Prescribed Burning in the Northern Great Plains: Yield and Cover Responses of 3 Forage Species in the Mixed Grass Prairie

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Abstract

Prescribed burning was conducted in the fall and spring to evaluate the effects of fire on productivity of 3 forage species. Yield measurements were obtained throughout the growing season at biweekly intervals on western wheatgrass, blue grama, and threadleaf sedge. Supplementary measurements were made on vegetation cover and soil moisture. Herbage yield depended upon individual species, sampling date, and treatment. Spring burning of western wheatgrass and blue grama stimulated production by mid- and late-June, whereas fall burning also stimulated productivity but to a lesser degree. Production of threadleaf sedge was relatively unaffected by spring burning and reduced by fall burning. Fire can be used as a management practice to increase forage yield in the Northern Great Plains, but timing of utilization by livestock must receive careful consideration to assure maximum benefit.

Fire has played an important historical role in the development of grassland communities (Daubenmire 1968; Komarek 1964, 1965). Nevertheless, negative attitudes toward burning have frequently limited application of fire as a management tool. Factors such as the threat of fire escaping the boundaries of a prescribed burn, temporary elimination of potentially usable forage, and the destructive effects of wildfires have all contributed to such attitudes.

Only limited research has been conducted on the effects of burning on forage species in the Northern Great Plains. Lodge (1960) examined the effects of burning on crested wheatgrass *(Agropyron desertorum),* while Dix (1960) and Kirsch and Kruse (1972) reported on the effects of wildfire on mixed grass prairies in North Dakota. Prescribed burning has also been conducted in western wheatgrass *(Agropyron smithii)* communities in South Dakota (Gartner et al. 1978) and in the fescue grasslands of Canada (Bailey and Anderson 1978; Anderson and Bailey 1980). In general, these studies demonstrated that fire has management potential although additional research is needed to determine how individual species may respond (Bailey 1978).

Our study was designed to evaluate the effects of prescribed burning on important forage species in the mixed grass prairie of eastern Montana. The primary objectives of the study were: (1) to examine post-burn herbage production of 3 species throughout the growing season, (2) to compare the effects of both fall and spring burning and (3) to determine if burning conditions could be simulated by a clipping treatment.

Methods

Three species were selected for investigation: western wheatgrass, blue grama *(Bouteloua gracilis),* and threadleaf sedge *(Carex filifolia).* These species are 3 preponderant plants in the Northern Great Plains, and they provide substantial forage for livestock grazing (Weaver and Clements 1938, Daubenmire 1978).

Three study sites were located in mixed grass prairie vegetation on the Livestock and Range Research Station near Miles City, Mont. Soils of the study sites ranged in texture from loam to silt loam. All had good drainage and high fertility. Topography was level. Long-term precipitation for Miles City is approximately 34 cm annually. About 60% of this amount is received between May and August. During the 1979 growing season, precipitation was near normal through June and below normal in July and August. It averaged approximately 75% of normal for the May through August period.

Site selection was based upon composition of the vegetation. An effort was made to locate study areas in plant communities with relatively uniform, pure stands of each of the 3 species. This facilitated yield and cover measurements of each species because grass separation was minimized. It also reduced interspecific interactions that might otherwise confound observed differences between treatments.

Individual 3 × 3 m plots were established in each study area and randomly assigned to 1 of 4 treatments. Treatments were: fall burn, spring burn, fall clip, and a control. Plots were grouped according to homogeneity of the vegetation to provide a total of 10 replications of each treatment in each vegetation type. In addition, the 40 plots were located so that preburn vegetation composition and yield were similar within each replicate. Data were subsequently analyzed as a randomized complete block design.

Plots were burned separately using the same technique as Sharrow and Wright (1977). Panels constructed of angle iron and sheet metal served to confine the fire within the treated area, while plot size was sufficiently large to approximate burning under natural conditions (Heyward 1938). Fall burning and clipping treatments were imposed during the second week of October, 1978, after all species had entered fall dormancy. The clipping treatment consisted of removal of standing herbage and residual litter so that treated plots physically resembled burned plots except for the ash. Burning was then completed on companion plots during the following spring prior to the onset of spring growth. Threadleaf sedge plots were burned on April 3, blue grama plots on April 9, and western wheatgrass plots on April 17. Plant responses to treatments were measured at regular intervals throughout the 1979 growing season.

Above-ground biomass was estimated using a capacitance meter combined with hand clipping to obtain regression relationships (Currie et al. 1973, Neal and Neal 1973). Ten 30 × 61 cm subplots were sampled on each of the treated plots on each sampling date. Capacitance readings were obtained on all 10 subplots, and 2 of the 10 subplots were clipped. Subplots which were not clipped were permanently located so that repeated measurements could be obtained from them throughout the growing season. This double sampling procedure resulted in biomass estimates that were usually within 10% of the true mean ($P<0.10$), and it was much more

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This research is a contribution from the Western Region, USDA-ARS, Livestock and Range Research Station and the Montana Agricultural Experiment Station, Journal Series No. 1185.

Manuscript received April 8, 1981.

efficient than clipping alone. Plots were sampled between late April and early July at 2-week intervals. They were sampled again in late July or mid-August.

Estimates of basal cover were taken in mid-July, 1979, using the microplot sampling technique outlined by Morris (1973). Each of the 8 permanently located subplots was sampled in each of the main plots. Soil moisture was estimated throughout the growing season with a shallow-depth neutron probe. Soil moisture measurements were taken on subplots that were concurrently clipped for yield estimates.

Results

Yield Estimates

Herbage yields varied considerably throughout the growing season depending upon sampling date, treatment, and individual species (Fig. 1, 2, 3). Comparison of peak seasonal biomass showed that burning stimulated blue grama yield but slightly depressed western wheatgrass production. Peak yields of threadleaf sedge were relatively unaffected by burning. Although peak yield provided a general impression of how each species reacted, differences among sampling dates furnished a more reliable estimate of season-long response to burning.

Spring growth of western wheatgrass from April 27 to May 8 was essentially the same on the fall-burned and unburned plots (Fig. 1). In contrast, plants on both the spring-burned and clipped treatments showed substantially less production during the same period. During late May and early June, western wheatgrass growth was greater on the unburned control than on either of the burning treatments; and this resulted in significantly higher herbage yields. Plants on the spring-burned plots overcame their slow initial growth in May and June and yielded about the same as those on fall-burned plots. Yields from the clipped treatment remained considerably lower than those from either the burned or control treatments. In mid-June both burning treatments produced significantly more herbage than the control by at least 100 kg/ha. This advantage, however, did not persist. When peak standing crop of western wheatgrass was measured in early July, there were no significant differences among any of the treatments. By the end of July, standing biomass for both the burning treatments and the clipped treatment showed a more rapid decline than did the control.

Blue grama responded differently than western wheatgrass (Fig. 2). As expected, early season growth was negligible for this warm-season species. However, when initial measurements were made in late May and early June, the blue grama control plots produced more than the burning treatments by 25 to 30% and about 40%

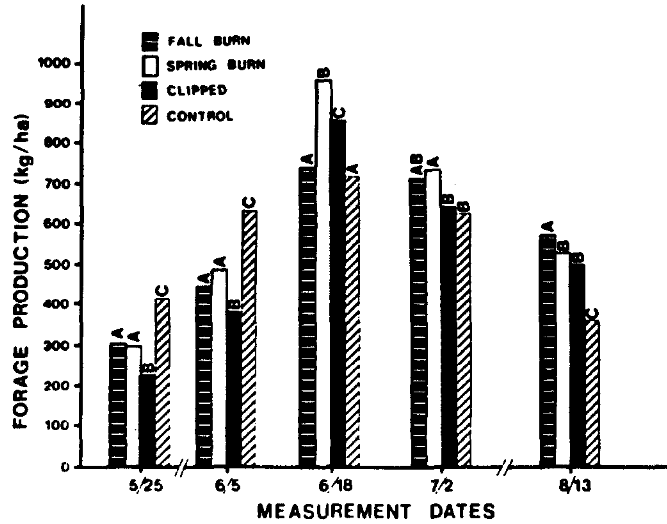

Fig. 2. *Herbage yield of blue grama throughout the growing season as influenced by burning or clipping treatments. Significant differences (P<0.05) between treatments within individual dates are represented by different letters above the mean values.*

more than the clipped treatment. After mid-June, herbage yields were greater from both the burned and clipped treatments than from the untreated control plots. When peak standing crop was measured on June 18, plants on the spring-burned plots outproduced those of the control by about 250 kg/ha, and yields from the clipped plots were almost 150 kg/ha higher than from the control. Average yield of blue grama from the fall-treated plots was slightly higher than the control on this date, but the difference was not significant. After peak standing crop was reached, standing biomass on the control plots decreased more rapidly than on any of the other treatments. Mid-August sampling showed that fall burning had resulted in 60% more herbage than the control, while spring burning or clipping treatments resulted in about 40% more herbage than from the control treatment.

Spring burning of threadleaf sedge yielded about the same amount of herbage through June as the unburned control (Fig. 3). In contrast, fall burning and clipping treatments showed about the same yields; but until mid-June, yields were significantly lower than from either the control or spring-burned plots. This difference resulted in about 25% less herbage being produced from clipped

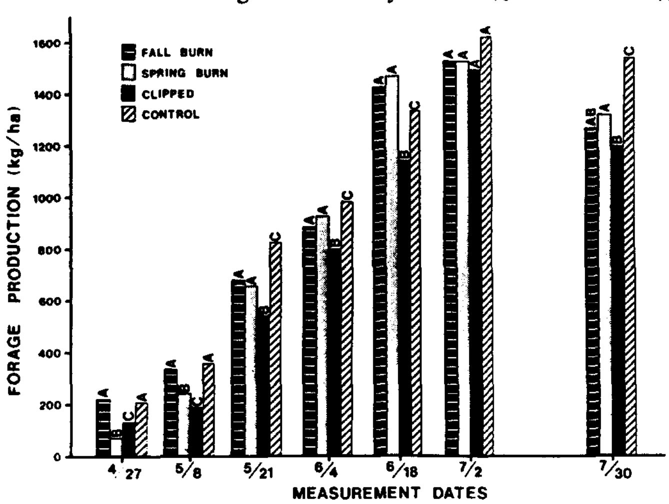

Fig. 1. *Herbage yield of western wheatgrass throughout the growing season as influenced by burning or clipping treatments. Significant differences (P<0.05) between treatments within individual dates are represented by different letters above the mean values.*

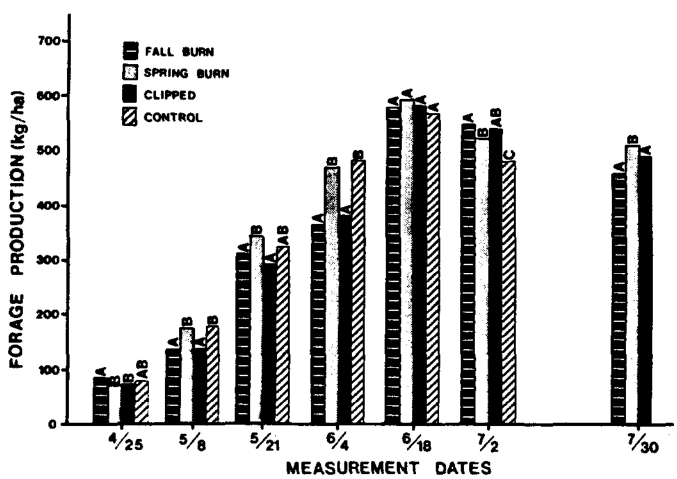

Fig. 3. *Herbage yield of threadleaf sedge throughout the growing season as influenced by burning or clipping treatments. Significant differences (P<0.05) between treatments within individual dates are represented by different letters above the mean values.*

and fall-burned treatments. When peak standing crop was measured on June 18, there were no significant differences among treatments. Later sampling showed that standing biomass of the control plots declined more rapidly than any of the other 3 treatments. Thus, yields were 10 to 15% higher on burned and clipped treatments on July 2.

Basal Cover

Burning and clipping treatments substantially reduced the litter component and increased the proportion of bare soil in the western wheatgrass and threadleaf sedge communities (Table 1). In the blue grama community, however, there was a slight increase in litter on the burned and clipped plots as compared to the control.

Basal cover of the dominant species in each of the 3 communities was only slightly affected by individual treatments (Table 1). In the western wheatgrass community fall burning increased western wheatgrass cover; but with either clipping or spring burning, basal cover was similar to that of the untreated control. In the blue grama community, the control showed about the same blue grama cover as fall and spring burning, but the clipped treatment had significantly less cover. Spring burning in the sedge community resulted in the highest threadleaf sedge cover, but there were no significant differences among other treatments.

Cover measurements of other species showed very little effect from the individual treatments except in the blue grama community (Table 1). Here annual grasses, cheatgrass *(Bromus tectorum)* and Japanese brome *(Bromus japonicus)*, comprised a substantially higher proportion of the overall plant community. Fall burning was the most effective treatment in reducing cheatgrass and Japanese brome cover. About a 70% reduction was observed in comparison with the control. Spring burning or clipping treatments, however, accounted for a 50 to 60% reduction.

Soil Moisture

No significant differences in soil moisture were observed between spring and fall burning treatments in any of the three plant communities (Table 2). However, spring-burned plots tended to have slightly higher soil moisture than fall-burned plots early in the growing season and lower soil moisture later in the season. Differences were usually less than 1%.

In the western wheatgrass community, both the spring- and fall-burned plots had consistently lower soil moisture than the control plots (Table 2). These differences were usually significant, and they amounted as much as 7% between treatments depending upon the sample date. Greater differences were observed during spring than in summer. Soil moisture in the clipped treatment was usually intermediate between burned and unburned treatments for all species.

In the spring and shortly after rain showers, fall and spring burns in the threadleaf sedge community had less soil moisture than the control. However, as soils became drier (i.e., around 5% moisture), no appreciable differences were noticed among treatments. Soil moisture levels in the clipped treatment were similar to the control plots throughout the growing season.

In the blue grama community, soil moisture differences among treatments were small throughout the season (Table 2). In early June, both spring- and fall-burned plots had higher soil moisture than the unburned control. Thereafter, burned plots had lower soil moisture. The clipped treatment provided a reasonable simulation of the burn treatments with no appreciable effects of fire being readily measurable.

Discussion

Studies dealing with effects of burning on forage production have generally based conclusions on data obtained from a single sampling interval. This interval is usually selected to correspond with peak standing crop so that a reliable estimate can be made of burning effects on total forage production. Results from such studies often appear to be contradictory. For example, Dix (1960) and Launchbaugh (1964) reported that burning reduced production in mixed and short grass communities, whereas Gartner et al. (1978) found that yield of western wheatgrass was increased by fall, winter or early spring burning. Much of the apparent discrepancy can be attributed to differences in soil moisture conditions during the pre- and post-burning period. As pointed out by Wright (1972, 1974), drought conditions tend to reduce forage production on burned sites to a higher degree than on unburned sites, while wet conditions usually stimulate forage productivity. Our results for western wheatgrass support these conclusions within a single growing season. Measurements in mid-June showed higher productivity on burned treatments than on control areas. Since plant growth continued beyond that date, soil moisture did not appear to be particularly limiting. As soil moisture became limited, however, plants on the control treatments out-produced those on the burning treatments. When peak production was reached on July 2, this difference was noticeable but not statistically significant. Measurements later in July showed standing biomass to be greater on the control than on the burned treatments, and this was probably related to continuing drought conditions.

Early season growth in western wheatgrass seemed related to both season of burning and soil moisture conditions. Early spring burning initially resulted in substantially lower production than

Table 1. Percent basal cover for 3 plant communities in mid-July as influenced by ground cover treatments.

Treatment	Litter	Bare soil	Rock	Western wheatgrass	Blue grama	Threadleaf sedge	Annual bromes	Other species
				Western wheatgrass community				
Fall burn	22.4	48.4	—	19.0 a[1]	—	—	1.0	9.3
Spring burn	33.1	43.1	—	14.3 b	—	—	2.0	7.8
Clipped	25.9	48.0	—	14.4 b	—	—	3.1	8.5
Control	66.8	5.1	—	15.3 b	—	—	3.1	8.7
				Blue grama community				
Fall burn	44.9	8.6	—	—	38.1 a	—	6.4 a	2.1
Spring burn	47.0	3.4	—	0.1	36.5 a	0.5	11.7 b	2.4
Clipped	50.9	9.5	—	0.1	25.5 b	—	12.2 bc	1.4
Control	38.5	2.6	—	0.4	35.5 a	—	20.5 c	2.8
				Threadleaf sedge community				
Fall burn	26.4	48.6	1.0	2.1	5.3	12.6 a	1.9	3.2
Spring burn	29.8	41.8	1.9	1.6	3.0	17.4 b	1.3	3.3
Clipped	39.5	29.9	1.5	2.1	9.6	11.1 a	3.4	3.1
Control	65.0	9.0	0.1	2.4	5.6	8.8 a	2.4	6.8

[1]Treatment differences within species in a plant community are significant ($P<0.05$) when followed by a different letter.

Table 2. Percent soil moisture at different dates at the 15 cm depth in 3 plant communities subjected to 4 ground cover treatments.

Date	Fall burn	Spring burn	Clip	Control
		Western wheatgrass community		
5/24	16.9 a[1]	17.4 a	16.7 a	18.4 b
6/4[2]	22.6 a	23.1 a	25.1 b	29.4 c
6/18	13.5 ab	14.2 a	14.1 ab	14.8 b
7/2	12.0 a	11.8 a	13.0 b	12.3 ab
7/30[2]	28.6 a	28.0 ab	28.5 a	31.1 b
		Blue grama community		
6/5	9.2 a	9.8 ab	9.5 a	8.8 b
6/18	5.9 a	5.7 a	5.7 a	6.0 a
7/2	5.2 a	4.9 a	4.9 a	5.4 a
8/13	5.5 a	5.5 a	6.0 a	5.9 a
		Threadleaf sedge community		
4/25	11.3 ab	12.3 a	13.0 b	13.2 b
5/22	5.5 a	5.6 a	6.4 a	5.9 a
6/4[2]	9.8 ab	10.4 a	10.4 ab	11.1 b
6/18	5.0 a	5.0 a	5.2 a	5.0 a
7/3	4.3 a	4.2 a	4.3 a	4.2 a
7/31[2]	8.2 a	8.9 a	9.0 a	10.6 b

[1]Treatment means within dates are significantly different ($P<0.05$) when followed by a different letter.

[2]Observations from this date reflect increases that resulted from rain showers in the previous week.

fall burning although soil moisture conditions after burning were similar between treatments. Apparently new shoots at primordial regions of the rhizomes were either damaged or retarded by burning in early spring. This effect was not persistent since fall- and spring-burned plants had similar yields after mid-May. Both the spring and fall-burned plots had less soil moisture than the control plots. This difference, however, did not clearly manifest itself in terms of yield until late May when the control plots had significantly greater yields. By mid-June, the effect of fire apparently exerted more influence on plant productivity than on soil moisture. The burned plots had higher yields than the control plots although soil moisture continued to be higher on the untreated areas. On the whole, western wheatgrass production was affected by at least 3 interacting factors: season of burn, soil moisture, and date of measurement.

Our results showed that burning reduced blue grama yield early in the growing season but increased it later in the summer. This is contrary to the results reported by Trlica and Schuster (1969) for a prescribed burn in Texas, but it is consistent with results reported by Dwyer (1967) in New Mexico. Other studies that have considered the response of blue grama to burning have utilized data derived from wildfires (Dix 1960, Launchbaugh 1964, Dwyer and Pieper 1967). These studies have shown that wildfire reduces total production in blue grama communities for 2 to 4 years. While such information may provide an indication of what to expect, it is generally inaccurate to equate wildfires with controlled burns (Wright 1974). Because we burned under favorable soil moisture conditions when blue grama was dormant, residual plant parts appeared to be relatively unaffected by fire. Subsequent growth was therefore able to proceed without an extended recovery period.

Responses in blue grama productivity could not be attributed to differences in soil moisture during the post-burn growing season. All treatments had virtually the same amount of water available. Relative changes in cover among species, however, could indirectly account for some of the increase in blue grama yield. The blue grama community that was burned had a relatively high proportion of cheatgrass and Japanese brome. When the proportion of these annuals was reduced by burning, the remaining blue grama was able to outproduce the control apparently because of a corresponding decrease in interspecific competition. Although the reduction in annual grasses was highest with fall burning, blue grama herbage yield was greatest on spring burning treatments. This conflict can probably be explained as a function of soil moisture conditions at the time of burning. Spring burning was conducted shortly after spring runoff when the soil profile was saturated. Consequently, reduced soil heat penetration would be expected, and tissue damage of blue grama would be minimal. Fall burning occurred under good soil moisture conditions, but the soil profile was below field capacity. Proportionately more soil heat penetration would be expected, and this may have impeded subsequent blue grama growth.

Our results showed that greatest cheatgrass and Japanese brome reduction was obtained by fall burning. Good control was also achieved by spring burning. Comparable results have also been reported by Gartner et al. (1978) on annual brome infested western wheatgrass communities in South Dakota. Burning therefore may have considerable management potential in controlling these species. From a forage production standpoint, our results indicated that greatest blue grama yields were obtained by spring burning. This should, however, be balanced against the potential benefits of improved annual brome control obtained by fall burning.

The increase in litter that was observed on burned plots in the blue grama community appeared somewhat contradictory. However, it may be due to the sampling date and the proclivity of blue grama to shed its leaves under adverse conditions. When cover measurements were taken in mid-July, drought conditions had already resulted in a considerable reduction of standing biomass as compared to peak standing crop. Consequently, leaves that were shed became part of the litter component. Leaf drop was most apparent in blue grama and less pronounced in western wheatgrass and threadleaf sedge. Moreover, since burned blue grama plots had substantially more herbage than the control at peak production, this process made a proportionately greater contribution. As a result, more litter accumulated on these treatments.

Spring burning of threadleaf sedge provided no advantage with respect to early season forage production, but fall-burned plots showed reduced yields. These results could not be attributed to soil moisture since moisture differences among treatments were negligible. However, examination of the cover data showed that spring burning resulted in increased cover. The increase in tillers apparently compensated for reduction in height so that early yields were comparable between the control and spring burning treatment. Measurements of standing biomass after peak production indicated that some advantages could be realized by summer grazing on either burning treatment. Plants in the control lost their leaves at a more rapid rate than burned plants. Consequently, more threadleaf sedge forage was available during the summer months.

Several studies reviewed by Daubenmire (1968) suggest that the effects of clipping are similar to burning. Our data, however, showed that this is not the case under our conditions. The only good correlation between burning and clipping was on fall-burned threadleaf sedge plots. The other species responses and spring burning of threadleaf sedge showed little relationship to the clipping treatment responses. We therefore believe that clipping is an unproductive technique to simulate burning conditions and would discourage its use for this purpose.

A number of management implications important to forage production resulted from this study. Vallentine (1971) pointed out that management after burning depends upon geographic locality and the nature of the resident vegetation among other factors. In the Northern Great Plains, prescribed burning on mixed grass prairies generally requires a short deferment period early in the growing season. By June, grazing can normally proceed on burned ranges albeit sometimes at a lower stocking rate. This is because favorable growing conditions usually allow rapid recovery of the dominant plant species. Our results indicate that the decision to burn should depend upon when forage needs are anticipated and also on what plant species are predominant. If grazing on a given site is needed in early June, our results indicate that burning should not be undertaken. At that time, plants on burn treatments never out-yielded those on the control. Conversely, if grazing can be deferred until mid- or late-June, burning may be effective in stimulating forage production. At that time, we found that all three species subjected to fall or spring burning out-produced the untreated control. Spring burning, however, usually resulted in higher productivity than fall burning. If grazing is postponed until summer, our results indicate that the decision to burn should depend upon species composition. If western wheatgrass is dominant, burning may not increase forage production. Plants on burned plots tended to dry out more rapidly and provided less standing biomass after early July. Blue grama and threadleaf sedge, in contrast, exhibited the opposite trend and had lower yields on the control than on burned plots. Consequently, there may be merit in burning ranges dominated by these species when late utilization is anticipated. Another key factor to consider is available moisture. Burning should not be conducted during the droughts that periodically occur in the Northern Great Plains.

Some research implications of our work should also be mentioned. We found that substantial shifts in herbage production frequently occurred over two-week intervals. These shifts might lead to gross misinterpretation of the treatment responses if observations are taken on only one date. Interpretation of burning results strongly depended upon when measurements were obtained. On one date burned plots might have less herbage than the control, while on a subsequent date this situation could be reversed. It would have been misleading, therefore, to have used only a single set of observations. Yet this is the sampling approach normally taken in range burning studies. It seems most appropriate, therefore, to provide for more extensive sampling. If peak standing crop is desired, for example, measurements might be taken at 3 intervals: shortly before, at, and shortly after the estimated time of maximum yield. If only one measurement is feasible, it would be more important to adjust the sampling date to reflect the greatest management impact.

In conclusion, our results indicate that burning has beneficial management applications on Northern Great Plains rangelands dominated by western wheatgrass, blue grama, or threadleaf sedge. Additional research studies are now desirable, however, to confirm our results and to evaluate such factors as varying seasonal weather patterns, persistence of burning effects, and optimum management alternatives.

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