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Abstract

Western juniper (*Juniperus occidentalis* spp. *occidentalis*) woodlands are rapidly replacing quaking aspen (*Populus tremuloides*) stands throughout the northern Great Basin. Aspen stands provide important habitat for many wildlife species and contain a high diversity of understory shrubs and herbaceous species. We studied two juniper removal treatments to restore aspen woodlands in Kiger Canyon on Steens Mountain, Oregon. Treatments included cutting 1/3 of the juniper trees followed by; 1) early fall burning (FALL); and 2) early spring burning (SPRING). Because of lack of fuels and high fuel moisture content partial cutting of juniper was done to create a fuels base to carry fire through woodlands. The project has evaluated; 1) the effectiveness of treatments at removing juniper from seedlings to mature trees; 2) monitored aspen recruitment; and 3) measured recovery of shrub and herbaceous cover and diversity. Fall burning eliminated all remaining juniper trees and seedlings, but understory cover and diversity were reduced significantly. By the second year after fire, aspen suckering in the FALL treatment averaged 12,000/ha. Spring burning produced a less intense fire, removing 80% of the mature juniper trees that remained after cutting. However, about 50% of the juniper seedlings survived in the SPRING treatment. Aspen suckering in the SPRING was only 4,000/ha but the understory remained largely intact and herbaceous cover and diversity increased. In conclusion, if the objective is to eliminate western juniper, with minimal cutting, and stimulate greater aspen suckering then we recommend woodlands be fall burned. If the objective is to maintain shrub and herbaceous layers, marginally increase aspen suckering, and retain a few mature junipers in the community, then spring burning is recommended.

Key words: diversity, herbaceous understory, *Juniperus occidentalis*, *Populus tremuloides*, succession.

Introduction

Quaking aspen (*Populous tremuloides*) woodlands are important plant communities in the interior mountain regions of the western United States. Though occupying relatively small areas within vast landscapes, aspen woodlands provide essential habitat for many wildlife species (Maser et al. 1984, DeByle 1985) and contain a high diversity of understory shrub and herbaceous species. Aspen was estimated by Brown (1985) to occupy 2.9 million hectares in the western United States[1] but these woodlands have declined the past century as a result of succession to coniferous forest (Schier 1975, Gruell 1979, Miller and Rose 1995, Bartos and Campbell 1998). Coniferous replacement of aspen negatively impacts water quality and reduces watershed yield (Jaynes 1978, Gifford et al. 1984, Bartos and Campbell 1998), reduces wildlife populations and diversity (Bartos and Mueggler 1980), and often results in decreased shrub-understory production and diversity (Kranz and Linder 1973, Bartos and Mueggler 1981 & 1982).

Most aspen decline has been documented in the Rocky Mountain States (Bartos and Campbell 1998). Only recently has the decline been described in the Great Basin (Miller and Rose 1995, Wall et al. 2001). Wall et al. (2001), in an extensive survey of aspen in southeast Oregon, northwest Nevada, and northeast California, reported significant stand replacement and/or encroachment by western juniper (*Juniperus occidentalis* spp. *occidentalis*) into aspen woodlands. The primary factor for the replacement of aspen by juniper and other

[1] Northern New Mexico and Arizona, Utah, Colorado, Wyoming, Montana, South Dakota, Idaho, Nevada, and eastern Oregon.

conifer species has been the lack of fire the past 100-150 years (Wall et al. 2001). In south-central Oregon, fire return intervals ranged from 12 to 22 years prior to 1897 (Miller and Rose 1999). They also reported that since 1897 no fires have been recorded in their study area and the last major fire took place in 1870.

The purpose of this study was evaluate two juniper control treatments to restore aspen stands in Kiger Canyon, Steens Mountain, Oregon. Because of a lack of fine fuels and high fuel moisture content partial cutting of juniper was performed to create a fuels base to carry fire through the woodlands. Treatments include: cutting 1/3 of mature juniper trees followed by early fall burning (FALL); and cutting 1/3 of the juniper followed by early spring burning (SPRING). The project evaluated; 1) the effectiveness of treatments at removing juniper from seedlings to mature trees; 2) measured aspen recruitment; and 3) measured recovery of shrub and herbaceous cover, density, and diversity. We hypothesized that partial cutting of juniper combined with fall burning would be more effective at removing juniper trees and seedlings, and result in greater aspen recruitment than the SPRING prescription. We also hypothesized that shrub and herbaceous understory cover and species richness would recover more quickly and be greater in the SPRING compared to the FALL prescription within the first two growing seasons after treatment.

Methods

Study Site

The study site was located in Kiger Creek Canyon on Steens Mountains, southeast Oregon. Kiger Creek is a main tributary in the Donner und Blitzen watershed that drains into the Malhuer-Harney Lake system. The aspen research area stretches along 2.5 km within the canyon, at elevations ranging from 1645 to 1830 meters. Aspen stands were found at the base of the toe-slopes and in pockets and draws in the uplands. There was little evidence of aspen having grown in close proximity to the stream because dead wood and/or aspen suckering were not noticeable in these areas. The aspen communities along toe-slope positions and uplands have been reduced in area and density as indicated by large numbers of dead aspen in the form of trunks and large branches lying on the ground. Individual aspen stands were small, averaging about 0.6 ha in size. Few mature aspen remained within stands, with most aspen relegated to the subcanopy. Western juniper dominated all original aspen stands. Juniper began establishing in these stands in the 1860's with steady increases up to the 1940s (Miller and Bates 2000). Trees establishing prior to 1940 were dominant in the overstory. Since the 1940's juniper has increased significantly in density and has fully stocked these stands. Juniper woodland successional development in these communities were rated as being in late to closed stages according to criteria developed by Miller et al. (2000). The understory was dominated by Kentucky bluegrass (*Poa pratensis*).

Treatments

Ten 0.40-ha sized blocks were established in aspen stands in May 2000. A block consisted of three treatments; a untreated control (CONTROL), partial juniper cutting followed by fall prescribed fire (FALL), and partial juniper cut followed by early spring burning (SPRING). Plots were approximately 0.13 ha in size. Partial cutting involved felling one third of mature juniper trees to create a fuels base to carry fire through the stand with the objective of removing remaining live juniper. Livestock were excluded from grazing in the study area in 2001, 2002, and 2003.

In each plot 1/3 of the dominant and subcanopy juniper size classes were marked with blue paint in fall 2000. Marked juniper were cut in winter and spring 2001. Fall burning was applied in the canyon in October 2001 by personnel of the Burns-BLM district. The prescribed fire technique used was a spot head fire using helicopter dropped delayed action ignition devices (DIADS). DIADS were chemically injected ping-pong balls. To prevent ignition in CONTROL and SPRING burning treatments plots were marked with strips of butcher block paper. Marked perimeters were located 100-200 meters from plots requiring protection. Spring burning was applied in April 2002 using drip torches with a 50:50 mixture of unleaded gas and diesel.

Of the original 10 blocks set up we used only 5 for analysis. The aspen plots were included in a landscape level juniper control project encompassing 2850 ha in Kiger Canyon and adjacent uplands. We established 10 blocks because given the fuel characteristics in the canyon, weather, and method of ignition there was the potential that some SPRING and CONTROL plots would be inadvertently burned in the fall applied fire prescription. Of the 10 blocks, SPRING and CONTROL plots in 5 of the blocks were wholly or partially consumed in the fall burn prescription.

Fuel moisture was determined for fine fuels, ground litter and 1-hour fuels (Table1). Soil moisture (0-10 cm) was determined the day prior to fire application. Weather data was recorded on the day of fire application. Fuel loads were not estimated.

Table 1. Weather and fuel moisture conditions for SPRING and FALL prescribed fire treatments.

	FALL	SPRING
Weather		
Air Temp (C°)	14-18 C°	12-18 C°
RH (%)	27-42 %	42-52 %
Wind Speed (kph)	15-20	6-8
Moisture Content		
Soil Moisture (0-10 cm)	11	35
Ground Litter	6	130
Fine Fuels	7	135
1-hr fuels	7	21

Vegetation Measurements

In each plot, three permanent 40 m transects were established (Figure 3). Transects were spaced approximately 10 m apart. Tree and shrub cover were estimated by line intercept along the 40 m transects. Tree density was measured along each transect 3-m on each side of the line. Densities of shrub species, aspen suckers (< 2-m in height), and seedling junipers were measured 1 meter to each side of transect lines. Juniper tree density and cover were separated into three size classes; dominants, subcanopy (< 75% of canopy dominant height), and seedlings (< 1-m in height). Aspen tree density and cover were separated into three size classes; dominants, subcanopy (< 75% of canopy dominant height), and suckers (< 2-m). Shrub species were separated into mature and juvenile categories. Juvenile shurbs were less than 20 cm height and lacking the presence of new or old reproductive stalks, heads, or capsules.

Understory cover was sampled every 3 meters along the transect lines (Figure 4). Cover was visually estimated for plant functional group (perennial grass, annual grass, perennial forb, annual and biennial forb, fern, moss), crust bare ground, rock, juniper litter, and other litter. A species list was compiled for each treatment plot using nomenclature from Hitchcock and Cronquist (1968).

Statistical Analysis

The study was set up as a randomized block design with five replicates of each treatment. A repeated measures analysis of variance (ANOVA) for a randomized block design (N=5) was used to assess year (N=3), treatment (N=3), and the year and treatment interaction for tree density and cover, shrub cover and density, and herbaceous cover and species. Pre-treatment data were analyzed to test for differences among treatments using ANOVA for randomized block design. Cover of herbaceous species and shrubs were also analyzed by year using ANOVA for a randomized block design to assist in explaining interactions. Data was tested for normality using the SAS univariate procedure (SAS Institute, 2001). Data not normally distributed were arcsin-square root transformed to stabilize variance. Back transformed means are reported in the results. Statistical significance of all tests were set at $P<0.05$. Treatment means and their interactions were separated using Fisher's protected LSD procedure when using ANOVAs comparing within year

Results and Discussion

Removal of Juniper

The juniper cutting and prescribed fire treatments resulted in significant reductions in juniper cover and density. Main effects (year, treatment) and the interaction (year x treatment) were highly significant for cover and density for all juniper size classes. Juniper cover was almost completely eliminated by the FALL treatment (Fig 1). In the SPRING juniper cover was reduced by 90% the first year after treatment. Juniper cover increased by 5% in the CONTROL, though the increase was not significant.

In the FALL treatment all dominant and subcanopy juniper were eliminated (Fig 2A & B). The SPRING treatment was effective at removing juniper dominants but was less effective at removing the subcanopy trees. In the SPRING, about 33% of the subcanopy juniper survived the treatment (Fig 2B). Density of seedling juniper was reduced by 95% in the FALL prescription (Fig 2C). The SPRING treatment resulted in the elimination of only 50% of the juvenile junipers. Surviving juvenile juniper in the SPRING may have been higher than is reported as it became difficult to count seedling junipers as a result of increased herbaceous growth.

Differences in the level of juniper mortality between SPRING and FALL treatments was a result of fire severity. Weather during the fire applications did not differ appreciably between the treatments but soil and fuel moisture were higher at the time of the SPRING burn (Table 1). The higher litter and fuel moisture content in the SPRING burn resulted in a less severe fire.

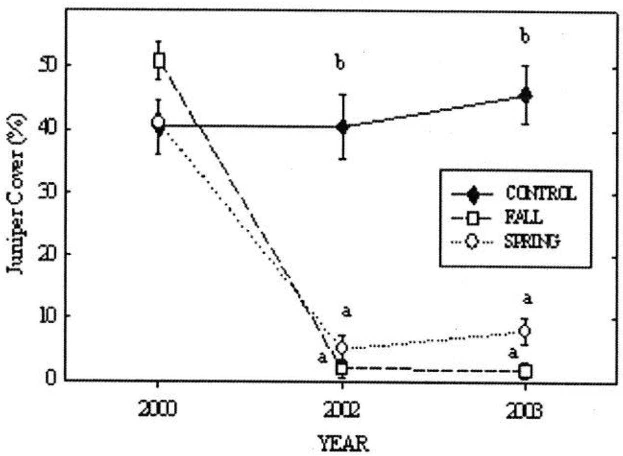

Figure 1: Western juniper cover (%) among the three treatments. Different lower case letters indicate significant differences($p<0.05$) among the treatments by year.

The severity of the fire was indicated by the level of downed juniper material consumed. In the SPRING only needles and small branches were consumed. In the FALL treatment, on average, all downed juniper material but the trunks were fully consumed.

Ground Cover Dynamics

Main effects (year and treatment) and the interaction showed significant treatment differences for ground cover response variables and herbaceous diversity. Prior to fire application there were no differences in ground cover response variables among the three treatments (Fig 3A). After treatments were applied the SPRING had significantly greater herbaceous cover than FALL and CONTROL treatments in 2002 and 2003 (Fig 3B & C). Both CONTROL and SPRING treatments had greater litter and shrub cover than the FALL in 2002 and 2003. Bare ground and rock increased ($P>0.05$) in the FALL and were greater in the FALL than the two other treatments.

Differences among treatments for ground cover response variables also indicate the severity of the burn prescriptions. In the FALL treatment, fine fuels and litter were completely consumed by the burn and this resulted in the increased level of bareground (Fig 3B & C). Remaining litter in the FALL consisted of charred wood from cut juniper. Although shrub cover was reduced by the FALL burn, most shrubs in the understory have resprouted and shrub cover is expected to recover in the next several years. Resprouting shrubs mainly consisted

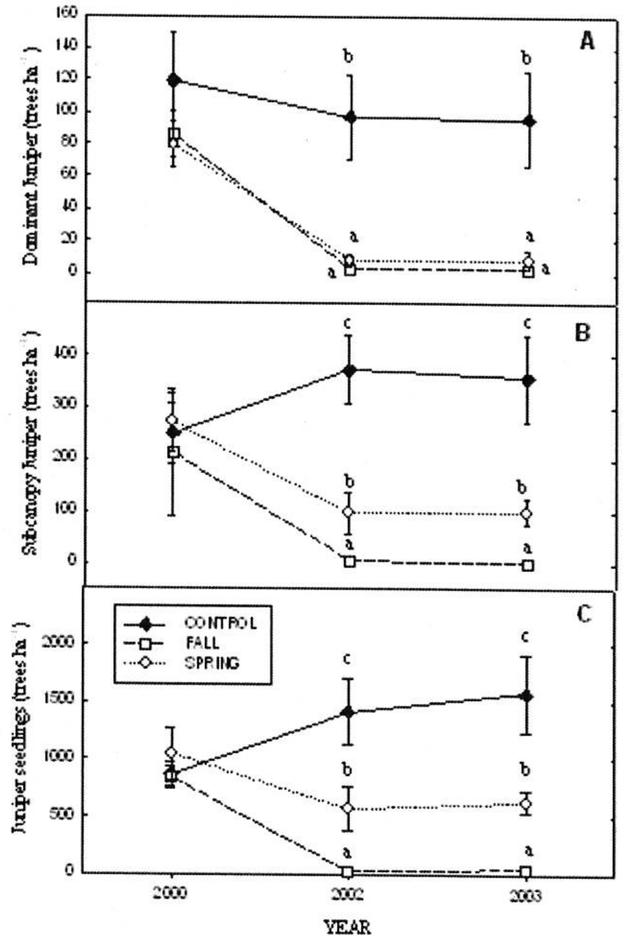

Figure 2: Western juniper tree densities among the three treatments for; A) juniper dominants, B) subcanopy juniper, and C) juniper seedlings. Different lower case letters indicate significant differences ($p<0.05$) among the treatments by year for each response variable.

of mountain snowberry (*Symphoricarpos oreophilus*) and wax currant (*Ribes cereum*). Other shrubs that resprouted, but remained minor components of the shrub layer, included gray and green rabbitbrush (*Chrysothamnus nauseosus* and *viscidiflorus*), golden currant (*Ribes aureum*), elderberry (*Sambucus racemosa*), Wood's rose (*Rosa woodsii*), Oregon grape (*Berberis repens*), and western serviceberry (*Amelanchier alnifolia*). Mountain and basin big sagebrush (*Artemisia tridentata* spp. *vaseyana* and *tridentata*) were eliminated on the FALL treatment.

In the SPRING, because fire intensity was less severe, there was no reduction in the cover of herbaceous and litter response variables the first growing season after treatment (Fig 3B). The rapid increase in herbaceous cover after treatment likely resulted from a combination of factors; 1) release from juniper interference and

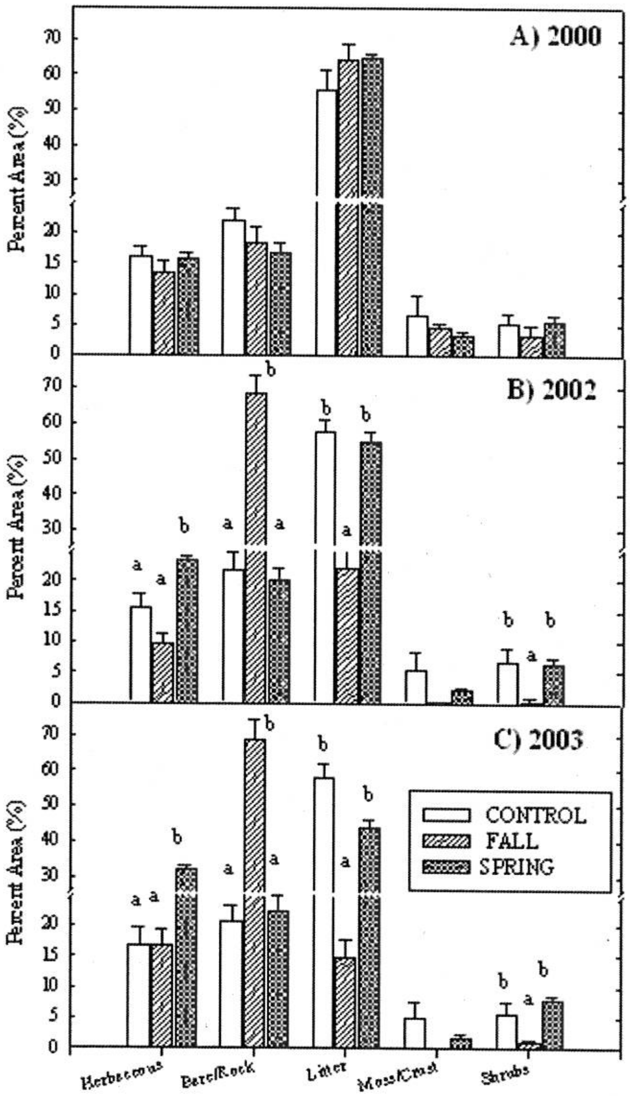

Figure 3: Understory ground cover (%) among the three treatments in; A) 2000, B) 2002, and C) 2003. Values are in means ± one standard error. Different lower case letters indicate significant differences (p<0.05) among the treatments by year for each response variable.

increased resource availability (light, water, and nutrients) 2) reduced level of aspen response, and 3) no measurable mortality of herbaceous species. Soil water and nutrients were not measured in this study but elsewhere soil water and nutrient availabilities have been shown to increase following juniper control (Thran and Everett 1987, Everett and Sharrow 1985, Bates et al. 2000 & 2002).

The composition of herbaceous cover and species richness also demonstrated the varying response to juniper treatment (Table 2). Perennial grass cover declined significantly ($p<0.05$) following the FALL treatment, particularly bunchgrasses which were largely eliminated by the fire. Kentucky bluegrass was the only perennial grass remaining in the FALL treatment. Perennial forb cover increased after the FALL applications but was not different than the CONTROL. The FALL application did result in a significant increase ($p<0.05$) in annual forb cover compared to the other two treatments.

In the SPRING prescription perennial grass and perennial forb cover were greater than both other treatments by the second growing season after treatment (Table 2). Kentucky bluegrass remained the dominate grass but other perennial grass species tended to increase slightly in cover. The number of species found was also significantly greater in the SPRING than the other treatments (Table 2). The greater number of species in the SPRING was a result of increased perennial forb richness. In all treatments the number of species declined in 2003. The drop in species numbers we assume was caused by drought conditions that prevailed across eastern Oregon in 2003.

Aspen Recruitment

Aspen cover and recruitment changed significantly among the treatments (Fig 4A & B). Main effects and year and treatment interactions were significant. In both cut and burn treatments there was a large decline in aspen cover compared to the CONTROL the first growing season after treatment (Fig 4A). By 2003, there was no difference in cover among the treatments. However, recovery of aspen cover has been slower in the SPRING than in the FALL treatment.

The treatments caused a shift in the age composition of aspen. In the FALL treatment, aspen cover in 2002 and 2003 was entirely composed of new aspen suckers (Fig 4B). In the SPRING treatment, about 60% of the cover was made up of resprouting aspen, the balance being comprised of mature and subcanopy trees. In the CONTROL, about 75% of total aspen cover was composed of dominant and subcanopy aspen.

The change in aspen composition and response to treatment can be further characterized by the density of new aspen suckers (Fig 4B). Aspen sucker density was been significantly higher in the FALL prescription, in both post-treatment years, than the SPRING. In 2003 aspen sucker density was 2.5 times greater in the FALL than the SPRING. In the CONTROL, sucker density has not changed and was significantly less than both cut and burn treatments by 2003.

DeByle (1984) suggested that sucker densities of greater than 25,000 stems per hectare are probably

Table 2. Herbaceous functional group cover (%) and number of species for the three treatments. Means and standard errors are shown. Different lower case letters indicates significant differences among the treatments by year for each response variable.

Year & Treatment	Perennial Grasses	Perennial Forbs	Annual Forbs	Number of Species
	%	%	%	
2000				
CONTROL	11.1 ± 1.2	4.3 ± 0.9 b	0.8 ± 0.5	27.8 ± 1.3
FALL	10.6 ± 1.4	2.7 ± 0.6 a	0.7 ± 0.4	28.6 ± 0.8
SPRING	10.4 ± 0.7	5.0 ± 0.5 b	0.2 ± 0.1	29.8 ± 0.5
2002				
CONTROL	8.7 ± 1.0 b	6.3 ± 1.6 a	0.5 ± 0.3 a	35.6 ± 1.6 b
FALL	3.3 ± 0.4 a	4.8 ± 1.4 a	1.7 ± 0.4 b	30.4 ± 2.2 a
SPRING	10.8 ± 0.8 b	12.4 ± 1.1 b	0.3 ± 0.1 a	40.6 ± 1.9 c
2003				
CONTROL	8.9 ± 1.2 a	6.1 ± 2.3 a	0.5 ± 0.2 a	25.0 ± 2.6 a
FALL	5.5 ± 1.1 a	6.9 ± 2.6 a	4.2 ± 0.9 b	24.6 ± 2.5 a
SPRING	19.5 ± 0.5 b	12.8 ± 0.4 b	0.4 ± 0.1 a	35.6 ± 1.0 b

required to regenerate aspen where there are wildlife concerns. In our study, aspen stem densities were well below this suggested leveled. We did not record any browsing of aspen suckers by wild ungulates. The lack of animal impacts to aspen may be a result of the fire prescription which was designed to treat a 2700 hectare area. Bartos and Mueggler (1980) suggested that these larger burn areas disperse animals over larger areas, thereby reducing their concentrations on individual sites. Though elk and mule deer frequent the study area they were rarely observed to use this stretch of the canyon. This was surprising given the remoteness of the site and minimal human activity much of the year.

In both SPRING and FALL treatments, post-fire stem densities of aspen were less than has been reported from other studies in the western United States. Burning or clearcutting of aspen stands in the Rocky Mountain states has been reported to increase aspen suckering from between 29,000 to 150,000 stems per hectare (Patton and Avant 1970, Bartos 1979). These values are 4 to 25 times greater than average stem densities reported in our study.

The low aspen suckering response is likely due to several factors. In both treatments aspen presence prior to treatment was scattered or confined to small portions of the plots. After treatments were applied aspen suckering was limited to areas in close proximity to live or fire killed aspen trees. There was no colonization of the open areas by aspen the first two years after treatment application. We expect aspen to reoccupy these areas overtime which would increase suckering response. These areas were previously occupied by aspen as indicated by the presence of aspen stumps and dead wood prior to treatment.

Aspen suckering in the SPRING may have been further limited by presence of live aspen trees and environmental conditions. Farmer (1962) and Schier (1973) reported that apical dominance of mature aspen trees restricts aspen suckering. In the SPRING prescription, survival of 40% of mature and subcanopy aspen stems likely reduced aspen suckering response by means of apical dominance. Because of the lower fire intensity in the SPRING there was no removal of the litter layer and the herbaceous component remained largely unaffected (Fig 3 & Table 2). Herbaceous and litter layers may have insulated soils and limited soil heating in the SPRING compared to the FALL treatment which had a higher proportion of bare ground. Higher soil temperatures are important for increasing cytokinin production in root meristems which stimulates aspen suckering response (Williams 1972).

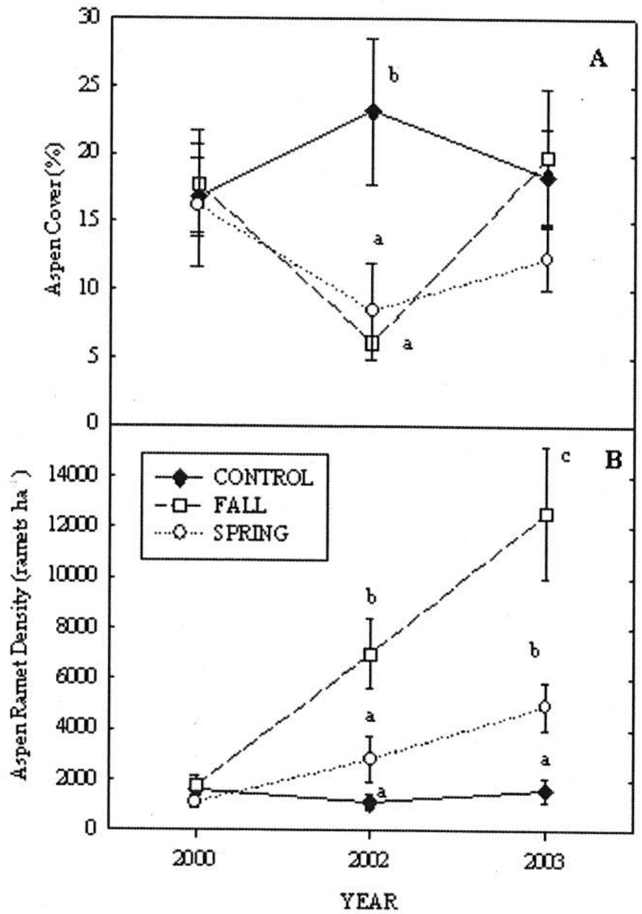

Figure 4. (A) Aspen cover (%) and (B) ramet densities (ramets ha^{-1}) in the three treatments. Data shown are in means ± one standard error. Different lower case letters indicate significant differences ($p<0.05$) among treatments by year.

Management Implications and Conclusions

The expansion of western juniper in the northern Great Basin has not only altered the structure and composition of plant communities but is also influencing fuel load characteristics and fire potentials. Aspen woodlands are already difficult to prescribe burn because of the limited time horizon when fuel moisture conditions and weather are favorable (Jones and DeByle 1985). As juniper occupies these communities, shrub and herbaceous layers, necessary to carry fire through stands, are further reduced (Miller et al 2000).

In this study, selective cutting of juniper to develop ladder fuels to carry fire through decadent aspen stands was highly successful at removing juniper and stimulating aspen suckering when burned in the fall. The SPRING prescription was not as successful at eliminating juniper and stimulating aspen suckering. However, spring burning may be useful in areas where the shrub/understory is depleted and managers desire a more rapid recovery of this vegetation layer.

An advantage of spring burning is the fire application can be confined to the treatment area without risk of escape. Aspen stands in the Great Basin are often intermixed with sagebrush and riparian plant communities. It may be desirable to protect these areas, particularly sagebrush communities because of potential negative impacts to some wildlife such as sage grouse. Spring burning provides the level of control necessary to protect these adjacent plant communities. The results also indicate that cutting combined with spring burning could also be applied in more forested systems to restore aspen and reduce the potential for fire to escape.

There are several disadvantages to a spring burning prescription in aspen woodlands. The areas burned will often be small. If surrounding vegetation communities are not included in the burn area, as was done in this study, there is the potential for wildlife and livestock to concentrate use on these small treated areas. Regeneration of aspen and associated species in the community could be slowed or arrested by excessive foraging use by native and domestic herbivores.

After spring burning, follow up management will be necessary to remove young western junipers that are missed in the initial treatment. In our study, there were enough juniper seedlings present in the SPRING to re-dominate these stands in 70-80 years.

In conclusion, if the objective is to eliminate western juniper, with minimal cutting, and stimulate greater aspen suckering then we recommend woodlands be fall burned. If the objective is to maintain shrub and herbaceous layers, marginally increase aspen suckering, and retain a few mature junipers in the community, then spring burning is recommended.

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