33. Treatment codes for plots at Henry Creek site.	
Code	**Treatment**
1	Check
2	Spray fall 2000 only
3	Burn spring 2001 only
4	Spray fall 2000, grow, burn spring 2002
5	Burn spring 2001, grow, spray fall 2001
6	Spray fall 200, burn spring 2001
7	Burn & spray spring 2001
8	Mueggler & Stewart rough fescue / bluebunch wheatgrass habitat type



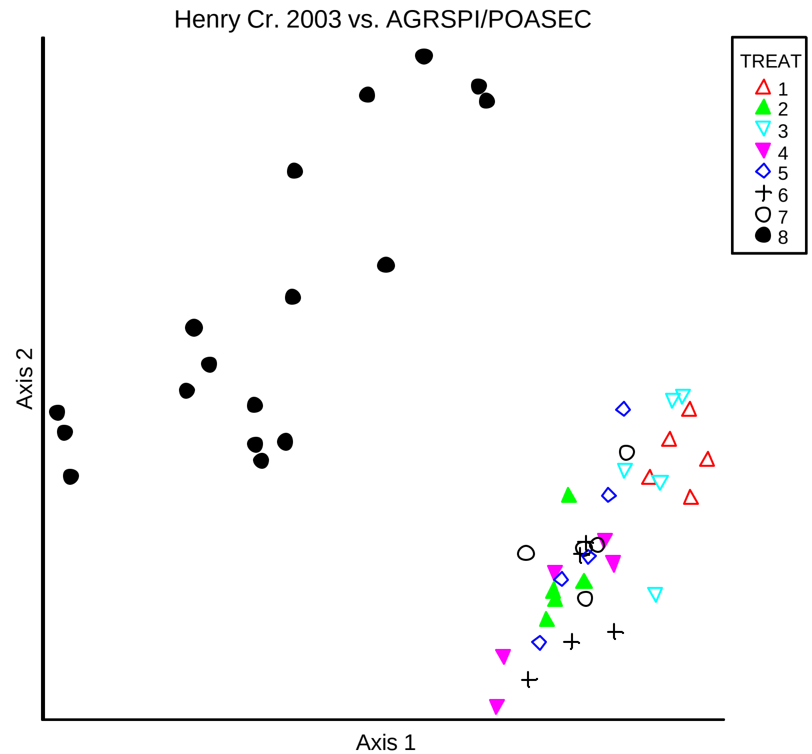


Figure 12. Ordination of pretreatment Henry Creek plots with Mueggler & Stewart bluebunch wheatgrass/Sandberg bluegrass definition plots (stress 14).

Figure 13. Ordination of 2003 Henry Creek plots with Mueggler & Stewart bluebunch wheatgrass/Sandberg bluegrass definition plots (stress 13).

North Hills Leafy Spurge Site Vegetation

Individual Species and Life Form Reponses

Leafy spurge canopy cover is graphed in Figure 14 from 2001 through 2004 for the seven treatments in the North Hills. The leafy spurge (EUPESU) canopy cover among the planned treatment plots did differ significantly in the summer of 2000 when sampled before the treatments were begun but in all three years after initiation of treatments there were highly (p<.001) differences (Table 34).

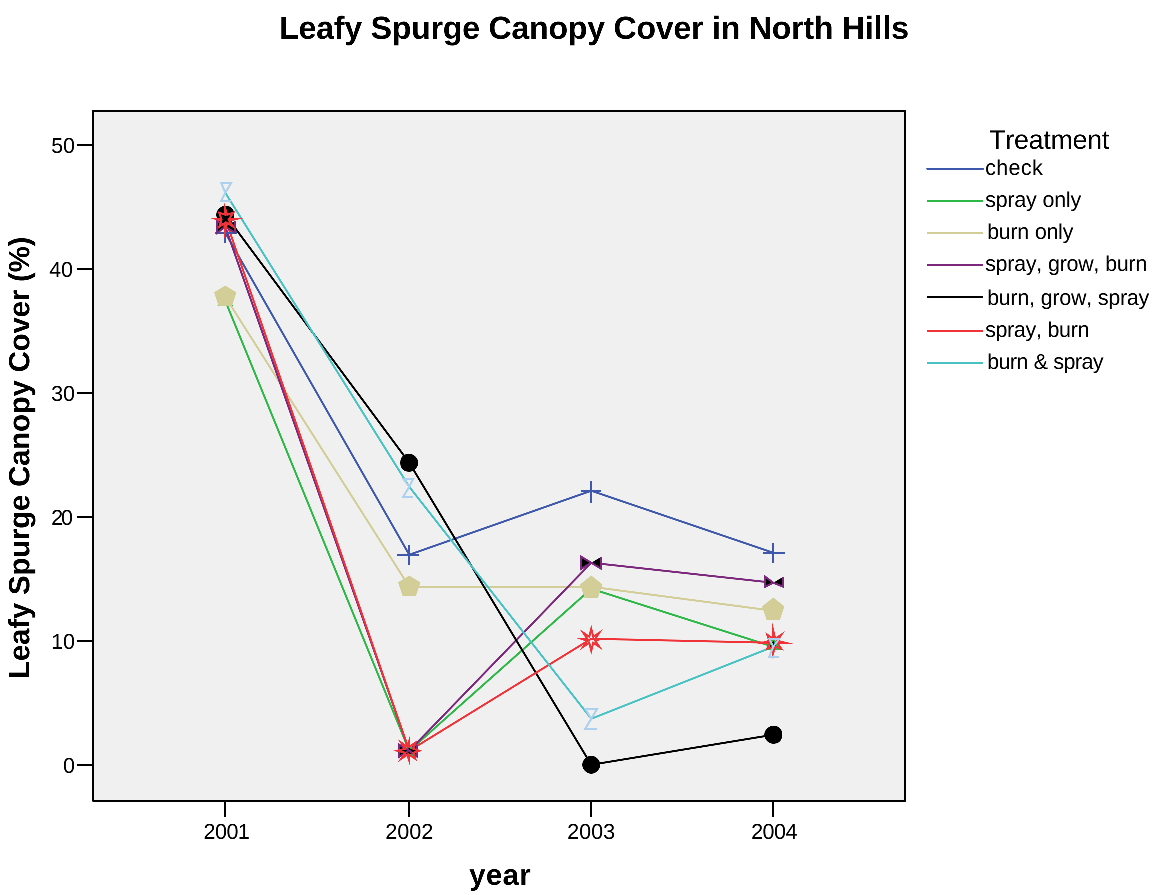


Figure 14. Leafy spurge canopy cover in North Hills from 2001 through 2004.

Table 34. Average leafy spurge (EUPESU) canopy cover at North Hills.

Treatment	EUPESU 2001	EUPESU 2002	EUPESU 2003	EUPESU 2004
Check	43.0	17.0	22.1	17.1
Spray fall 2001 only	37.4	<1.2	14.3	9.6
Burn spring 2002 only	37.8	14.4	14.3	12.5
Spray fall 2001, grow, burn spring 2003	43.4	<1.2	16.4	14.8
Burn spring 2002, grow, spray fall 2002	44.4	24.4	0.1	2.4
Spray fall 2001, burn spring 2002	44.0	<1.2	10.1	9.9
Burn & spray spring 2002	46.2	22.4	3.8	9.5
p. treatment effects ANOVA or ANCOVAR	0.727	<.001	<.001	<.001

p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Leafy spurge canopy cover was reduced to less than 1.2% in 2002 on all three treatment sets that had been sprayed the preceding fall (Table 35). The 2002 reduction in target weed cover relative to the check plots at 17% leafy spurge canopy cover was significant for all three treatments at p=.065 or less. Treatment plots that had not been sprayed the preceding fall but where burned in the spring of 2002 did not differ significantly from the check plots during the 2002 growing season. The canopy cover of plots that were burned in spring of 2002 in addition to having been sprayed the preceding fall had the same low spurge abundance(<1.2%) as the plots for which the treatment was spray fall 2000 only. Leafy spurge began to recover in the second growing season (i.e. 2003) after fall 2001 spraying when the spray fall 2001 only plots at 14.3% canopy cover and the spray fall 2001, grow, burn spring 2003 plots at 16.4% canopy cover did not differ significantly from the check plots which averaged 22.1 leafy spurge canopy cover. However the spray fall 2001, burn spring 2002 at 10.1% canopy cover was still significantly lower than the check plots in 2003. The two more recently sprayed treatment sets (burn spring 2002, grow, spray fall 2002 at 0.1% canopy cover and burn & spray spring 2002 at 3.8% canopy cover) did have significantly less leafy spurge than the check plots in 2003. Including burning in either spring of 2002 or 2003 along with fall 2001 spraying did not result in a leafy spurge abundance that was significantly different than just spaying fall 2001 only. Although there continued to be more leafy spurge (17.1%) in the check plots in 2004 than in five treatment sets that included spraying this reduction was not significant except for the plots that had been most recently sprayed (burn spring 2002, grow, spray fall 2002 at 2.4% canopy cover p<.001). In 2004, as in the two preceding years, the treatment sets that had added burning to fall 2001 spraying did not have significantly better or worse control that the plots that received the spray fall 2001 only treatment.

Percent leafy spurge control relative to check plots at one and two growing seasons after spraying (GAS) was also calculated to see if a burn affect could be detected (Table 36). Although there was considerably higher suppression (85.6%) of leafy spurge at two growing seasons after spraying in the burn spring 2002, grow, spray fall 2002 treatment plots than the spray fall 2001 only plots (35.3%) none of these four pairwise comparisons revealed a significant burn effect.

Table 35. Bonferroni adjusted pairwise comparisons of leafy spurge canopy cover in treatments (n=5) of interest at North Hills.

Year	Treatment One Canopy Cover	Treatment Two Canopy Cover	p.
2002	Check	Spray fall 2001 only	
	17.0	<1.2	.065
		Spray fall 2001, grow, burn spring 2003	
		<1.2	.012
		Spray fall 2001, burn spring 2002	
		<1.2	.010
2002	Check	Burn spring 2002 only	
	17.0	14.4	ns
		Burn spring 2002, grow, spray fall 2002	
		24.4	ns
		Burn & spray spring 2002	
		22.4	ns
2002	Spray fall 2001 only	Spray fall 2001, burn spring 2002	
	<1.2	<1.2	ns
2003	Check	Spray fall 2001 only	
	22.1	14.3	ns
		Spray fall 2001, grow, burn spring 2003	
		16.4	ns
		Spray fall 2001, burn spring 2002	
		10.1	.021
		Burn spring 2002, grow, spray fall 2002	
		0.1	<.001
		Burn & spray spring 2002	
		3.8	<.001
2003	Spray fall 2001 only	Spray fall 2001, burn spring 2002	
	14.3	10.1	ns
		Spray fall 2001, grow, burn spring 2003	
		16.4	ns
2004	Check	Spray fall 2001 only	
	17.1	9.6	ns
		Spray fall 2001, grow, burn spring 2003	
		12.5	ns
		Spray fall 2001, burn spring 2002	
		9.9	ns
		Burn spring 2002, grow, spray fall 2002	
		2.4	<.001
		Burn & spray spring 2002	
		9.5	ns
2004	Spray fall 2001 only	Spray fall 2001, burn spring 2002	
	9.6	9.9	ns
		Spray fall 2001, grow, burn spring 2003	
		14.8	ns

ns=p>.05

p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Table 36. Bonferroni adjusted pairwise comparison of percent control of leafy spurge in the North Hill between spray only treatment and treatments (n=5) of interest that included burning.

GAS	Treatment One % Control†	Treatment Two % Control†	p.
1	Spray fall 2001 only	Burn spring 2002, grow, spray fall 2002	
	92.9	99.8	.468
		Burn & spray spring 2002	
		82.9	.150
2	Spray fall 2001 only	Burn spring 2002, grow, spray fall 2002	
	35.3	85.9	.071
		Burn & spray spring 2002	
		44.3	1.000

GAS=growing seasons after spraying, pairs sprayed in different years
†percent control of target weed relative to abundance in check plots in growing season when sampled
p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Perennial grass canopy cover in the North Hills for 2001 through 2004 is graphed in Figure 15. In the pretreatment summer sample there was no significant difference among the planned treatment group (Table 37). The overall analyses of covariance indicated highly significant differences among the treatment groups in the three growing seasons after the initiation of treatments in the fall of 2001. However under the droughty conditions in 2002 the grasses were slow to respond to the release from weed competition, and no significant differences ($p>.05$) were indicated with the Bonferroni pairwise comparisons although the three treatment plot sets that had been sprayed the preceding fall did have the most perennial grass cover (Table 38, Figure 15). The 2002 perennial grass canopy cover on treatment plot sets that had been burned in the spring of 2002 was almost identical to that in check plots, and burning in spring 2002 in addition to fall 2001 spraying did result in perennial grass canopy cover that differed much from the spray fall 2001 only treatment. However in 2003 a positive grass response continued to where all five treatment sets that had been sprayed had three-fold more perennial grass canopy cover than the check plots ($p<.001$ in all five comparisons). Although spraying had increased perennial grass growth in 2003 the addition of burning in spring of 2002 or burning in spring 2003 with spraying in fall 2001did not change grass response relative to the spray fall 2001 only treatment ($p>.05$). The positive perennial grass response to spraying was maintained in 2004 although the increased grass growth at 20% canopy cover on the spray fall 2001 only plots was significant at just $p=.082$ relative to the check plot perennial grass canopy cover of 12%. The higher perennial grass covers in 2004 on the four other treatments that included spraying were significant at $p=.001$ when compared to the check plots. The slightly higher 2004 perennial grass cover on the two treatments that included burning in spring 2002 or spring 2003 with fall 2001 spraying did not differ significantly from the spray fall 2001 only treatment.

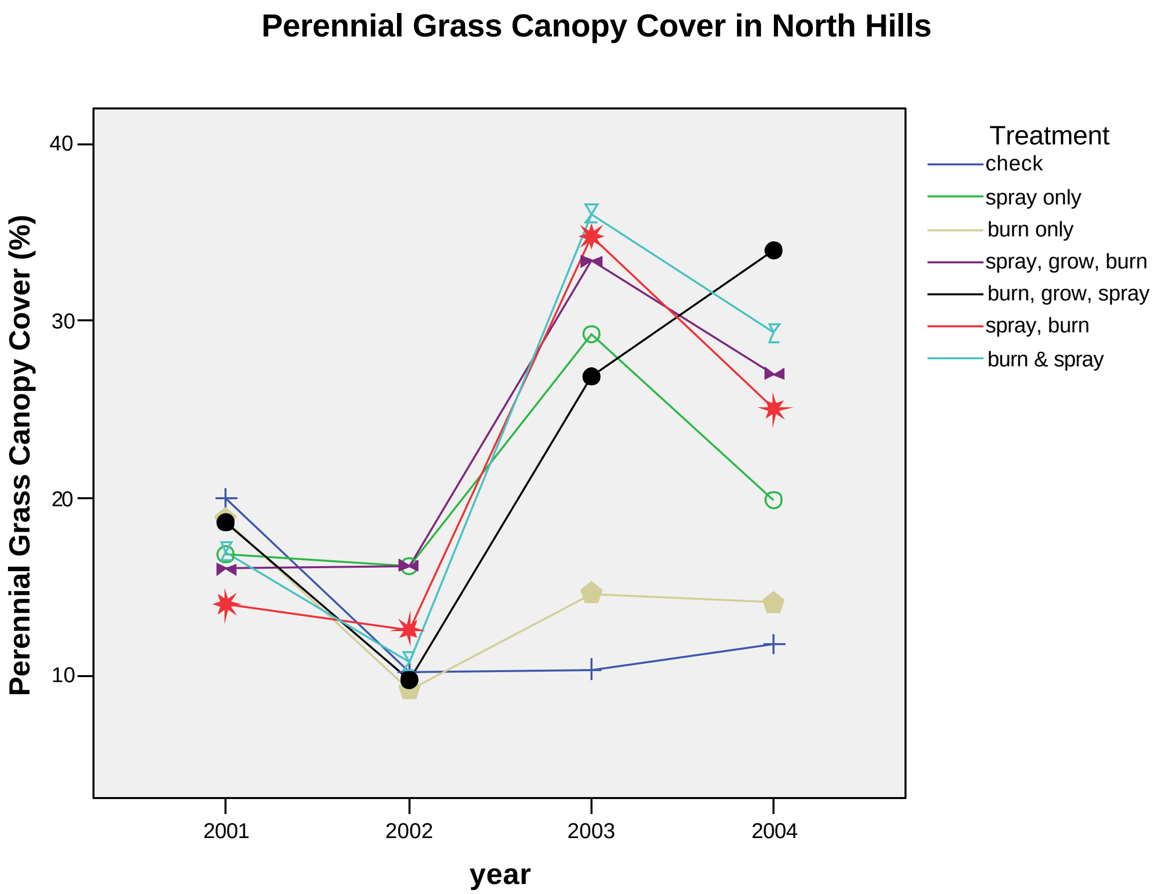


Figure 15. Perennial grass canopy cover in North Hills from 2001 through 2004.

Table 37. Average perennial grass canopy cover at North Hills.

Treatment	8 Per. Grasses 2001	8 Per. Grasses 2002	8 Per. Grasses 2003	8 Per. Grasses 2004
Check	20	10	10	12
Spray fall 2001 only	17	16	29	20
Burn spring 2002 only	19	9	15	14
Spray fall 2001, grow, burn spring 2003	16	16	33	27
Burn spring 2002, grow, spray fall 2002	19	10	27	34
Spray fall 2001, burn spring 2002	14	13	35	25
Burn & spray spring 2002	17	11	36	29
p. treatment effects ANOVA or ANCOVAR	0.928	.007	<.001	<.001

p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Table 38. Bonferroni adjusted pairwise comparisons of perennial grass cover in treatments of interest at North Hills.

Year	Treatment One Canopy Cover	Treatment Two Canopy Cover	p.
2002	Check	Spray fall 2001 only	
	10	16	.145
		Spray fall 2001, grow, burn spring 2003	
		16	.118
		Spray fall 2001, burn spring 2002	
		13	ns
2002	Check	Burn spring 2002 only	
	10	9	ns
		Burn spring 2002, grow, spray fall 2002	
		10	ns
		Burn & spray spring 2002	
		11	ns
2002	Spray fall 2001 only	Spray fall 2001, burn spring 2002	
	16	13	ns
2003	Check	Spray fall 2001 only	
	10	29	<.001
		Spray fall 2001, grow, burn spring 2003	
		33	<.001
		Spray fall 2001, burn spring 2002	
		35	<.001
		Burn spring 2002, grow, spray fall 2002	
		27	<.001
		Burn & spray spring 2002	
		36	<.001
2003	Spray fall 2001 only	Spray fall 2001, burn spring 2002	
	29	35	ns
		Spray fall 2001, grow, burn spring 2003	
		33	ns
2004	Check	Spray fall 2001 only	
	12	20	.082
		Spray fall 2001, grow, burn spring 2003	
		27	<.001
		Spray fall 2001, burn spring 2002	
		25	.001
		Burn spring 2002, grow, spray fall 2002	
		34	<.001
		Burn & spray spring 2002	
		29	<.001
2004	Spray fall 2001 only	Spray fall 2001, burn spring 2002	
	20	25	ns
		Spray fall 2001, grow, burn spring 2003	
		27	ns

ns=p>.05

p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

The canopy cover of annual bromes in the North Hills is graphed in Figure 16 for 2001 through 2004. The annual brome abundance did not differ significantly among the planned treatment plot sets in the 2001 pretreatment sample (Table 39). The overall analysis of covariance was significant (p=.021) for 2002 but no two treatment differences were large enough to be significant. Although there was more separation among treatment means in 2003 and 2004 the analyses of covariance for annual bromes canopy cover was not significant. The check plots had intermediate levels of annual bromes (Figure 16) and canopy cover variance was high for this data set.

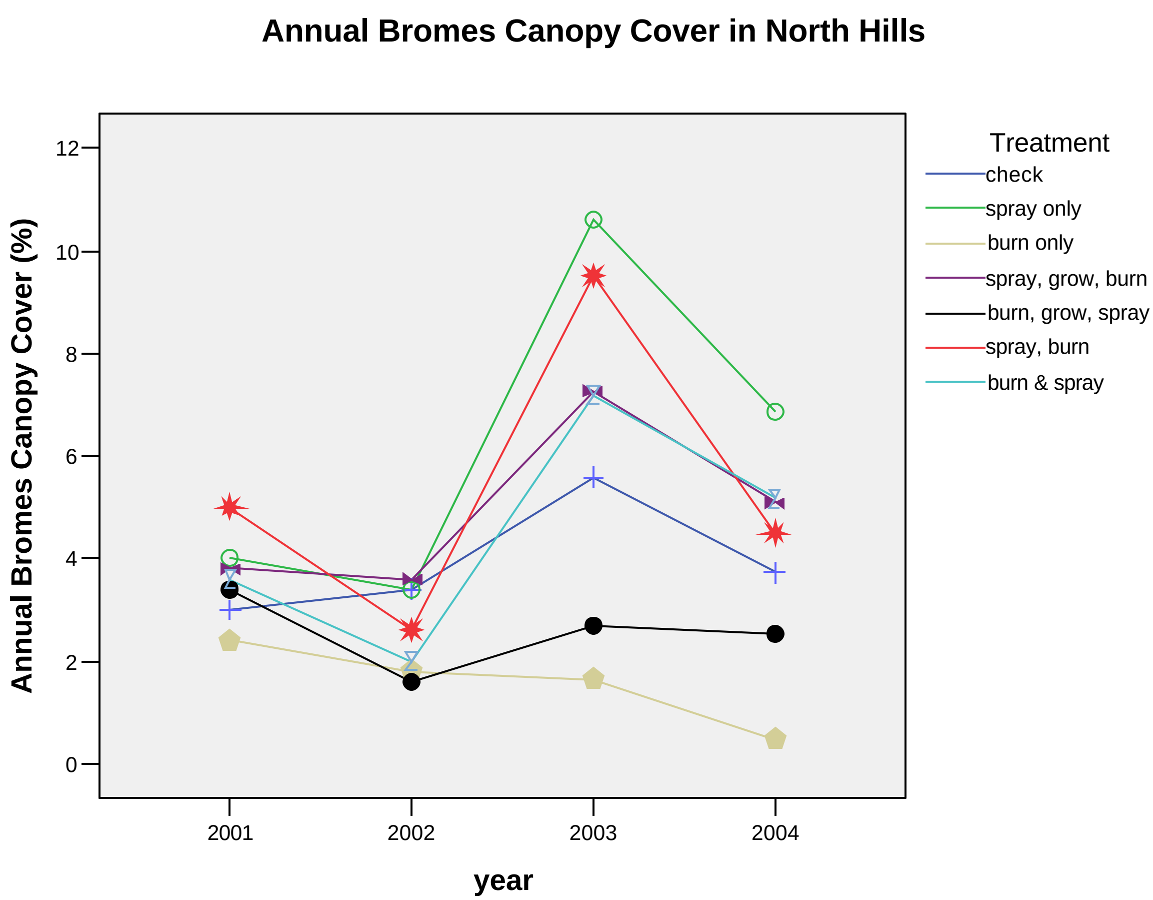


Figure 16. Annual bromes canopy cover in North Hills from 2001 through 2004.

Table 39. Average canopy cover of annual brome grasses at North Hills.

Treatment	Annual Bromes 2001	Annual Bromes 2002	Annual Bromes 2003	Annual Bromes 2004
check	3.0	3.4	5.6	3.7
spray only	4.0	3.4	10.6	6.9
burn only	2.4	1.8	1.6	0.5
spray, grow, burn	3.8	3.6	7.3	5.1
burn, grow, spray	3.4	1.6	2.7	2.5
spray, burn	5.0	2.6	9.5	4.5
burn & spray	3.6	2.0	7.2	5.2
p. treatment effects ANOVA or ANCOVAR	.692	.021[†]	0.687	0.631

p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values
[†]Although the 2002 covariate ANOVA indicated there was significant variation among the seven treatments, no two treatment differences were large enough to be significant.

Community Level Comparisons of Treatments

Block 5 is excluded from the community level analyses of the North Hills site as this block is dominated by introduced rhizomatous grasses such that overall composition is quite different form the other four blocks where remnant native bunchgrasses are still common. Community composition in the North Hills did not vary among treatment sets in 2000 before treatments were initiated (p=.995). However, in the first growing season after treatments there were very highly significant differences among the seven treatments (p<.001) (Table 40). The spray fall 2001 only communities differed greatly from the composition of the check plots (p=.03, effect size .49). Burning in the spring of 2002 did not alter the 2002 composition relative to the check plots, and following spraying in fall 2001 with spring 2002 burning did not result in a community composition that was any different than just spraying the preceding fall.

Table 40. Treatment group community similarity comparisons at the North Hills leafy spurge site in 2002 (without block 5).

Treatments Compared	p	Effect Size
All seven in 2001 (pre-treatment)	.955	-.04
All seven in 2002	<.001	.26
Spray fall 2001 only vs. check in 2002	.030	.49
Burn spring 2002 only vs. check in 2002	.687	-.03
Spray fall 2001 only vs. spray fall 2001, burn spring 2002 in 2002	.815	-.08

Analyses were by Blocked Multi-Response Permutation Procedures.

Community composition differences were also present among the seven treatment sets in 2003 (Table 41). The composition of all five treatments sets that included spraying differed significantly (p<.04) from the check plots with the effect size ranging from .19 to as large as .37. However, among the five treatments that included spraying there was almost no difference in composition (effect size .02, p=.25) indicating that including burning was having a minimal effect on the plant community. Similarly the contrast of burn only in spring 2002 vs. check in 2003 still had a non-significant effect size of only .03.

Table 41. Treatment group community similarity comparisons at the North Hills leafy spurge site in 2003 (without block 5).

Treatments Compared	p	Effect Size
All seven in 2001 (pre-treatment)	.955	-.04
All seven in 2003	<.001	.12
Spray fall 2001only vs. check in 2003	.035	.19
Spray fall 2001, grow, burn spring 2003 vs. check in 2003	.031	.22
Burn spring 2002, grow, spray fall 2002 vs. check in 2003	.030	.37
Spray fall 2001, burn spring 2002 vs. check in 2003	.034	.21
Burn & spray spring 2002 vs. check in 2003	.032	.22
Burn only spring 2002 vs. check in 2003	.295	.03
All five treatments with spraying as of 2003	.250	.02

Analyses were by Blocked Multi-Response Permutation Procedures.

The pattern of composition difference in 2004 among the five treatments that include spraying indicated that herbicide application was still associated with shifts in species composition and abundance relative to check plots (p<.05), and within this group of five treatments the addition of burning did not have an additional affect (p=.494) (Table 42). However, in 2004 the plots that had the burn spring 2002 only treatment now differed significantly (p=.029) to a moderate degree (effect size .12) in composition from the check plot set. This separation of the burn only plots from the check plots is evident in the 2004 ordination diagram (Figure 18).

Table 42. Treatment group community similarity comparisons at the North Hills leafy spurge site in 2004 (without block 5).

Treatments Compared	p	Effect Size
All seven in 2001 (pre-treatment)	.955	-.04
All seven in 2004	.002	.09
Spray fall 2001only vs. check in 2004	.030	.19
Spray fall 2001, grow, burn spring 2003 vs. check in 2004	.050	.13
Burn spring 2002, grow, spray fall 2002 vs. check in 2004	.030	.27
Spray fall 2001, burn spring 2002 vs. check in 2004	.031	.26
Burn & spray spring 2002 vs. check in 2004	.044	.12
Burn spring 2002 only vs. check in 2004	.029	.12
All five treatments with spraying as of 2004	.494	.00

Analyses were by Blocked Multi-Response Permutation Procedures.

Ordination With Habitat Type Definition

As with the multi response permutation procedure analysis of community composition of the North Hill plots in the summer of 2001, prior to treatment initiation, these plots did not form any similar grouping by planned treatment groups (Figure 17). Table 43 contains the treatments codes for the ordination graphics. The ordination also reveals that the North Hills plots are drastically dissimilar from the Mueggler and Stewart definition plots for the bluebunch wheatgrass/Sandberg bluegrass habitat type. As of 2004 there was some progression towards the habitat type definition but none of the North Hills plots had a composition within that definition sphere. The check plots are least similar with the burn only plots falling between the check plots and those treatment sets which included spraying.

Table 43. Treatment codes for plots at the North Hills leafy spurge site.

Code	Treatment
1	Check
2	Spray fall 2001 only
3	Burn spring 2002 only
4	Spray fall 2001, grow, burn spring 2003
5	Burn spring 2002, grow, spray fall 2002
6	Spray fall 2001, burn spring 2002
7	Burn & spray spring 2002
8	Mueggler & Stewart bluebunch wheatgrass / Sandberg bluegrass habitat type

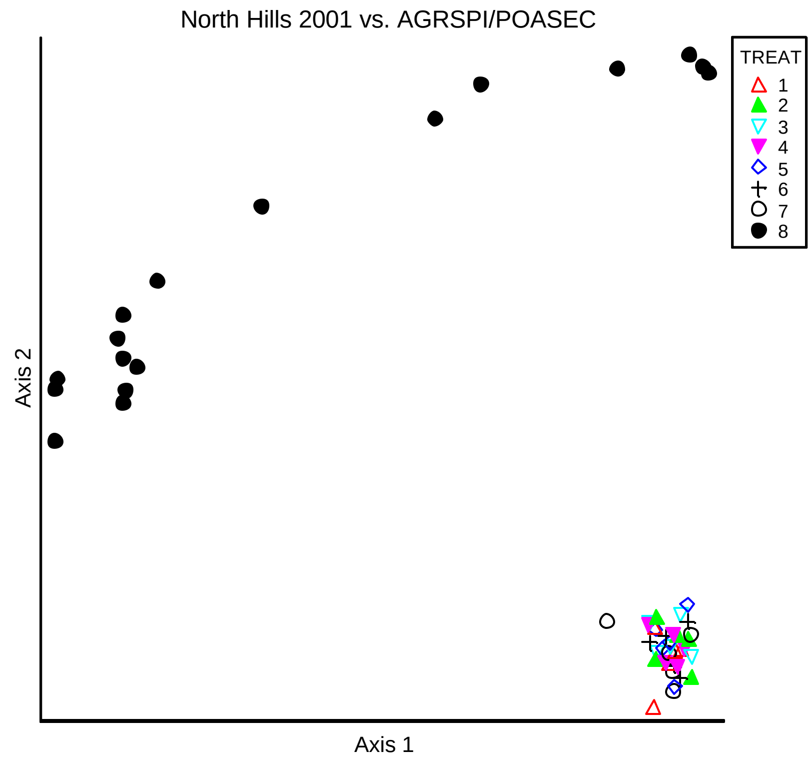


Figure 17. Ordination of pretreatment North Hills plots with Mueggler & Stewart bluebunch wheatgrass/Sandberg bluegrass definition plots (stress 7).

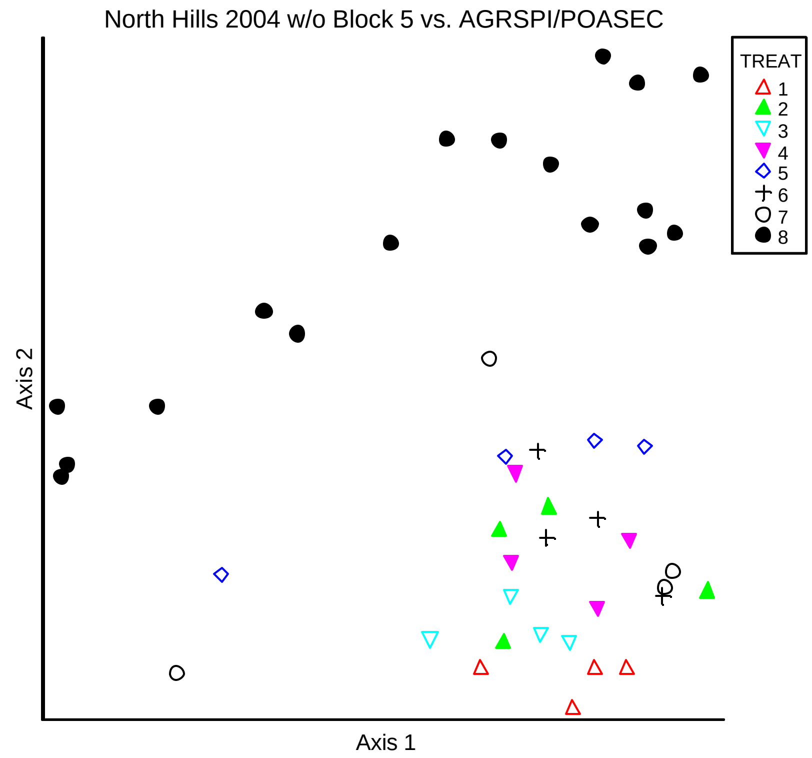


Figure 18. Ordination of 2004 North Hills plots with Mueggler & Stewart bluebunch wheatgrass/Sandberg bluegrass definition plots (stress 13).

Bison Range Dalmatian Toadflax Site Vegetation

Early and rapid greenup of rough fescue at the Bison range site precluded burning in the spring of 2001 so the burning treatments were just done in spring 2002. Accordingly the treatment types/sequences at the Bison Range differ from the other three sites.

Individual Species and Life Form Reponses

The Bison Range site had the highest abundance of native grasses of the four study sites. With still vigorous bunchgrass population the canopy cover of dalmatian toadflax (<4%) and St. Johnswort (<6%) was low but here were many individual weed stems throughout this grassland. Therefore target weed response for the Bison Range is presented as frequency of occurrence. The dalmatian toadflax frequency of occurrence is graphed in Figure 19 from 2000 through 2003 for the six treatments at the Bison Range. Table 44 summarizes these mean dalmatian toadflax frequency of occurrence by treatments across years. Prior to initiation of treatments these means were similar but there were very highly significant differences in post treatment initiation years.

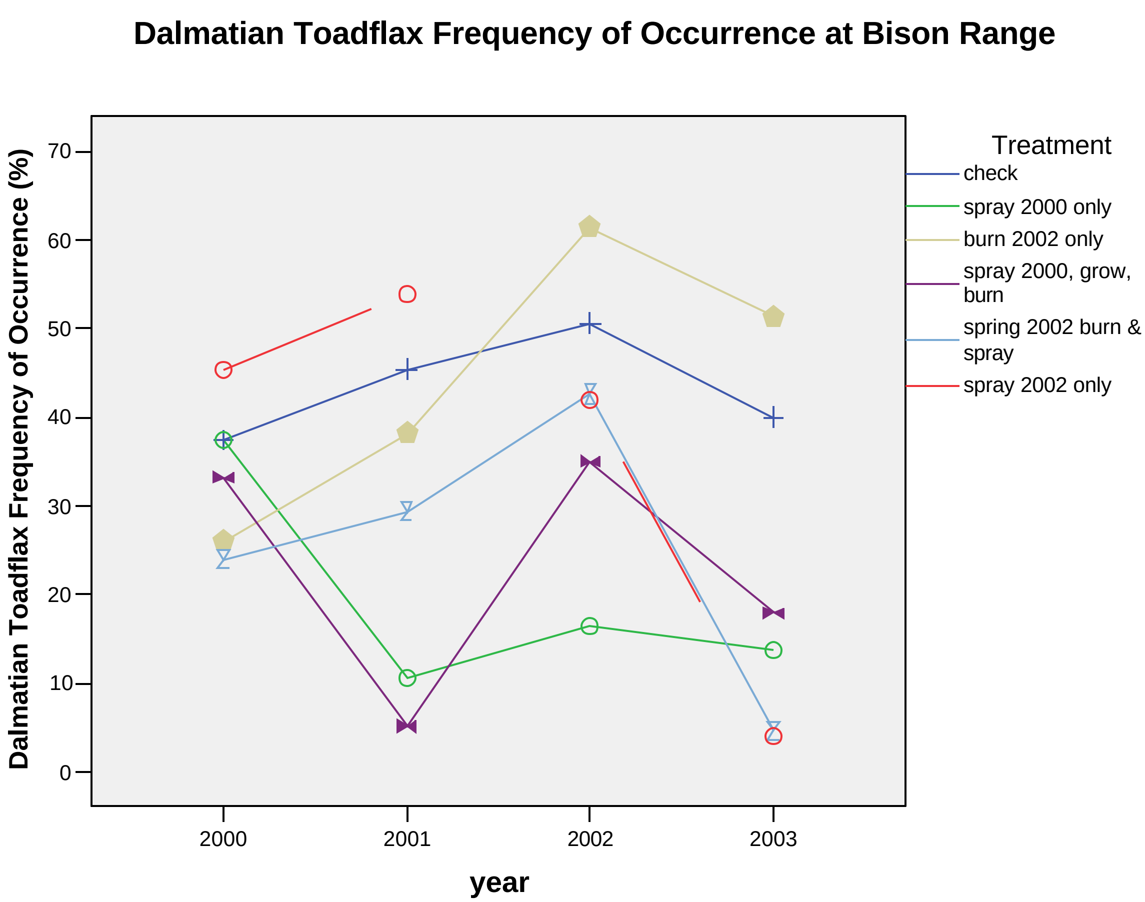


Figure 19. Dalmatian toadflax frequency of occurrence at Bison Range from 2000 through 2003.

Table 44. Dalmatian toadflax frequency of occurrence (%) at Bison Range.

Treatment	LINDAL 2000	LINDAL 2001	LINDAL 2002	LINDAL 2003
Check	37.4	45.4	50.6	40.0
Spray fall 2000 only	37.4	10.6	16.4	13.7
Burn spring 2002 only	26.0	38.2	61.4	51.3
Spray fall 2000, grow, burn spring 2002	33.2	5.2	35.0	18.0
Spring 2002 burn & spray	24.0	29.4	42.6	4.7
Spray spring 2002 only	45.4	53.8	42.0	4.0
p. treatment effects ANOVA or ANCOVAR	0.142	<.001	<.001	<.001

p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

The two treatments sets that were sprayed in fall 2000 had lower frequency of occurrence of dalmatian toadflax in 2001 relative to the check plots ($p<001$) (Table 45). In 2002 the suppression of dalmatian toadflax relative to check plots was still significant ($p<.05$) in the spray fall 2000 only treatment plots, but the mean 35% measured frequency of occurrence in spray fall 2000, grow, burn spring 2002 treatment plots did not differ significantly from the 50.6% frequency of occurrence in the check plot. This 2002 spike appears to be anomalous as the measured frequency of occurrence for in 2003 for the spray fall 2000, grow, burn spring 2002 treatment was again similarly low as other treatment sets that included spraying. The two treatments sets that were burned in the spring of 2002 but were not at least one full growing season post spray did not differ significantly from the check plots. In addition including burning in spring 2002 with spraying in fall 2000 did result in a 2002 frequency of occurrence of dalmatian toadflax that differed from spraying fall 2000 only. In 2003 all four treatment sets that had included spraying had significantly less dalmatian toadflax than the check plots with the greatest suppression in the most recently sprayed treatment sets. The plots that had the spring 2002 burn and spray treatment had the same dalmatian toadflax abundance in 2003 as the plots that were just sprayed in spring 2002.

Table 45. Bonferroni adjusted pairwise comparisons of dalmatian toadflax frequency of occurrence (%) in treatments (n=5) of interest at Bison Range.

Year	Treatment One Frequency	Treatment Two Frequency	p.
2001	Check	Spray fall 2000 only	
	45.4	10.6	<.001
		Spray fall 2000, grow, burn spring 2002	
		5.2	<.001
2002	Check	Spray fall 2000 only	
	50.6	16.4	.048
		Spray fall 2000, grow, burn spring 2002	
		35.0	ns
2002	Check	Burn spring 2002 only	
	50.6	61.4	ns
		Spring 2002 burn & spray	
		42.6	ns
2002	Spray fall 2000 only	Spray fall 2000, grow, burn spring 2002	
	16.4	35.0	ns
2003	Check	Spray fall 2000 only	
	40.0	13.7	.001
		Spray fall 2000, grow, burn spring 2002	
		18.0	.010
		Spring 2002 burn & spray	
		4.7	<.001
		Spray spring 2002 only	
		4.0	<.001
2003	Spray spring 2002 only	Spring 2002 burn & spray	
	4.0	4.7	ns

ns=p>.05
p calculated on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

The St. Johnswort (HYPPER) canopy cover at the Bison Range declined drastically starting in 2001 as it did at the Henry Creek site (Table 46). The frequency of occurrence of St. Johnswort at the Bison Range is graphed in Figure 20 from 2000 through 2003 for the six treatments. Table 47 summarizes these mean dalmatian toadflax frequency of occurrence by treatments across years at the Bison range. Prior to initiation of treatments these frequency of occurrence means were similar but there were very highly significant differences in frequency of occurrence of St. Johnswort among treatments in years after initiation of treatments in spite of the overall decline in canopy cover (p<.001).

Table 46. Decline of St. Johnswort (HYPPER) canopy cover (%) in check plots at the Bison Range and Henry Creek.

Site & Treatment	HYPPER 2000	HYPPER 2001	HYPPER 2002	HYPPER 2003
Bison Range check	6.0	2.0	1.0	0.8
Henry Creek check	9.0	5.8	1.2	0.1

St. Johnswort Frequency of Occurrence at Bison Range

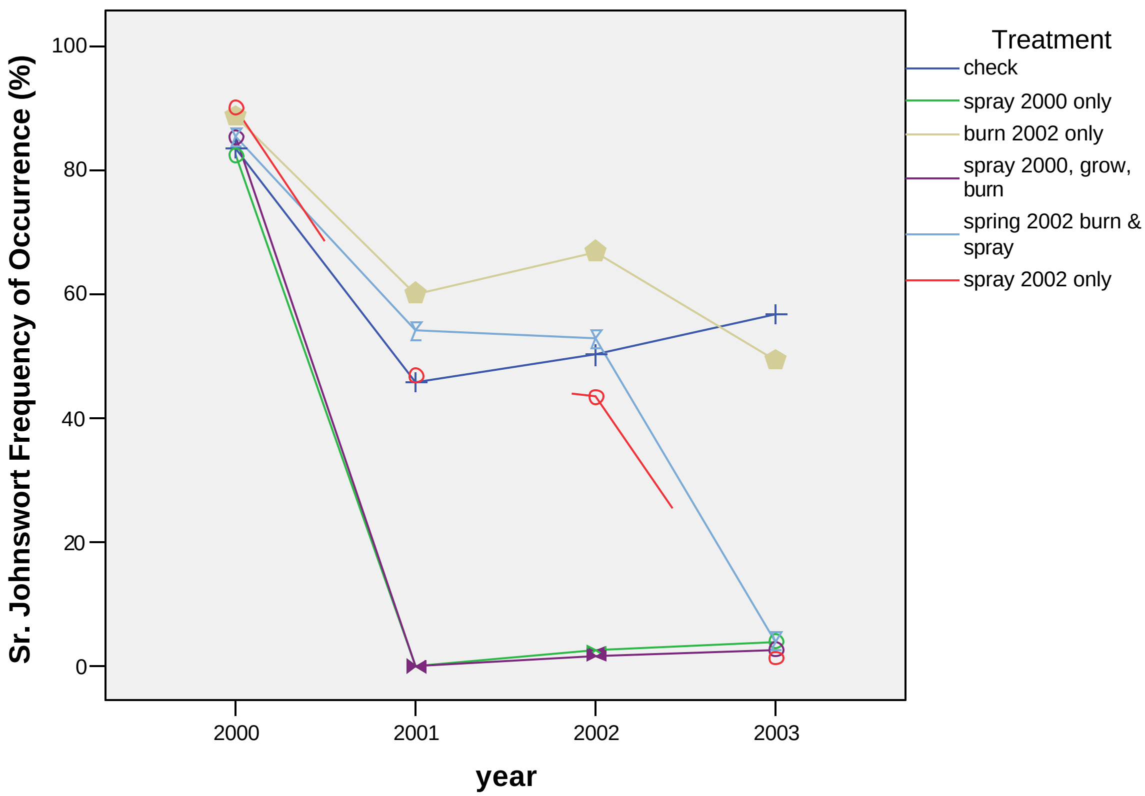


Figure 20. St. Johnswort frequency of occurrence at Bison Range from 2000 through 2003.

Table 47. St. Johnswort frequency of occurrence (%) at Bison Range.

Treatment	HYPPER 2000	HYPPER 2001	HYPPER 2002	HYPPER 2003
Check	83.4	45.8	50.2	56.7
Spray fall 2000 only	82.3	0.0	2.5	4.0
Burn spring 2002 only	88.6	60.0	66.8	49.3
Spray fall 2000, grow, burn spring 2002	85.2	0.0	1.8	2.7
Spring 2002 burn & spray	85.2	54.0	52.8	4.0
Spray spring 2002 only	90.0	46.8	43.4	1.3
p. treatment effects ANOVA or ANCOVAR	0.632	<.001	<.001	<.001

Spraying in the fall of 2000 totally suppressed St. Johnswort at the Bison Range site in 2001 (Table 48). In the second growing post spray there was some reemergence of St. Johnswort on the plots that had been sprayed in fall 2000 but this 2002 regrowth was much less than that on the check plots (p<.001). Burning in spring 2002 did not result in 2002 St. Johnswort frequency of occurrence that was any different than the check plots. Burning in spring 2002 addition to having sprayed in fall 2002 did not change the low 2002 frequency of occurrence resultant from just spraying in fall 2000. In 2003 frequency of occurrence was quite low in all treatment sets that had been sprayed in either fall 200o or spring 2002 and this suppression was very highly significant relative to the check plots. Burning in spring of 2002 in addition to spraying in spring 2002 did not result in a response that differed from just spraying in spring 2002.

Table 48. Bonferroni adjusted pairwise comparisons of St. Johnswort frequency of occurrence (%) in treatments (n=5) of interest at Bison Range.

Year	Treatment One Frequency	Treatment Two Frequency	p.
2001	Check	Spray fall 2000 only	
	45.8	0.00	.001
		Spray fall 2000, grow, burn spring 2002	
		0.00	.001
2002	Check	Spray fall 2000 only	
	50.2	2.5	<.001
		Spray fall 2000, grow, burn spring 2002	
		1.8	<.001
2002	Check	Burn spring 2002 only	
	50.2	66.8	ns
		Spring 2002 burn & spray	
		52.8	ns
2002	Spray fall 2000 only	Spray fall 2000, grow, burn spring 2002	
	2.5	1.8	ns
2003	Check	Spray fall 2000 only	
	56.7	4.0	<.001
		Spray fall 2000, grow, burn spring 2002	
		2.7	<.001
		Spring 2002 burn & spray	
		4.0	<.001
		Spray spring 2002 only	
		1.3	<.001
2003	Spray spring 2002 only	Spring 2002 burn & spray	
	1.3	4.0	ns

ns=p>.05

p calculated on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Perennial grass canopy cover at the Bison Range for 2000 through 2003 is graphed in Figure 21. The means are summarized in Table 49. There were no pretreatment differences. In 2001 the two treatment sets that had been sprayed the proceeding fall had the highest perennial grass canopy cover and the overall analysis of covariance was marginally significant (p=.055). Significant differences were realized in 2002 and 2003.

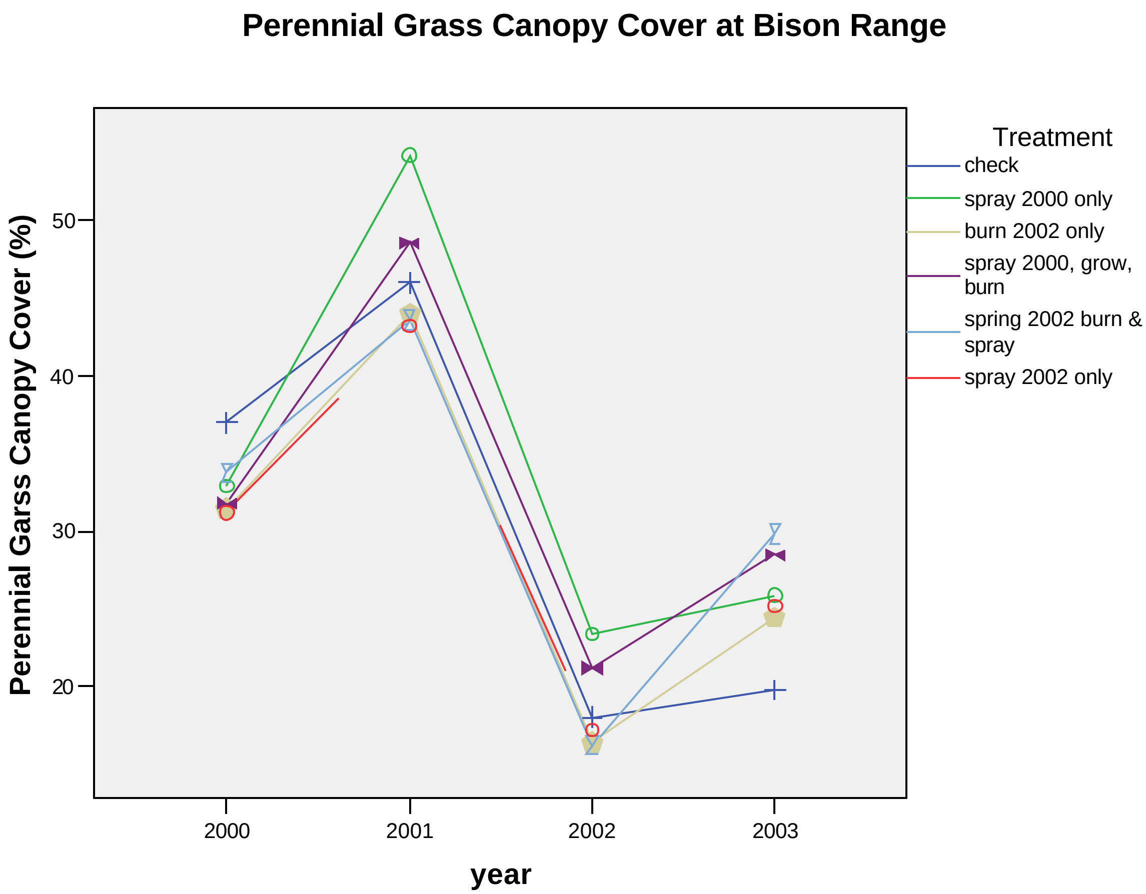


Figure 21. Perennial grass canopy at Bison Range from 2000 through 2003.

Table 49. Perennial grass canopy cover at Bison Range.

Treatment	Per. Grasses 2000	Per. Grasses 2001	Per. Grasses 2002	Per. Grasses 2003
Check	37	46	18	20
Spray fall 2000 only	33	54	23	26
Burn spring 2002 only	31	44	16	24
Spray fall 2000, grow, burn spring 2002	32	49	21	29
Spring 2002 burn & spray	34	44	16	30
Spray spring 2002 only	31	43	17	25
p. treatment effects ANOVA or ANCOVAR	0.270	0.055	0.002	0.032

p based on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

As expected from analysis of covariance for 2001 the Bonferroni comparison of the two treatment sets that had been sprayed the preceding fall did not result in a significant p value for the increased 2001grass growth relative to the check plots. In 2002 comparison of the spray fall 2000 only treatment increased perennial grass cover relative to the check plots was significant (p=.009), but the smaller measured increase in spray fall 2000, grow, burn spring 2002 was not. The perennial grass canopy cover on the two other treatment sets that were burned in spring 2002 (burn spring 2002 only, spring 2002 burn & spray) did not differ from the check plots. Likewise there was no burn effect in 2002 indicated by the contrast of spray fall 2000, grow, burn spring 2002 with spray fall 2000 only. A less restrictive LSD pairwise comparison of covariate adjusted 2002 rough fescue canopy cover in spray fall 2000 only plots (16.0%) vs. the spray fall 2000, grow, burn 2002 treatment set (11.0%) suggested that the spring burn may have reduced rough fescue growth in that growing season immediately after the spring burn (p=.023). No other relevant pairwise comparisons suggested a significant perennial grass burn effect. In 2003 the check plots had the least canopy cover of perennial grasses (20%), but only the spring 2002 burn and spray treatment was significantly higher than the check and the contrast of spring 2002 burn and spray with spring 2002 spray only was not significant suggesting there was no burn effect as of 2003.

Table 50. Bonferroni adjusted pairwise comparisons of perennial grass canopy cover in treatments (n=5) of interest at Bison Range.

Year	Treatment One Canopy Cover	Treatment Two Canopy Cover	p.
2001	Check	Spray fall 2000 only	
	46	54	ns
		Spray fall 2000, grow, burn spring 2002	
		49	ns
2002	Check	Spray fall 2000 only	
	18	23	.009
		Spray fall 2000, grow, burn spring 2002	
		21	ns
2002	Check	Burn spring 2002 only	
	18	17	ns
		Spring 2002 burn & spray	
		16	ns
2002	Spray fall 2000 only	Spray fall 2000, grow, burn spring 2002	
	23	21	ns
2003	Check	Spray fall 2000 only	
	20	26	ns
		Spray fall 2000, grow, burn spring 2002	
		29	.068
		Spring 2002 burn & spray	
		30	.030
		Spray spring 2002 only	
		25	ns
2003	Spray spring 2002 only	Spring 2002 burn & spray	
	25	30	ns

ns=p>>.05; p calculated on estimated marginal means as corrected by pre-spray year covariate but tabled means are observed values

Annual bromes canopy cover is graphed in Figure 22 for 2000 through 2003. The means are summarized in Table 51. Overall significant differences were not measured until 2003 (p=.001) (Table 51), when burn spring 2002 only plots had more canopy cover (0.35%) of annual bromes than check plots (0.03%, p=.005) and more than the spring 2002 burn & spray plots (0.02%, p=.002) (Table 52). We do not consider these small canopy cover values to be of ecological importance.

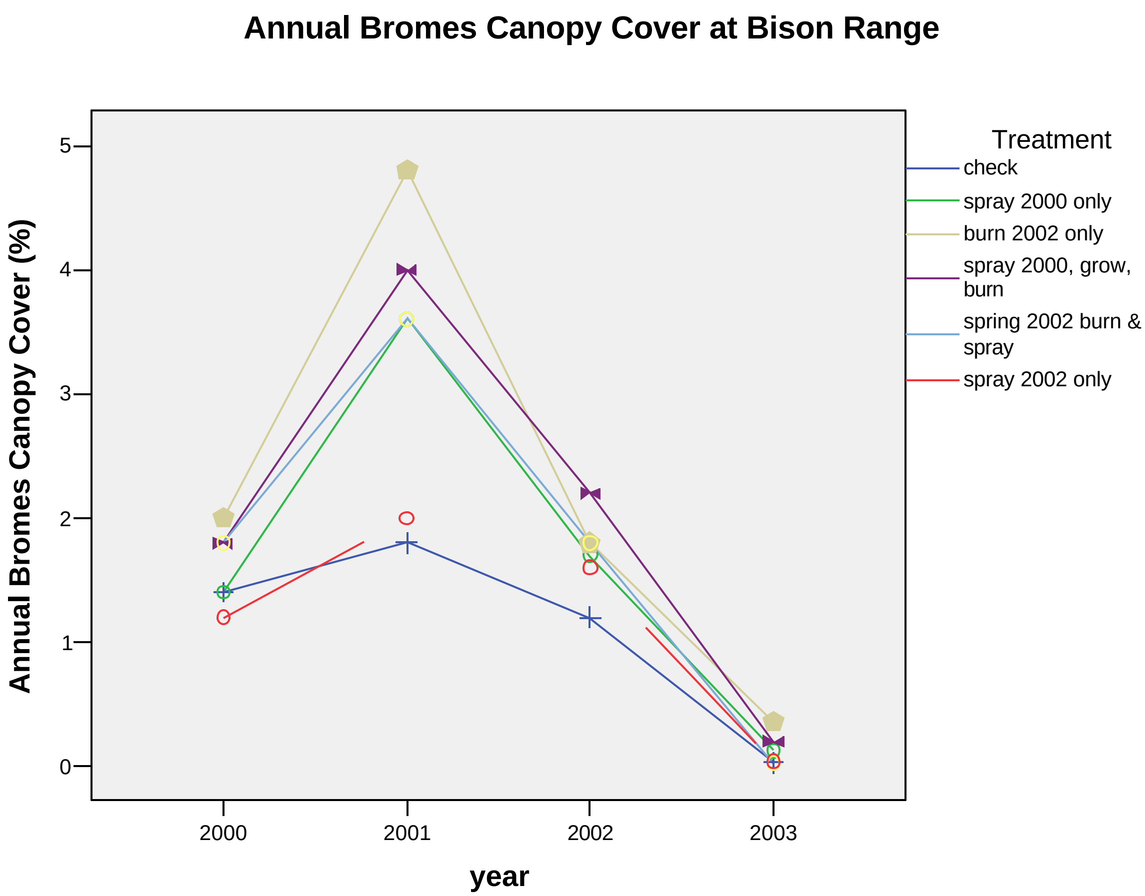


Figure 22. Canopy cover of annual bromes at Bison range from 2000 through 2003.

Table 51. Average canopy cover of annual bromes at Bison Range.

Treatment	A. Brome 2000	A. Brome 2001	A. Brome 2002	A. Brome 2003
Check	1.40	1.80	1.20	0.03
Spray fall 2000 only	1.40	3.60	1.70	0.12
Burn spring 2002 only	2.00	4.80	1.80	0.35
Spray fall 2000, grow, burn spring 2002	1.80	4.00	2.20	0.20
Spring 2002 burn & spray	1.80	3.60	1.80	0.02
Spray spring 2002 only	1.20	2.00	1.60	0.04
p. treatment effects ANOVA or ANCOVAR	0.684	0.199	0.615	0.001

p based on estimated marginal means of log (X+1) as corrected by pre-spray year covariate but tabled means are observed values

Table 52. Bonferroni adjusted pairwise comparisons of annual bromes canopy cover in treatments (n=5) of interest at Bison Range.

2003	Check	Spray fall 2000 only	
	0.03	0.12	ns
		Spray fall 2000, grow, burn spring 2002	
		0.20	ns
		Spring 2002 burn & spray	
		0.02	ns
		Spray spring 2002 only	
		0.04	ns
		Burn spring 2002 only	
		0.35	.005
2003	Burn spring 2002 only	Spring 2002 burn & spray	
	0.35	.02	.002

ns=p>.05

p calculated as estimated marginal means of log (X+1) as corrected by pre-spray year covariate but tabled means are observed values

Community Level Comparisons of Treatments

The Bison Range communities did not differ among the treatment plot sets in summer 2000 before initiation of treatments (Table 53). In 2002 significant differences among the six treatments were measured (p,.001, effect size 17). The composition of spray fall 2000 only plots differed from the check plots (p=.027) with an effect size of .17. The burn spring 2002 only plots shifted composition slightly (effect size .10) in comparison to the check plots (p=.047) suggesting a small burn effect. A 2002 community level burn effect was also indicated for the two treatment sets that included burning with spraying. Spray fall 2000, grow, burn spring 2002 vs. spray fall 2000 compositions differed greatly (p=.017, effect size .38), and burn and spray spring 2002 composition differed somewhat from spray spring 2002 only (p=.055, effect size .11). The habitat type indicator rough fescue is the most abundant species at this site. LSD pairwise comparison of rough fescue canopy cover indicates a significant (p= .023) reduction in 2002 growth in spray fall 2000, grow, burn spring 2002 plots estimated marginal mean of 16.0% compared to the spray 2000 only plots estimated marginal mean of 11.0%. Burning reduced the measured 2002 rough fescue canopy cover from ~12% to ~9% on the burn spring 2002 only vs. check plots and the burn and spray spring 2002 vs. spray spring 2002 plots although the p values were only <.26.

Table 53. Treatment group community similarity comparisons at Bison Range dalmatian toadflax site in 2002.

Treatments Compared	p	Effect Size
All six in 2000 (pre-treatment)	.104	.03
All six in 2002	<.001	.17
Spray fall 2000 only vs. check in 2002	.027	.17
Burn spring 2002 only vs. check in 2002	.047	.10
Spray fall 2000, grow, burn spring 2002 vs. spray fall 2000 only in 2002	.017	.38
Burn and spray spring 2002 vs. spray spring 2002 only in 2002	.055	.11

Analyses were by Blocked Multi-Response Permutation Procedures.

In 2003 there also were differences in community composition among the Bison range treatment sets (Table 54). The spray fall 2000 only plots still differed some from the check plots (p=.046, effect size .10). The plots that were treated by spraying only in 2002 differed in comparison from the check plots (p=.027, effect size .19) in 2003. The burn and spray spring 2002 plots also differed significantly from check plots in 2003 (p=.015, effect size .26). However, the separations in 2002 between the three treatment sets that had included burning in comparisons with their no burn pairing were no longer present in 2003, suggesting that the community level burn effect was limited to just the growing season immediately after the early spring burn.

Table 54. Treatment group community similarity comparisons at Bison Range dalmatian toadflax site in 2003.

Treatments Compared	p	Effect Size
All six in 2000 (pre-treatment)	.104	.03
All six in 2003	.003	.11
Spray fall 2000 only vs. check in 2003	.046	.10
Spray spring 2002 only vs. check in 2003	.027	.19
Burn spring 2002 only vs. check in 2003	.572	-.02
Spray fall 2000, grow, burn spring 2002 vs. spray fall 2000 only in 2003	.060	.14
Burn and spray spring 2002 vs. spray spring 2002 only in 2003	.400	.01
Burn & spray spring 2002 vs. check in 2003	.015	.26

Analyses were by Blocked Multi-Response Permutation Procedures.

Ordination With Habitat Type Definition

As with the multi response permutation procedure analysis of community composition the Bison Range plots in the summer of 2000, prior to treatment initiation, did not form any similar grouping by planned treatment groups and their composition was distinctly different from the Mueggler and Stewart definition plots for the rough fescue/Idaho fescue habitat type (Figure 23). Table 55 contains the treatments codes for the ordination graphics. As of 2003 there was progression towards the habitat type definition for most of the plots in all four treatment sets that had included spraying (Figure 24). However the check plots and the burn spring 2002 plot groups were least similar to the rough fescue/Idaho fescue reference standard.

Table 55. Treatment codes for plots at Bison Range site

Code	Treatment
1	Check
2	Spray fall 2000 only
3	Burn spring 2002 only
4	Spray fall 2000, grow, burn spring 2002
5	Spring 2002 burn & spray
6	Spray spring 2002 only
8	Mueggler & Stewart rough fescue / Idaho fescue habitat type

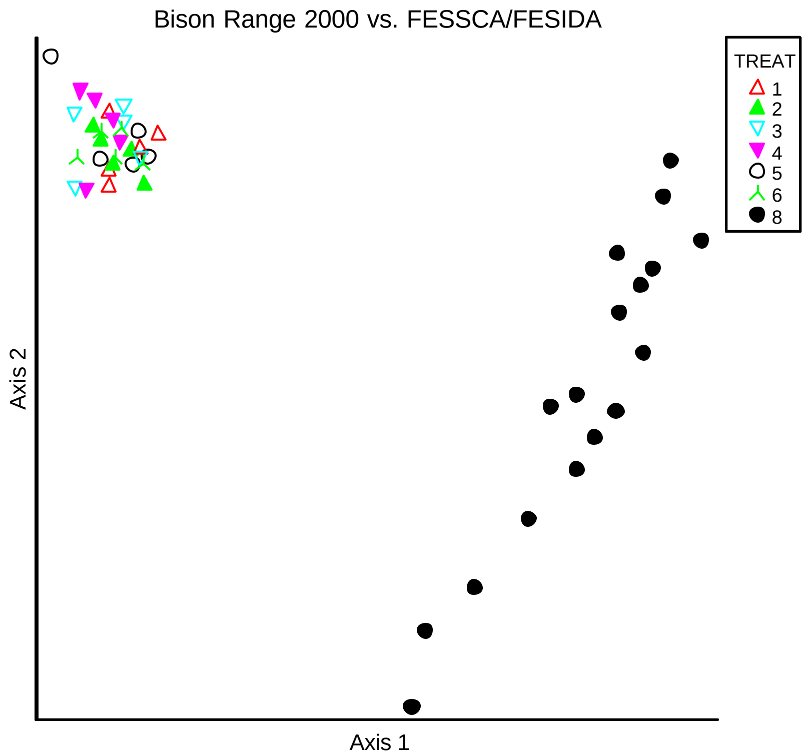


Figure 23. Ordination of pretreatment Bison Range plots with Mueggler & Stewart bluebunch rough fescue/Idaho fescue definition plots (stress 9).

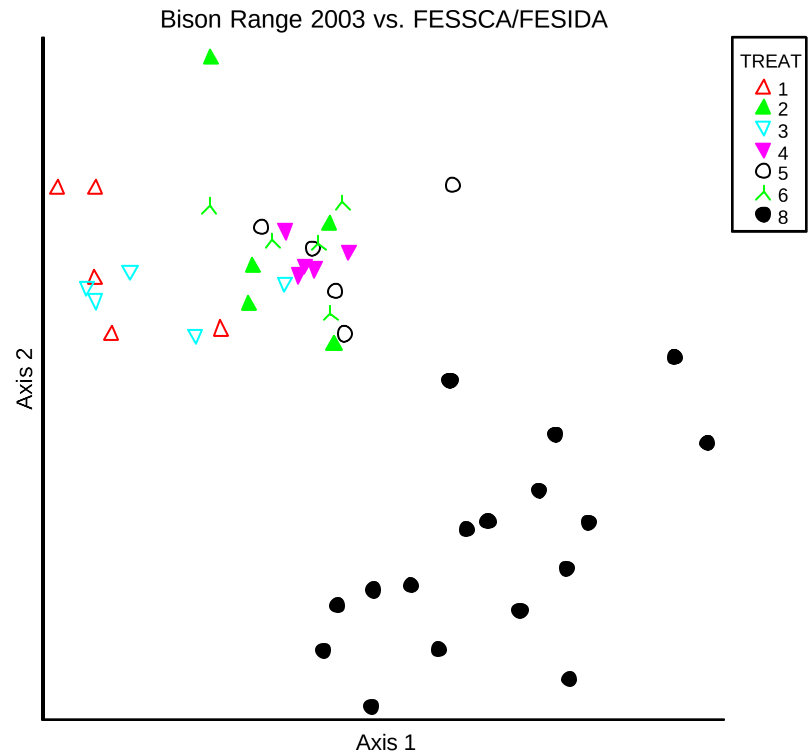


Figure 24. Ordination of 2003 Bison Range plots with Mueggler & Stewart bluebunch rough fescue/Idaho fescue definition plots (stress 10).

Conclusions

Tordon 22K applied at standard rates of 1 pt/ac for spotted knapweed and 1 qt/ac for St. Johnswort and dalmatian toadflax provided near total suppression of canopy cover for three years after the applications. Tordon 22K at 2 qt/ac for leafy spurge provided 83% to 99% canopy cover control in the first growing after spraying, but the leafy spurge began to recover in the second and third growing seasons after spraying such that control only ranged from 14% to 44% in the third growing season after spraying. Perennial grasses, both native bunchgrasses and introduced rhizomatous grasses, responded to the released from the weed competition by increasing canopy cover relative to check and burn only treatments. In some cases the increased perennial grass abundance was not significant until the second growing season after spraying. This delayed rate of post spray expansion of perennial grasses is presumed to a reflection of droughty conditions that prevailed during the period of this study.

Annual brome grass species, primarily cheatgrass, increased significantly in abundance at one of the study sites which was deficient in abundance of remnant perennial grasses and was sprayed at the 1 qt/ac rate. Trends for annual bromes to increase in 2001 for some treatment sets at the first growing season post spray at two other sites which had more remnant perennial grasses were not significant.

The low severity early spring burns implemented in this study did not affect weed abundances during the period of response measurement. Target weed abundance on burn only plots did not differ from target weed abundance on the check plots. Nor did including a spring burn in combination with herbicide application alter weed abundance relative to plots that been only sprayed. However it should be recalled that spraying efficacy was very high. Weed suppression, as measured by canopy cover, approached one hundred percent in most cases for one to three years for all the target weeds except leafy spurge.

The spring burning did suppress rough fescue canopy cover in the first growing season following the burn at the Bison Range site. Many of the rough fescue plants at this site were one foot or more in diameter and the bunch bases contained large amounts of decadent flammable material in addition to the perennating buds. There was a trend for perennial grass growth to be retarded in blocks 1 and 2 at the Blue Mountain site in the growing season immediately after burning. The perennial grasses in these two Blue Mountain blocks are primarily native bunchgrasses that are susceptible to fire injury. Rough fescue, Idaho fescue, and bluebunch wheatgrass were codominants and had 22% combined canopy cover at the initiation of the experiment, while the introduced rhizomatous grasses had less than 0.3% canopy cover. The initial suppression effect of burning on native bunchgrass regrowth at these two sites was not observed in subsequent growing seasons. The abundance of perennial grasses was not affected by the burning at the two other sites. Cheatgrass and other annual bromes abundance was not influenced by these spring prescribed burns at any of the four sites.

The community composition of plots that were sprayed was similar but distinct from check plots at all four sites. At three sites the composition of plots that were just burned did not differ from the check plots and plots that included burning in addition to spraying was similar to plots that had been just sprayed. A burn influence on overall community composition was observed only at the rough fescue dominated Bison Range site and that affect was limited to the growing season immediately after the spring burn.

Prior to treatments the species composition at these four sites differed considerably from their respective Mueggler and Stewart habitat type definition plots. The herbicide spraying made the species composition more similar to the potential natural communities for the plots that still had remnant habitat type indicator bunchgrasses. The sprayed plots that responded with progression towards the habitat type definitions were at the Bison Range and in several blocks at the Blue Mountain and North Hills sites. The three Blue Mountain plots that had co-dominant introduced rhizomatous grass species, the fifth block in the North Hills which was dominated by introduced rhizomatous grasses, and the Henry Creek site which was lacking in indicator bunchgrass species went on floristic trajectories that will not lead to the habitat type definition even with spraying. Adding a burn to the spray treatment did not increase the progression towards the potential natural communities, nor did burning alone foster that restoration goal. In fact burning at the Bison Range site was retrogressive relative to the habitat type definition.

Unfavorable precipitation and temperatures have been suppressing herbaceous growth during the period of this study. Total canopy cover is much less than that measured in the 1971-1973 period when the Mueggler and Stewart plots were sampled. This suppression of total growth may be confounding interpretation of the magnitude of floristic shifts among treatments and particularly relative to the habitat type definitions.

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