Grazing and Burning Japanese Brome (*Bromus japonicus*) on Mixed Grass Rangelands

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ABSTRACT

Japanese brome (*Bromus japonicus* Thunb.) is an annual cool-season grass introduced from Eurasia that has adapted well to deep soils with deep mulch layers of the central and northern Great Plains. Infestations of Japanese brome have been shown to negatively impact perennial grasses and to decrease seasonal animal gains. Interruption of the Japanese brome life cycle through prescribed spring burning or spring defoliation has been effective in reducing annual brome density or cover, but little information is available that directly compares the two common strategies. The objectives of this study were to 1) compare the effectiveness of annual spring burning and defoliation from early spring grazing to reduce Japanese brome populations, and 2) evaluate trends of vegetative composition and biomass in burned, grazed, and unburned rangelands infested with Japanese brome. Pasture paddocks with a uniform infestation of Japanese brome were assigned to one of the four following treatments: 1) annual prescribed spring burning, 2) early spring and late spring grazing, 3) a combination of annual prescribed spring burning and late spring grazing, and 4) a rested idle control with no vegetative removal. Treatments were applied annually for five years, from 2000 to 2004. Japanese brome density increased and was much greater in the idle control treatments in all years except 2003, when limited winter and early spring precipitation also limited Japanese brome recruitment. Prescribed spring burning resulted in less than 65% litter cover the last three years, while the idle control and the grazed only treatments had over 80% litter cover the last four years. Buffalograss [*Buchloe dactyloides* (Nutt.) J.T. Columbus] composition increased with prescribed

spring burning and grazing in combination, while buffalograss composition was negatively impacted by resting and lack of defoliation. Blue grama [*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths] and sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.] composition differed between years, but was similar between all treatments. A decrease in western wheatgrass [*Pascopyrum smithii* (Rydb.) A. Löve] with spring grazing over time, burned or unburned, was the only adverse effect found on native grass vegetation. Even though treatments were effective in limiting Japanese brome density increase and biomass compared to the idle control, Japanese brome was still present after five years of annual prescribed spring burning, early and late spring grazing, and a combination of burning and grazing, which indicates the difficulty of completely eradicating Japanese brome from ecosystems where it has become a naturalized component.

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Japanese brome (*Bromus japonicus* Thunb.) is an annual cool-season grass introduced from Eurasia that has been naturalized in much of the western and northern Great Plains. Rangelands in the western and northern Great Plains with deep soils and deep mulch layers are particularly conducive to Japanese brome recruitment and growth (Nicholson and Hui, 1993). Japanese brome can negatively impact perennial grasses (Haferkamp, 1997) and seasonal animal gains (Haferkamp et al., 2001). Prescribed burning is an effective measure to reduce annual brome density (Gillen et. al., 1987; Schacht and Stubbendieck, 1985; Whisenant and Uresk, 1990) or cover (Anderson et. al., 1970; White and Currie, 1983) for one to two years following the burn. Haferkamp and Karl (1999) showed that Japanese brome biomass could also be reduced from bi-weekly clipping at 7.5 cm compared to a 15.0 cm residual height. Haferkamp and Karl (1999) also suggest that intensive defoliation at the correct stages in the Japanese brome life cycle can reduce Japanese brome seedling density by reducing seed production as well as by reducing biomass that results in surface mulch that can aid in seed germination. The best time to control an annual brome population with defoliation was found to be approximately one week after seedhead emergence (Finnerty and Klingman, 1962). However, little information is available that directly compares the two common strategies, spring burning and spring defoliation through grazing, to reduce Japanese brome populations. The objectives of this study were to 1) compare the effectiveness of annual spring burning and early spring grazing to reduce Japanese brome populations, and 2) evaluate trends of vegetative composition and biomass in burned, grazed, and unburned rangelands infested with Japanese brome.

MATERIALS AND METHODS

Research was conducted at the Kansas State University Ag. Research Center - Hays from 2000-2004. Pasture used for this study consisted of a lowland terrace native rangeland site with big bluestem (*Andropogon gerardii* Vitman), western wheatgrass, blue grama, sideoats grama, and buffalograss as the main native grass species. Japanese brome was the most common introduced species and was uniformly dispersed across the pasture, with an average density across treatments of 1084 plants m^{-2} before any spring treatments were applied in 2000. Pastures had been used predominately for continuous summer and late fall grazing and had not been burned for at least 20 years prior to this experiment. Experimental units consisted of 12 pens each measuring 15 m by 26 m and surrounded by high tensile electric fencing. Pasture management systems were compared for their ability to manipulate Japanese brome populations on mixed grass rangelands and included the following management strategies: 1) annual prescribed spring burning, 2) early spring and late spring grazing, 3) a combination of annual prescribed spring burning and late spring grazing, and 4) a rested idle control with no vegetative removal. The four pasture treatments were replicated three times for a total of twelve experimental units. Two steers ranging from 225 to 295 kg were stocked the second or third week of April in each early grazing treatment unit for five days. The early spring grazing treatments were also stocked 4-5 weeks later in May or early June with one steer for five days for a season total of two defoliation periods. Residual height of available forage was at or below 10 cm after each grazing period. The early prescribed spring burning treatments were also applied in early April. The early prescribed spring burned and grazed treatment was burned in early April and was also grazed in May or June at the same time as the grazed only treatment. Prescribed burning was performed on individual units, and burning was completed on all units within two hours of onset during all five years. Conditions were conducive to uniform and complete burns all years except in 2001 when green growth of Japanese brome in one replication of the burned only treatment was adequate to prevent a uniform burn across the entire experimental unit and created small patches of unburned area. Borders of each experimental unit were mowed and wetted prior to burning, and a ring fire technique was used to complete each burn. All burns were performed between 10:00 a.m. and 12:00 p.m. with environmental conditions consisting of temperatures between 4 and 15 ^{o}C, winds between 9 and 27 km hr^{-1}, and relative humidity between 60 and 82 percent.

Four permanent plot locations were established in each of the 12 experimental units. Each March prior to application of management strategies, Japanese brome plant density was counted from a 0.10 m^2 frame at each permanent plot location. In mid to late June, following the grazed period of the burned and grazed treatments and following the second grazing period of the early spring grazing treatments, Japanese brome plant density was counted again from the permanent plot locations in each unit. At peak standing crop in mid July each season, vegetative composition was estimated from ten 0.2 m^2 frames from each unit using the dry-weight-rank method using unweighted multipliers (Gillen and Smith, 1986) to estimate the proportion of Japanese brome biomass in the stand. Furthermore, litter cover (1999-2004) and plant basal composition (2000-2004) was estimated along two permanent transects spanning each unit by using the modified step point technique at 0.33 m intervals along each transect each season (Owensby, 1973). Each transect consisted of 66 random points. Litter and composition data were transformed using *arcsin* √*proportion*, and results of statistical analysis were similar to non-transformed data which are presented. Biomass from each unit was estimated at the end of every growing season by clipping two samples to ground level, each 0.2 m^2. However, in 2004, four samples per unit were hand clipped at the end of the growing season. Residual dry matter at the end of each season was left in tact, except for the winter of 2003 in which the idle treatment had standing dry matter removed to allow an estimate of 2004 current season biomass accumulation at the end of the 2004 growing season. Japanese brome biomass was estimated by multiplying the proportion of Japanese brome in the stand from the dry weight rank procedure with the total biomass clipped from each experimental unit. Management treatment, count date, and year were used as fixed independent variables for analysis of Japanese brome density, while management treatment and year were used as fixed independent variables for all other measured traits. Mixed model procedures of SAS were used for all analyses (SAS, 1996).

RESULTS

Japanese Brome Density

A significant treatment X count date X year interaction (P= 0.033) resulted for Japanese brome density, so data were sorted by year and re-analyzed. In 2000, Japanese brome density had a significant treatment X count date interaction (P=0.048). Both the burned and the burned and grazed combination treatments had lower Japanese brome density in June following treatment, while the idle and the grazed only units had similar Japanese brome density before and after treatment (Table 1). In 2001, only the main effect of treatment differed, with all burned or grazed treatments having reduced Japanese brome density compared to the idle control (P= 0.021). Japanese brome had quite favorable precipitation conditions for germination and survival in both the fall of 2000 and the spring of 2001 (Table 2), and it showed by the very high density found in all treatments at the first count date in the spring of 2001. In 2002, the same treatment trend occurred as in 2001 (P= 0.001), but count date also differed (P= 0.020). The first count date had much greater Japanese brome density than the second count date (Table 1). Much above normal precipitation in September of 2001 resulted in great numbers of Japanese brome seedlings in the fall of 2001 that overwintered into the spring of 2002. The extremely dry conditions in the spring of 2002 reduced survivability of these seedlings, which was noticed in the difference between count dates of the idle control treatment for 2002 (Table 2). The seedlings that did survive in all treatments resulted in plants that remained small in stature and accumulated almost no measurable biomass through the spring of 2002. Japanese brome density did not differ between treatments or count dates in 2003. Five months (November 2002 through March 2003) of negligible precipitation limited Japanese brome recruitment for the spring of

2003 in all treatments (Table 2). In 2004, Japanese brome density differed between treatments (P= 0.029). The idle control had greater Japanese brome density than all other management treatments. Both treatments that included prescribed spring burning had 1566 to 1668 plants m^{-2} less Japanese brome density than the grazed only treatment (Table 1), but the burned and grazed treatments were not statistically different at the P< 0.10 level. Five months (October 2003 through February 2004) of negligible precipitation did not reduce seedling recruitment as it did in 2003. Much above normal precipitation in September 2003 and more precipitation in March 2004 helped to increase recruitment in 2004 compared to 2003 (Table 2).

Great variation in March Japanese brome density occurred depending on seasonal precipitation, and March Japanese brome densities were four times greater in the last year than in the first year of the study for the idle and the grazed only treatments (Table 1). However, early and late spring grazing significantly reduced Japanese brome density in 2004. March and June Japanese brome densities were rather similar for the burned and the burned and grazed combination treatments during the first and the last years of the study, showing that the total Japanese brome population had not decreased over time (Table 1). However, compared to the non-grazed idle control, early spring grazing management, prescribed spring burning, and a combination of prescribed spring burning and grazing have limited Japanese brome population growth following five seasons of treatment.

Litter Cover

Proportion of ground covered by litter was sampled at the end of the growing season the year prior to treatments through 2004. Proportion of litter cover had a significant treatment X year interaction (P< 0.0001), and increased from 1999 to 2001 in all treatments (Fig. 1). From 2001 to 2004, litter cover maintained 2001 levels in the idle control and the grazed only management treatments. From 2001 to 2003, proportion of litter cover decreased in the burned and the burned and grazed combination treatments. Litter cover increased again from 2003 to 2004 in both treatments with prescribed burning. Litter in the burned and grazed combination treatment in 2004 was equal to levels measured in 2000. Although the burned only treatment increased in litter cover from 2003 to 2004, proportion of litter cover in 2004 was much lower than levels measured in 2000 or 2001.

Vegetative Composition

Buffalograss basal composition declined in all treatments from 2000 to 2001 (Fig. 2). Buffalograss composition remained lower from 2001 to 2004 in the idle treatment. In the grazed only treatment, buffalograss composition was similar at the beginning of the experiment in 2000 and the end of the experiment in 2004. Buffalograss composition increased from 2001 to 2003 in the burned only treatment, but 2004 had similar composition as 2000. In the burned and grazed combination treatment, composition greatly increased from 2000 and 2001 to the last two seasons of the experiment.

In 2001, western wheatgrass composition was similar between all treatments and was reduced from the prior year (Fig. 2). The grazed only and the burned and grazed combination treatments had less western wheatgrass the last four years of the study than during the first year of the study. Following 2001, the burned only and idle treatments increased in western wheatgrass composition. The burned only treatment recovered to levels of western wheatgrass that were similar to the first year. The idle control finished the last three years of the study with more western wheatgrass than any other treatment, and with nearly twice as much western wheatgrass than during the first year.

Western ragweed (*Ambrosia psilostachya* DC.) proportion declined from 2000 to 2001 in all treatments and was rarely found in 2001 (Fig. 3). Starting in 2002, western ragweed had a greater increase in composition in the burned only treatment than the other three treatments. The last three years of the study, composition proportions were similar to starting proportions of 2000 in all treatments.

Sedges (*Carex* spp.) either declined or remained stable in all treatments from 2000 to 2001 (Fig. 3). All treatments except the burned and grazed combination increased in sedge proportion from 2001 to 2002. At the end of 2004, the burned and the burned and grazed combination treatments had less sedge composition than when the study began in 2000. The grazed only treatment finished 2004 with the same sedge composition as when it started in 2000, while the idle treatment was the only treatment with an increase in sedge composition from 2000 to 2004.

Sideoats grama and blue grama composition in each of the treatments was similar over the course of the study. Sideoats grama and blue grama composition did differ by year, and both had their greatest proportions in 2002 and 2004 (Fig. 4). Both gramas had their lowest proportions in 2001 when precipitation and Japanese brome density was greatest. Proportion of big bluestem remained similar from 2000 to 2004 in all treatments (data not shown).

Fall Biomass

Fall dry matter at the end of five seasons was significantly different between treatments ($P = 0.012$) and years ($P = 0.0002$), but no interaction resulted. The idle control and the burned only treatments produced similar residual total biomass across the five years (Fig. 5). The grazed only and the burned and grazed combination management systems also had similar biomass across the five years, and were 750 to 980 kg ha^{-1} less than the treatments without grazing. It appears that early spring grazing was able to reduce Japanese brome populations by utilizing it as a main source of forage in the early and late spring along with the native vegetation.

Biomass of native vegetation (total vegetation minus Japanese brome) was greatest in the burned only treatment (P= 0.085), but did not interact with year (Fig. 5). Year alone did cause differences in native vegetation biomass (Fig. 6), and was positively correlated with annual precipitation (data not shown). Season-long rest in the idle treatment did not reduce Japanese brome density or it's contribution to forage dry matter, and native vegetation biomass did not increase with deferment. Burning alone, or burning and then utilizing the native vegetation as the main source of forage, also reduced the Japanese brome population, while pasture production was maintained even following the annual burns. Except for 2002, when Japanese brome lacked production from dry spring conditions in all treatments, the idle control treatment had greater Japanese brome biomass than any of the other burned or grazed treatments each season (Fig. 7).

DISCUSSION

Burned, grazed, or burned and grazed management strategies had lower Japanese brome densities compared to the idle control in all but one of the five years of this study. Amount of litter is one of the most prevalent factors determining Japanese brome density and persistence, with greater amounts of litter supporting greater Japanese brome germination and survival, especially during dry periods in the fall (Whisenant, 1990). Contrary to the previous finding, intensive but intermittent grazing in the present study reduced Japanese brome density but did not greatly effect litter cover. Heavy, season-long grazing on sites similar to this study greatly reduced mulch accumulation (Hopkins, 1954). Greater litter accumulation and ground cover was found to significantly increase water infiltration into soils at the current site, and also reduced moisture loss due to evaporation (Launchbaugh, 1964; Hopkins, 1954). Continuous season-long grazing was implemented for several years prior to the current study and resulted in heavy Japanese brome composition in the study site. The presence of Japanese brome can influence litter accumulation and litter decay, and thus alters ecosystem properties compared to sites without Japanese brome (Ogle et al., 2003). Prescribed spring burning greatly reduced Japanese brome density, but also reduced litter cover over the five years of the present study through the combustion of already accumulated litter and by preventing early spring standing dead vegetation from contributing to the litter layer. As a result, soil surface conditions were less than ideal for Japanese brome germination and seedling survival in burned areas. A stand of Japanese brome is capable of producing several thousand seeds m^{-2}, so the loss of seedlings and accumulated viable seeds in the litter layer from prescribed spring burning likely helped reduce future production of Japanese brome seeds and served to deplete the soil seed bank.

Early spring wildfire reduced rangeland yield for two seasons following the burn on upland range sites at this location (Launchbaugh, 1964), but prescribed burning three weeks later on a lowland terrace soil resulted in no yield reductions, even with annual burning, in this experiment. Blue grama and sideoats grama composition were not affected by annual prescribed burning. White and Currie (1983) and Schacht and Stubbendieck (1985) also showed mid to late April spring burning did not suppress season yield of blue grama dominated rangelands in northern and central mixed prairie. The only negative effect of annual prescribed spring burning, early and late spring grazing, or a combination of burning and grazing on native grass vegetation in the current study was a reduction of western wheatgrass composition with spring grazing.

Lack of grazing or burning in the idle control treatments resulted in heavy litter accumulation that created ideal conditions for Japanese brome germination and seedling survival. The significantly greater spring density of Japanese brome in the idle control plots shows that litter accumulation and lack of life cycle interruption perpetuate Japanese brome populations. Others have also shown that even well rested rangelands and rangelands in excellent condition can maintain annual brome populations once infested (Robertson, 1971; Svejcar and Tausch, 1991; West et al., 1984).

Haferkamp and Karl (1999) suggested that interrupting the life cycle of Japanese brome may help reduce populations. Even though litter cover under the grazed only treatment remained high during the study, apparently the intensive intermittent grazing was able to interrupt the Japanese brome life cycle enough to reduce seed production. Finnerty and Klingman (1952) suggested that one week following seedhead emergence as the ideal time to defoliate annual brome to reduce the population. The early grazing period would have missed this goal, but the second grazing period utilized for the grazed only treatment and the first grazing period in the burned and grazed combination treatment would have utilized Japanese brome forage after seedhead emergence and prior to seed drop. Therefore, the grazed treatments were likely successful in reducing viable seed. Herbicides at various rates and timing have successfully controlled downy brome for a season, but grazing to remove seedheads in addition to herbicide treatments would result in greater control (Whitson and Koch, 1998). Haferkamp

(2001) also stated that grazing Japanese brome in early spring negatively impacts Japanese brome through seed and litter reduction, but intensively stocking ranges in the time frame necessary to achieve ideal defoliation can be difficult. We were able to closely control timing and duration of intensive defoliation in this experiment.

Japanese brome seed typically remains viable in the seedbank for two to three years, but five years of annual burning and/or intensive defoliation did not completely eradicate Japanese brome from the study site. Schacht and Stubbendieck (1985) observed a great increase in Japanese brome the year following a prescribed burn, which is similar to results observed the year following treatment with herbicides. Unless herbicides are applied for two or more years, Japanese brome will revert to stands as thick as if it had never been treated (Hewlett et al., 1981).

Managers in regions with suitable prescribed spring burning conditions should be able to limit Japanese brome density and biomass with annual burns. Alternatively, the ability to defoliate Japanese brome vegetation in a timely manner to reduce growth and mature seed production was viable to limit overall brome seedling densities compared to the idle control treatment. Although Japanese brome densities were greatly limited in this study by prescribed spring burning and grazing strategies compared to the idle control, persistence of Japanese brome was evident. Pre- and post-treatment densities in the burned only, grazed only, and grazed and burned combination were similar in the first and last year of the study. This could have occurred either through isolated plants escaping the burning and the intensive grazing strategies, or by seed being dispersed into the experimental area through animal, wind, or water transport. This study demonstrated the short-term ability to significantly limit the presence of Japanese brome on rangelands through burning and grazing management compared to idle rest, but also the difficulty in completely eradicating it from the mixed grass community where it has become a naturalized component.

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Table 1. Japanese brome plant density counted in early March prior to management treatments and in mid June following management treatments.

	Treatment	Idle	Graze	Burn	Burn & Graze	Avg.
Year		plants m^{-2}	plants m^{-2}	plants m^{-2}	plants m^{-2}	plants m^{-2}
2000†	March	1128 a	900 abc	1028 ab	1279 a	1084
	June	1207 a	549 abc	311 c	380 bc	612
	Avg.	1167	724	670	830	
2001‡	March	7541	1903	2751	1661	3464
	June	6271	771	2461	971	2618
	Avg.	6906 a	1337 b	2606 b	1316 b	
2002‡ﬀ	March	10345	2573	5025	2483	5107 y
	June	3662	105	463	179	1102 z
	Avg.	7003 a	1339 b	2744 b	1331 b	
2003	March	939	719	240	300	549
	June	634	333	92	108	292
	Avg.	787	526	166	204	
2004‡	March	4740	4323	1043	1046	2788
	June	3679	255	402	196	1133
	Avg.	4209 a	2289 b	723 b	621 b	

† - Within a year, management treatment and count date combination means within or among columns and rows followed by different letters are significantly different at $P<0.10$.
‡ - Within a year, means of management treatments when averaged across count dates followed by different letters are significantly different at $P<0.10$.
ﬀ - Within a year, means of count dates when averaged across management treatments followed by different letters are significantly different at $P<0.10$.

Table 2. Monthly, annual, and long-term average precipitation for Hays, KS, from 2000-2004.

Month	Year 2000	2001	2002	2003	2004	Long-term Average
			(mm)			
January	7	29	13	0	8	13
February	20	41	8	11	17	16
March	108	31	10	56	52	50
April	47	36	55	95	38	55
May	70	171	53	59	39	80
June	33	83	24	114	108	67
July	157	120	65	0	189	96
August	7	47	102	76	45	74
September	18	138	34	164	50	41
October	68	30	77	10	45	36
November	34	13	2	4	20	31
December	4	1	1	11	0	17
Total	572	739	443	599	611	576

Fig. 1. Proportion of ground covered by litter following annual burning, early spring grazing, or both to control Japanese brome on mixed grass rangelands near Hays, KS. Bars are ±1 SE. $LSD_{0.05} = 0.044$.

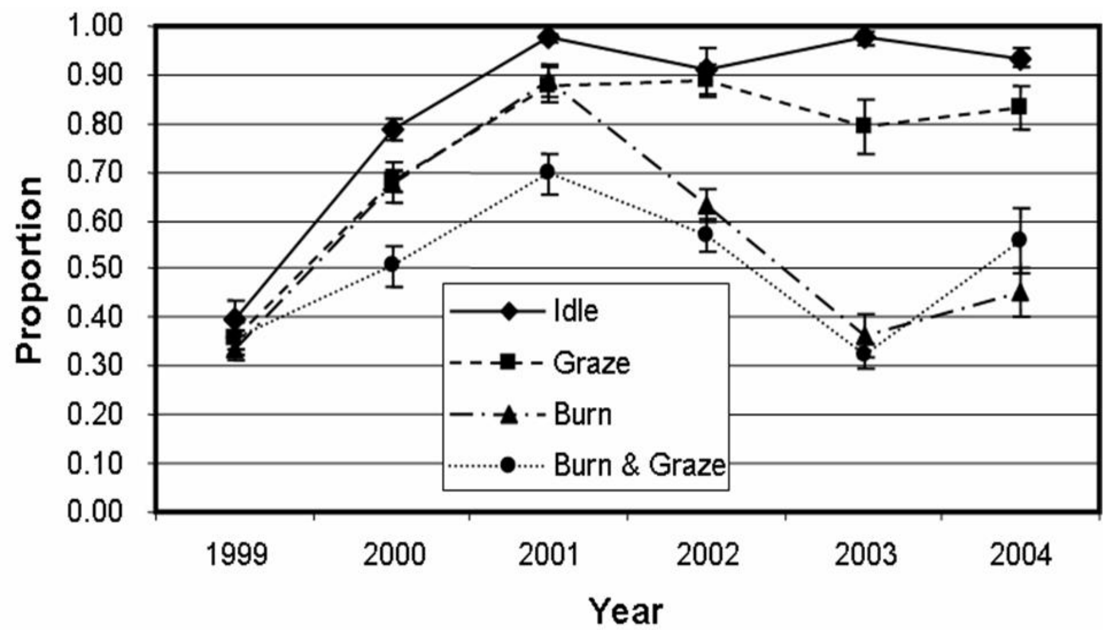

Fig. 2. Proportion of buffalograss and western wheatgrass in mixed grass prairie following annual burning, early spring grazing, or both to control Japanese brome from 2000-2004 near Hays, KS. Bars are ±1 SE. Buffalograss $LSD_{0.05}$ = 0.095; Western wheatgrass $LSD_{0.05}$ = 0.037.

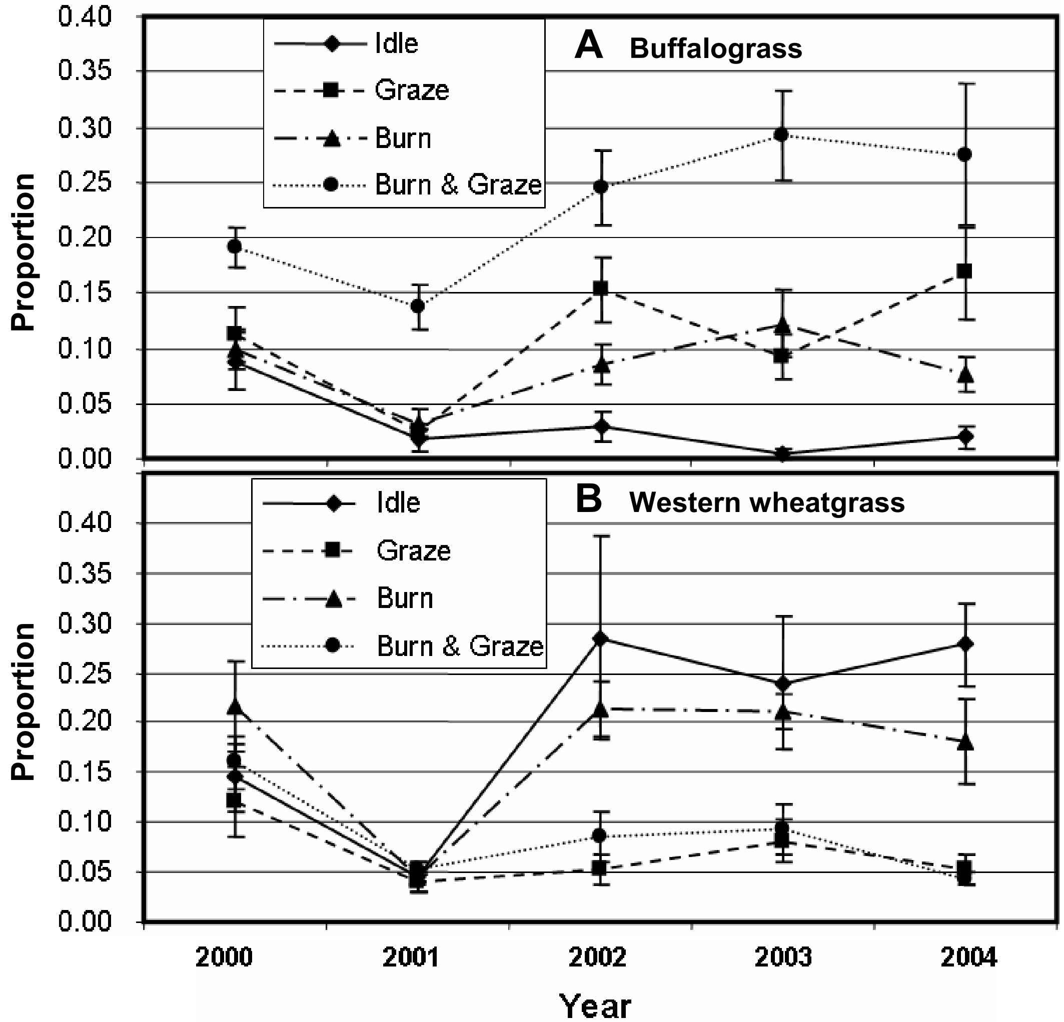

Fig. 3. Proportion of western ragweed and sedges in mixed grass prairie following annual burning, early spring grazing, or both to control Japanese brome from 2000-2004 near Hays, KS. Bars are ±1 SE. Western ragweed $LSD_{0.05}$ = 0.048; Sedge $LSD_{0.05}$ = 0.021.

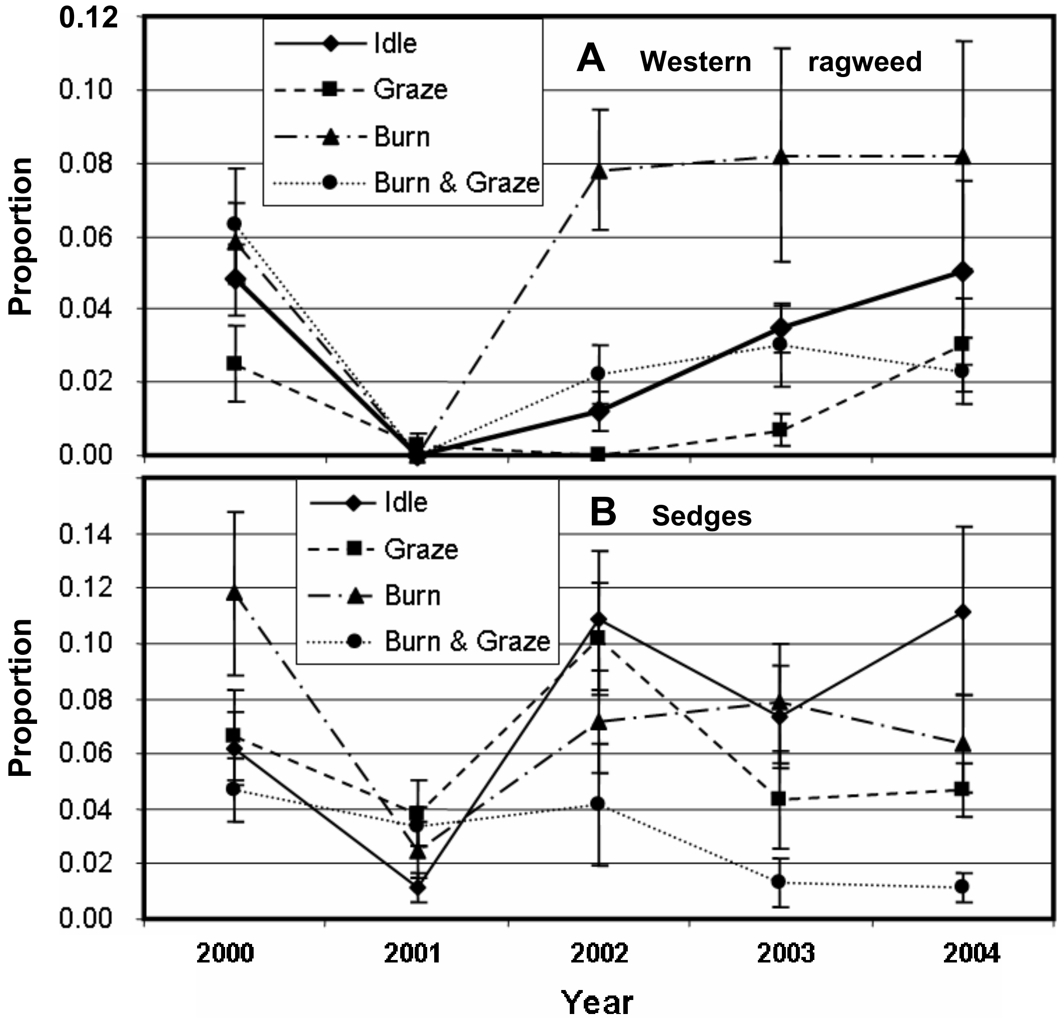

Fig. 4. Proportion of sideoats grama and blue grama in mixed grass prairie averaged across annual burning, early spring grazing, or both to control Japanese brome from 2000-2004 near Hays, KS. Bars are ±1 SE. Bars within a species with different letters are statistically different at the P<0.05 level.

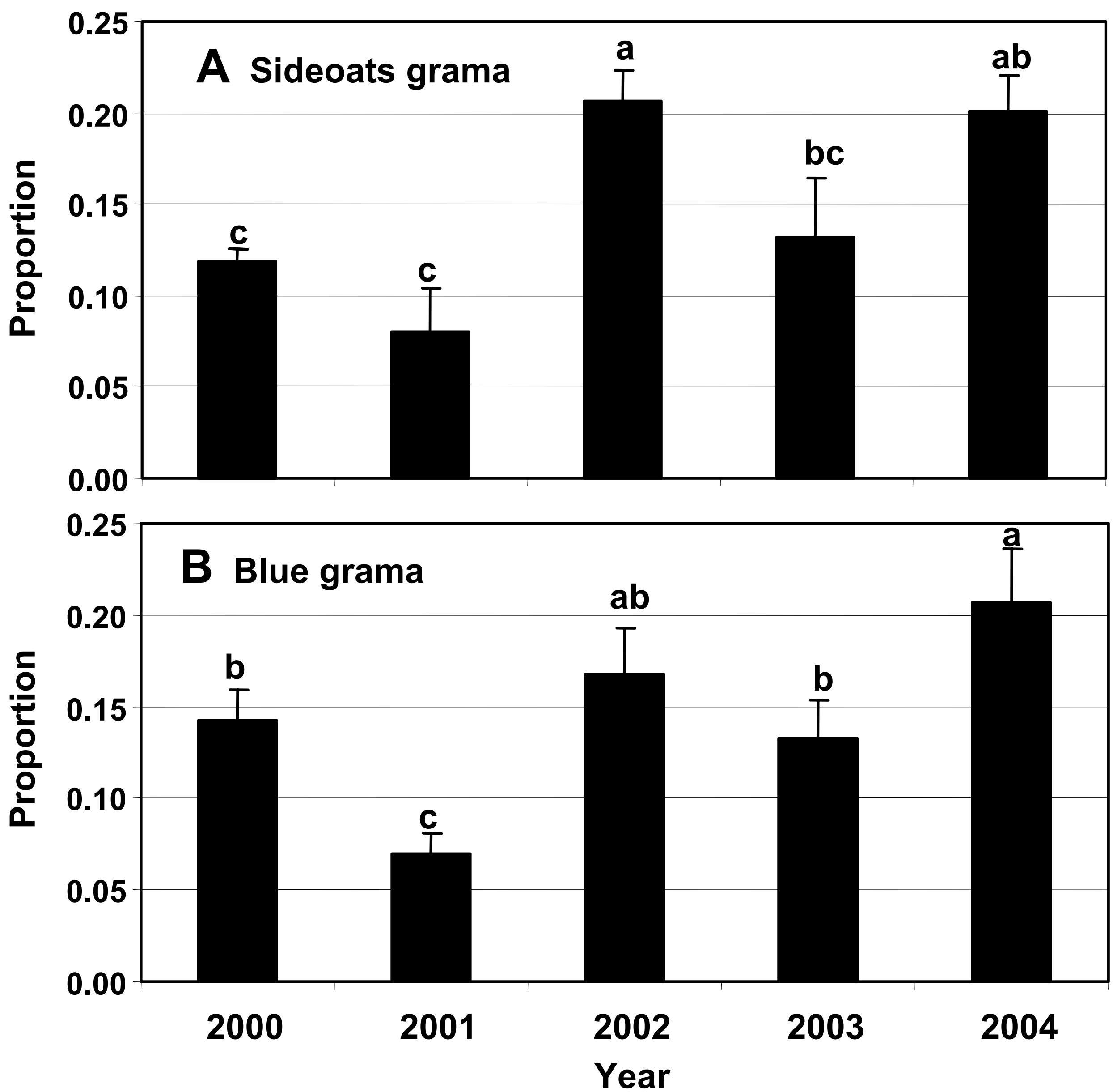

Fig. 5. Fall biomass of total vegetation and native vegetation (total minus Japanese brome) in mixed grass prairie following annual burning, early spring grazing, or both to control Japanese brome from 2000-2004 near Hays, KS. Bars are ±1 SE. Treatments with different letters are statistically different within the total (P= 0.012) and native vegetation (P= 0.085) biomass types.

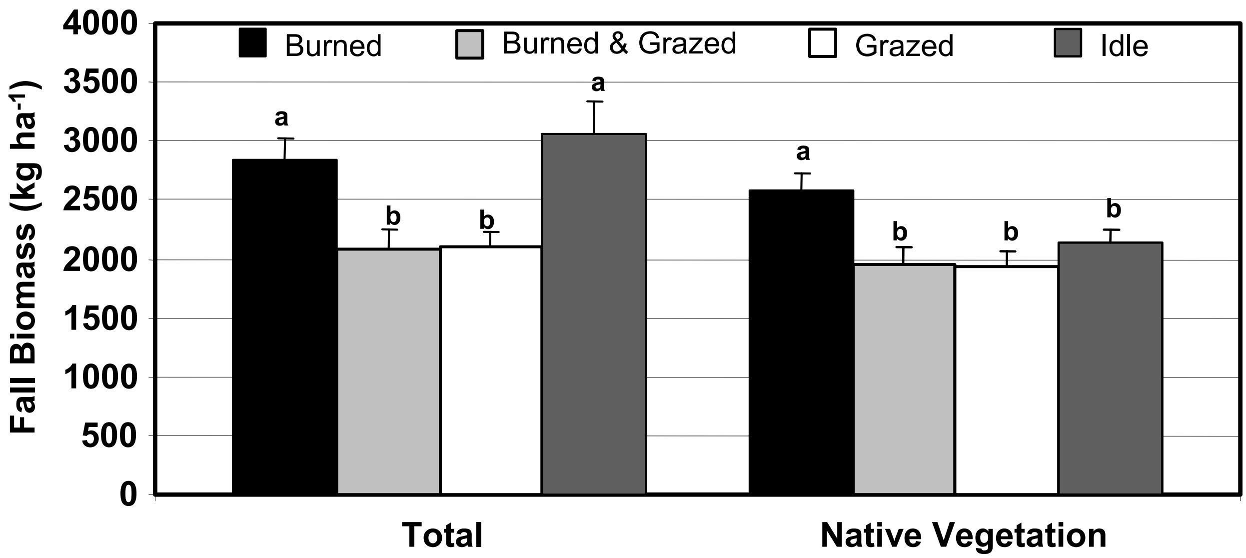

Fig. 6. Fall biomass of native vegetation (total minus Japanese brome) in mixed grass prairie for 2000 - 2004 across all annual burning, early spring grazing, and idle treatments to control Japanese brome near Hays, KS. Bars are ±1 SE. Bars with different letters are statistically different (P= 0.017).

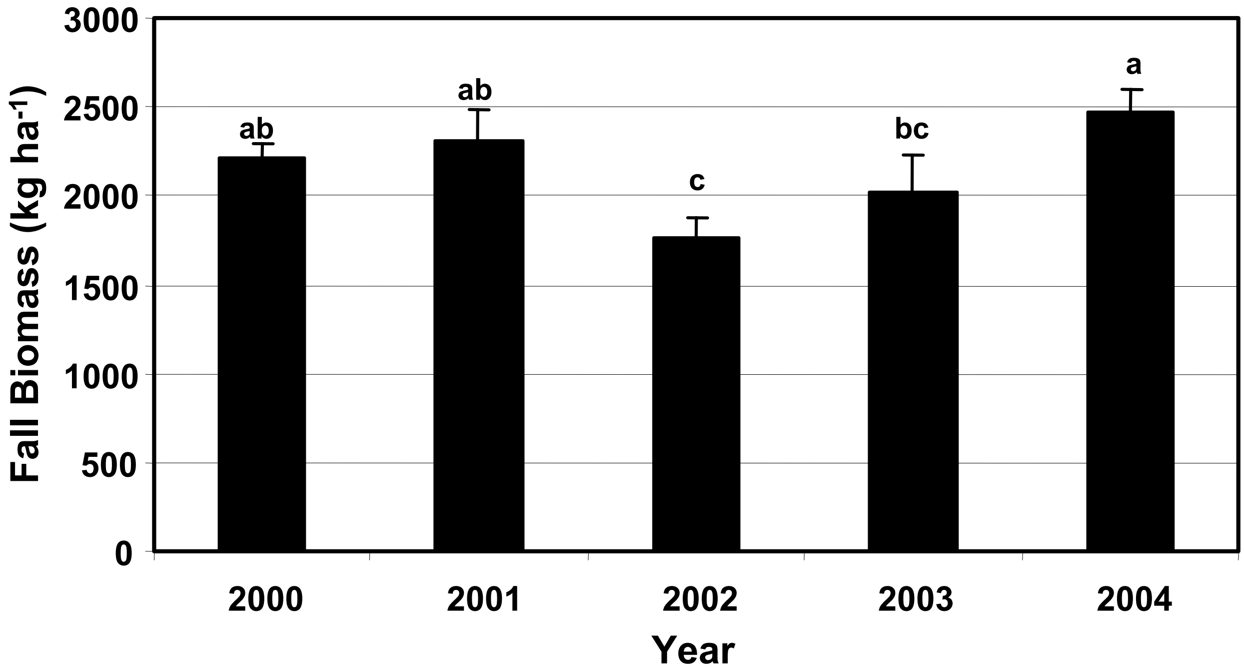

Fig. 7. Biomass of Japanese brome vegetation in mixed grass prairie for 2000 - 2004 after escaping annual burning and early spring grazing near Hays, KS. Bars are ±1 SE. Letters above bars that are different within a year depict statistical significance at the P<0.10 level.