

# Spring burning Japanese brome in a western wheatgrass community

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## Abstract

Plots dominated by Japanese brome (*Bromus japonicus*) and western wheatgrass (*Agropyron smithii*) were burned in Badlands National Park, South Dakota, in April 1983 and/or 1984. Standing crop of all species and tiller densities of the 2 dominant species were determined for 4 years. Burning favored western wheatgrass and reduced Japanese brome tiller density and standing crop for at least 1 growing season. In years where no burning occurred, Japanese brome standing crop and tiller density were dependent on the presence of litter on the soil surface. Burning in April killed Japanese brome seedlings for 1 growing season and reduced subsequent generations by reducing surface litter accumulations, with the effect being greatest when autumn precipitation was below average. April burning reduced the standing crop of green needlegrass (*Stipa viridula*) for at least 3 growing seasons after burning but increased standing crop of buffalograss (*Buchloe dactyloides*) and sand dropseed (*Sporobolus cryptandrus*) for 3 to 4 years after burning. Threadleaf sedge (*Carex filifolia*) standing crop was not significantly affected by burning.

**Key Words:** *Bromus japonicus*, *Agropyron smithii*, *Sporobolus cryptandrus*, *Buchloe dactyloides*, *Carex filifolia*, *Stipa viridula*

Managed natural areas and parks in the northern Great Plains have often excluded fire and livestock. The resulting increased litter accumulations may have been partially responsible for the increased abundance of Japanese brome (*Bromus japonicus* Thunb.). Japanese brome is an exotic, annual grass which has become a common component of many mixed prairie communities. Kirsch and Kruse (1972) hypothesized that reduced fire frequencies—and the resulting higher litter accumulations—following the settlement of the northern Great Plains aided the establishment and spread of Japanese brome.

Year-to-year differences in populations of annual grasses have usually been attributed to different climatic or microenvironmental conditions. For example, plant litter on the soil surface was found to enhance establishment of downy brome (*Bromus tectorum* L.) in Nevada by creating a seedbed environment more conducive to seed germination and seedling establishment (Evans and Young 1970).

Prescribed fire has been suggested as a possible method of reducing Japanese brome abundance. Gartner et al. (1978) stated that burning in the fall, winter, or spring reduced Japanese brome densities for 2 growing seasons in South Dakota. Another study conducted in South Dakota during 2 years with above-average rainfall concluded that fire killed Japanese brome seedling but had little impact on subsequent generations of Japanese brome (Whisenant and Bulsiewicz 1986). Whisenant et al. (1984) stated that Japanese brome seedlings in Texas were killed by fire but popula-

tions returned to unburned levels during the second growing season. A Montana study indicated spring burning resulted in good Japanese brome control for 1 growing season after burning but did not evaluate the treatments in subsequent years (White and Currie 1983). These studies indicate a potential for Japanese brome control during the first post-burn growing season, but do not provide a clear understanding of what happens in subsequent years. A longer-term study which examines the causes of Japanese brome population changes would yield a clearer indication of the effects of burning on Japanese brome.

Understanding the dynamics of Japanese brome populations and using that information to develop burning strategies requires an understanding of the relationships between fire, Japanese brome, precipitation, and plant litter. The primary objective of this study was to determine the relationship between Japanese brome, precipitation, and litter frequency by examining post-burn tiller density and standing crop responses. The secondary objective was to follow standing crop changes. Following these attributes for 3 to 4 growing seasons after fires conducted in different years was an important component of this study. This enabled us to study Japanese brome response to burning under a variety of environmental conditions.

## Study Areas and Methods

### Study Area

The study area was in Badlands National Park in west-central South Dakota. Mean annual precipitation for the study area is about 38 cm. Western wheatgrass (*Agropyron smithii* Rydb.) and Japanese brome were codominants on the study plots. Green needlegrass [*Stipa viridula* (Trin.)], sand dropseed [*Sporobolus cryptandrus* (Torr.) A. Gray], threadleaf sedge [*Carex filifolia* (Nutt.)], and buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.] were less abundant. The soil was a Larvie silty clay (fine, montmorillonitic, mesic vertic Camborthid).

The area had not been cultivated or grazed by domestic livestock for at least 25 years. There were white-tailed deer (*Odocoileus virginianus*), pronghorn (*Antilocapra americana*), bison (*Bison bison*), and a few Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) within the park boundary. Grazing was spread over 415 km<sup>2</sup> and the effects were not apparent on the study site. In this relatively undisturbed area, Japanese brome maintained tiller densities averaging 1,500 m<sup>-2</sup> in a good stand of native, perennial grass (273 western wheatgrass tillers m<sup>-2</sup>).

### Experimental Design and Data Collection

Twelve 5- by 5-m plots were established in a randomized complete block design with 3 replications of 4 treatments. Treatments were: (1) unburned, (2) burned 20 April 1983, (3) burned 16 April 1984, (4) burned 20 April 1983 and 16 April 1984.

Fine-fuel weight and fuel-water contents were determined before each burn by clipping 5, 0.10 m<sup>-2</sup> quadrats, drying at 60° C for 48 hr, and weighing. Air temperature, relative humidity, and instantaneous wind speed were measured with a mercury thermometer, sling psychrometer, and a hand-held wind meter immediately before, during and after each fire.

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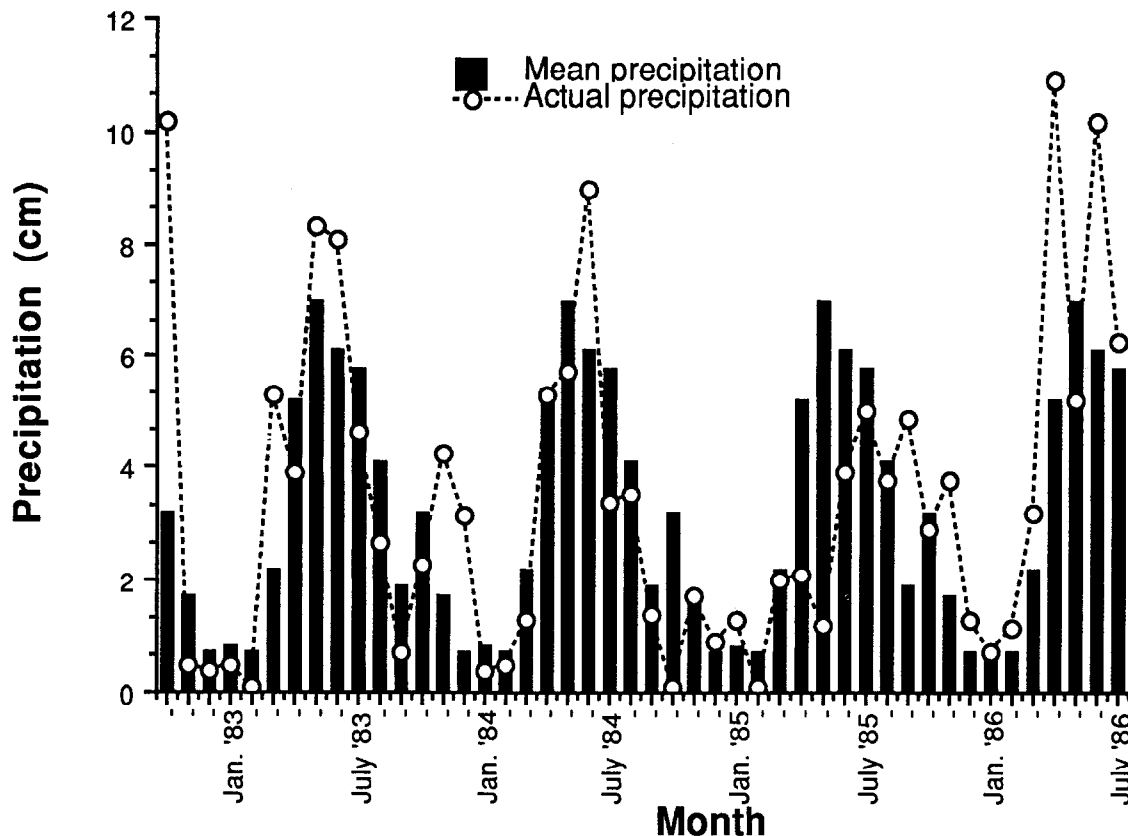


Fig. 1. Actual and long-term mean precipitation for the study site at Badlands National Park, South Dakota.

Litter frequency was determined each year with 10 placements of a 10-point frame in each plot. Therefore, plot frequency was based on 100 points per plot. Japanese brome tiller density in July was used as the dependent variable and litter frequency and fall precipitation (October and November) were used as independent variables in regression analysis.

Western wheatgrass and Japanese brome tiller densities and standing crops were determined in July 1983, 1984, 1985, and 1986 using 5 placements of a 0.10-m<sup>2</sup> quadrat on each plot. Tiller density was measured on permanently marked locations, so that data in different years were collected on the same spots. When several Japanese brome seeds within an intact, buried spikelet germinated, it was difficult to discern individual plants without destructive sampling. However, most Japanese brome tillers were individual plants, thus tiller density was considered a good approximation of plant density. Individual western wheatgrass plants were also difficult to determine, so tiller density was used. Standing crops in July 1983, 1984, 1985, and 1986 were used as an estimate of annual above-ground production. Significant treatment differences in each of the response variables (density and standing crop) were determined with analysis of variance and Tukey's HSD procedure at the 5% level.

## Results and Discussion

### Environmental Conditions

During the 1983 and 1984 fires, Japanese brome seedlings were approximately 3- to 5-cm in height, but few western wheatgrass tillers had emerged. Fires on 20 April 1983 were conducted at 22° C and 40% relative humidity, with 211 g m<sup>-2</sup> (18% fuel water) and winds of 6 to 9 km hr<sup>-1</sup>. Fires on 16 April 1984 were conducted at 14° C and 43% relative humidity, with 276 g m<sup>-2</sup> (13% fuel water)

and winds of 5 to 13 km hr<sup>-1</sup>. On 16 April 1984 those plots also burned in 1983 contained 139 g m<sup>-2</sup> (20% fuel water). Growing conditions were less favorable for plant growth in 1985 because of reduced precipitation (Fig. 1).

### Japanese Brome

Spring burning significantly reduced both the number and standing crop of Japanese brome plants for the first growing season (Tables 1 and 2). This reduction occurred following the 1983 and 1984 burns and on plots burned in both years. In 1984, plots previously burned in 1983 contained too little fuel for a satisfactory burn. As a result, Japanese brome density in 1984 was greater on plots burned 2 consecutive years than on plots only burned in 1984 (Table 1).

Table 1. Tiller densities (m<sup>-2</sup>) of Japanese brome and western wheatgrass in July following burning on 20 April 1983 and/or 16 April 1984 in Badlands National Park, South Dakota<sup>1</sup>.

Species	Year burned	Evaluation year			
		1983	1984	1985	1986
Japanese brome	None	2328a	2617a	306a	467a
	1983	690b	2456a	217b	342a
	1984	2250a	23c	14c	112b
	1983 & 1984	719b	580b	81c	196b
Western wheatgrass	None	295b	375b	222ab	206b
	1983	453a	304b	172b	237b
	1984	300b	507a	299a	424a
	1983 & 1984	432a	333b	153b	319ab

<sup>1</sup>Means, within a species and evaluation date, followed by the same letter are not significantly different ( $P \leq 0.05$ ) according to Tukey's HSD procedure.

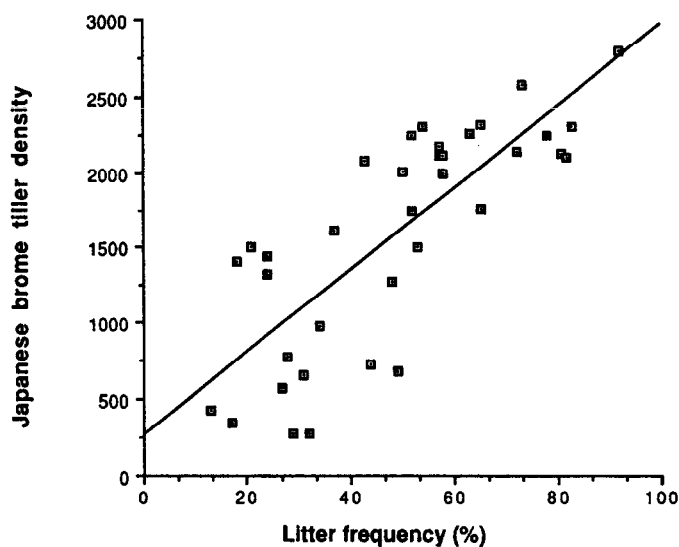
**Table 2. Above-ground standing crops (g m<sup>-2</sup>) of 6 species in July following burning on 20 April 1983 and/or 16 April 1984 in Badlands National Park, South Dakota<sup>1</sup>.**

Species	Year burned	Evaluation year			
		1983	1984	1985	1986
Japanese brome	None	75a	75a	21a	150a
	1983	35b	101a	19a	123a
	1984	81a	4b	1a	18b
	1983 & 1984	43b	14b	2a	85a
Western wheatgrass	None	88a	106a	51a	58b
	1983	105a	42b	37a	86b
	1984	82a	112a	66a	182a
	1983 & 1984	93a	92a	36a	80b
Buffalo grass	None	4b	6b	2b	7a
	1983	8a	10a	5a	6a
	1984	5b	9a	5a	8a
	1983 & 1984	7a	9a	5a	8a
Sand dropseed	None	2b	2c	1c	3b
	1983	5a	5ab	4a	5a
	1984	3b	6a	5a	7a
	1983 & 1984	5a	4b	3b	5b
Green needlegrass	None	3a	4a	3a	6a
	1983	1b	1b	0c	2b
	1984	4a	0c	1b	1b
	1983 & 1984	0c	0c	0c	1b

<sup>1</sup>Means, within a species and evaluation date, followed by the same letter are not significantly different ( $P < 0.05$ ) according to Tukey's HSD procedure.

In a dry year (i.e., 1985), Japanese brome densities and standing crops were lower on all plots, with the reductions being greatest on plots with less frequent surface litter (Tables 1 and 2). When Japanese brome densities in July were plotted as a function of litter frequency on those plots not burned in the same year, this relationship was readily apparent (Fig. 2). Plots burned in the same year were excluded from this analysis because the fire killed the Japanese brome seedlings and subsequent density was a function of fire rather than litter. Linear regression using July density as the dependent variable and litter frequency as the independent variable indicated a significant ( $p < 0.05$ ) relationship. The resulting equation was:  $Y = 264.9 + B_1 * (27.1)$  ( $r^2 = 0.62$ ) where Y is Japanese brome tiller density in July and  $B_1$  is litter frequency. Litter frequency was less important when the autumn precipitation was above average. The greater variability at low litter frequencies (Fig. 2) occurred when the previous autumn precipitation was high and tiller densities were high even when litter frequency was low. Adding October and November precipitation (cm) as an independent variable increased the  $r^2$  from 0.62 to 0.67, with the resulting equation:  $Y = -156.9 + B_1 * (21.7) + B_2 * (10.9)$  where  $B_2$  is October and November precipitation (cm).

The major influence of burning on subsequent generations of Japanese brome was through modification of the microenvironment, principally surface litter frequency. Without livestock, litter accumulations in the northern mixed prairie stabilize 5 to 6 years after burning (Dix 1960, Aboungendia and Whitman 1979). Burning intervals of less than 5 years should reduce litter and Japanese brome densities. Japanese brome germination, like downy brome (Evans and Young 1984), required some litter on the soil surface, particularly when autumn precipitation was below average. This creates a paradox for natural resource managers. Management practices designed to improve these grasslands (i.e., reduced grazing which increases litter) create a more desirable microenvironment for this introduced species. This can also be observed indirectly, by comparing the abundance of Japanese brome in the grasslands of Badlands National Park with that of surrounding



**Fig. 2. Relationship of Japanese brome tiller densities (m<sup>-2</sup>) and surface litter frequency (%) on plots at Badlands National Park (July density = 264.9 + litter frequency\*(27.1) ( $r^2 = 0.62$ )). Data from plots burned during the same year were excluded from this analysis.**

grasslands grazed by domestic livestock. Japanese brome abundance of the surrounding rangelands appears to be much lower than within Badlands National Park (Uresk 1984).

Seed immigration into the plots was not measured, but did not appear to be a controlling factor. A previous study in this area indicated that Japanese brome seed banks are large (11,000 to 12,000 m<sup>-2</sup>) (Whisenant and Bulsiewicz 1986) and probably last for several years. Although seeds were abundant, Japanese brome populations were reduced for at least 2 to 3 years after burning (Table 1). The longer-term response to burning was a function of precipitation and litter accumulations, rather than seed availability.

These data strongly indicate that spring burning will not greatly reduce more than 1 generation of Japanese brome, unless burning is followed by dry weather. Japanese brome germination is largely dependent on litter accumulations and Japanese brome will increase as litter accumulates on the soil surface. Livestock grazing and/or fire decrease litter accumulations and will reduce Japanese brome. It is highly unlikely that a reasonable grazing and prescribed burning program would remove Japanese brome from these communities, but it could significantly reduce the relative herbage contribution of Japanese brome.

#### Western Wheatgrass

Burning increased western wheatgrass tiller densities and standing crops during the first growing season after burning (Tables 1 and 2). However, during the second growing season both tiller densities and standing crops were similar to untreated plots. Clarke et al. (1943) reported spring burning on a western wheatgrass-thickspike wheatgrass [*Agropyron dasystachyum* (Hook.) Scribn.] community reduced standing crops 50% the first year, 15% the second year with full recovery in the third year. In western South Dakota spring burning usually increases western wheatgrass production (Schripsema 1977, Gartner et al. 1978). Spring burning in the semiarid northern, mixed prairie of eastern Montana increased standing crops of western wheatgrass for the first post-burn growing season (White and Currie 1983). They suggested that additional research was necessary to evaluate the persistence of burning effects.

The persistence of burning effects on western wheatgrass was greatly influenced by Japanese brome abundance. Western wheatgrass densities and standing crops were increased during the first

growing season after burning. When the second postburn growing season was favorable for Japanese brome growth (i.e., 1984), western wheatgrass standing crops and tiller densities were reduced. When the second postburn growing season was unfavorable for Japanese brome (i.e., 1985), western wheatgrass standing crops and tiller densities were increased relative to the unburned plots.

### Green Needlegrass and Threadleaf Sedge

Burning in April significantly reduced the standing crop of green needlegrass for at least 3 growing seasons after burning (Table 2). All 3 burning treatments reduced standing crops to about one third that on unburned plots. Coupland (1973) studied the effects of an August wildfire on green needlegrass in southwestern Saskatchewan and found herbage yields were increased 45% one year after the fire. Dix (1960) found that a late May wildfire increased green needlegrass frequency in western North Dakota. Schripsema (1977) found spring burning decreased green needlegrass in western South Dakota. Wright and Bailey (1982) considered current information on the effects of fire on green needlegrass to be inadequate. The results of this study were similar to those from a more recent study by Engle and Bultsma (1984), which found that burning in May or June—during a drought—was detrimental to green needlegrass. Based on the results of this and other studies, green needlegrass should be considered intolerant of spring burning.

Threadleaf sedge standing crops were not significantly affected by any of the 3 burning treatments in this study (data not shown). This is consistent with data from eastern Montana (White and Currie 1983) and western South Dakota (Schripsema 1977) where spring burning had little effect on threadleaf sedge, except during a dry year.

### Buffalograss and Sand Dropseed

Buffalograss standing crops were increased for 2 to 3 years after burning (Table 2). In western South Dakota spring burning increased buffalograss production (Schripsema 1977). April burning of loess hills mixed prairie in southern Nebraska had no significant effect on buffalograss standing crops (Schacht and Stubbenieck 1985). Spring burning increased sand dropseed standing crops for 3 to 4 growing seasons (Table 2). Burning 2 consecutive years also increased sand dropseed standing crops. These data are consistent with the data of Schacht and Stubbenieck (1985) who found sand dropseed increased following spring burning. A study of the long-term effects of fire on major grass species of west Texas indicated that buffalograss and sand dropseed were neither harmed nor benefitted by fire (Wright 1974).

Spring burning increased the productivity of  $C_4$  species (i.e., buffalograss and sand dropseed), although  $C_3$  species continued to dominate the community. The  $C_4$  species were a relatively minor component of the total productivity. Composition shifts toward  $C_4$  species have also been reported following spring burning in the mesic mixed prairie of north-central South Dakota by Steuter (1987) and Engle and Bultsma (1984).

### Design Considerations

The plot size used in this study (5 by 5 m) may not have allowed the fire to develop maximum potential intensity. However, there is considerable support for the use of small plots in research involving uniformly distributed grass species. This approach has been used by several investigators to reduce site, soil, and topographic variability (Old 1969, Hulbert 1969, Sharrow and Wright 1977, Whisenant et al. 1984, White and Currie 1983, Hulbert 1988). Other studies have found that temperature differences due to plot size were of little importance. Heyward (1938) found temperatures were no different in fires 3 by 3 m and those 16 ha in size. Daubenmire (1968) concluded that for areas 3 by 3 m or larger, size was not important in experimental burning or grasslands. Stinson and Wright (1969) stated "where the chief fuel is grass, size of plot for

measuring temperatures is of minor importance." In addition, most studies have attributed the effects of burning grasslands to litter removal and alterations in the microenvironment rather than to the direct effects of heat (Old 1969, Hulbert 1969, Sharrow and Wright 1977, Whisenant et al. 1984, Hulbert 1988). Where grasses are of primary concern and uniformly distributed, the potential problems resulting from the use of small plots are minor relative to the advantages of their use.

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