J. Range Manage.
51:32-36 January 1998

Harvest frequency and burning effects on vigor of native grasses

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Abstract

Burning and harvest frequency can affect the vigor of switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon gerardii* Vitman), and indiangrass [*Sorghastrum nutans* (L.) Nash]. A field study was established in 1986 and from 1988 to 1991 treatments were applied with burning in March, April, or May with unburned controls. Forage was harvested from plots 1 (June), 2 (June and July), or 3 (June, July, and August) times with unharvested control plots included. Treatments were applied to the same plots annually and were arranged in a split-split plot, randomized complete block design. The main plot was species, the subplot was burning, and the sub-subplot was harvest frequency. Big bluestem produced 147 and 122% more etiolated biomass in spring than did switchgrass or indiangrass, respectively. Effects of harvest management on plant vigor occurred after 1 growing-season, but changed little during the remainder of the study. Etiolated biomass declined more as harvest frequency increased from 2 to 3 harvests than from 1 to 2 harvests (213, 205, and 162 g m^{-2} for 1, 2, and 3 harvests per summer, respectively). Big bluestem produced 95 and 33% more tillers than switchgrass and indiangrass, respectively, and burning stimulated tillering an average of 32% across all species and harvest treatments. Harvest frequency increased tiller density. However, plant vigor as measured by etiolated growth decreased as harvest frequency increased. This suggests that with these species tillering may occur at the expense of energy storage with frequent defoliation. Vigorous spring etiolated growth and high tillering potential may partially explain the dominance of big bluestem in the tallgrass prairie.

Key Words: Energy reserves, etiolated growth, basal cover, tiller density, *Panicum virgatum*, *Andropogon gerardii*, *Sorghastrum nutans*

Resumen

La frecuencia del quemado y la cosecha puede afectar el vigor del switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon gerardii* Vitman), e indiangrass [*Sorghastrum nutans* (L.) Nash]. Un campo de estudios se estableció en 1986 y de 1988 a 1991 se aplicó tratamientos de quemado en Marzo, Abril, o Mayo con control no quemados. El forraje fue cosechado de las parcelas 1 (Junio), 2 (Junio y Julio), ó 3 (Junio, Julio, y Agostos) tiempo en que se incluyó las parcelas de control no cosechadas. El tratamiento fue aplicado anualmente a las mismas parcelas las cuales fueron organizados en planos divididos-divididos en diseño de bloque completamente aleatorio. El plano principal eran especies, el plano secundario era el quemado y el plano sub-secundario era la frecuencia de la cosecha. El big bluestem produjo 147 y 122% más masa viva crecida en la oscuridad (etiolated biomass) en la primavera que lo que produjo el switchgrass o el indiangrass, respectivamente. El efecto de la administración de la cosecha, en el vigor de la planta, ocurrió después de una estación de cultivo, pero cambió un poco durante el resto del estudio. La masa viva crecida en la oscuridad (etiolated biomass) declinó más al aumentar la frecuencia de la cosecha de 2 a 3 cosechas que de 1 a 2 cosechas (213, 205, y 162 g m^{-2} por 1,2, y 3 cosechas por verano, respectivamente). El big bluestem produjo de 95 a 33% más serpollo que el switchgrass y el indiangrass, respectivamente, y el quemado estimuló el serpollado en un promedio de 32% a través de todas las especies y tratamientos de cosecha. La frecuencia de la cosecha aumenta la densidad del serpollo. Sin embargo, el vigor de la planta cuando es medido por crecimiento en la oscuridad (etiolated growth), disminuye cuando la frecuencia de cosecha aumenta. Esto sugiere que con estas especies el serpollado podría ocurrir a expensas de almacenar la energía con la frecuente defoliación. El crecimiento en la oscuridad (etiolated growth), vigoroso de la primavera y el alto potencial del serpollado podrían explicar parcialmente el predominio del big bluestem en las llanuras de yerba alta (tallgrass).

Burning and harvesting are 2 mechanisms by which plants can be defoliated, but defoliation must be timed to ensure the maintenance of adequate energy reserves for plant survival and reasonable productivity over years (White 1973). The effects of such defoliation on monocultures of switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon gerardii* Vitman), and indiangrass [*Sorghastrum nutans* (L.) Nash] were the focus of this research.

Frequent defoliation of perennial grass reduces basal cover (Heinrichs and Clark 1961, McKendrick and Sharp 1970, Buwai and Trlica 1977). For switchgrass, defoliation that removes shoot apices often leads to a decline in shoot density (Branson 1953, Anderson et al. 1989).

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Manuscript accepted 24 Feb. 1997.

Anderson et al. (1989) reported that non-defoliated switchgrass plants contained 22 to 40% more total non-structural carbohydrates (TNC) than clipped plants at the end of the growing season. However, Davidson and Milthorpe (1965) noted that TNC formed only a part of the labile pool of substrates used in regrowth and thus may not accurately measure the ability of defoliated plants to regrow.

Little research has been done on the effect of defoliation by burning on plant vigor. However, in Oklahoma burning doubled big bluestem tiller density (Svejcar and Browning 1988). In Kansas, burning increased indiangrass tiller density but had less effect on big bluestem (Hulbert 1984). These studies examined mixed stands which resulted in individual species responses that are confounded by species interactions. The objective of this study was to determine the effect of burning and harvest frequency on spring etiolated growth from stored energy reserves, basal cover, and tiller density of switchgrass, big bluestem, and indiangrass using monocultures to avoid such interspecific interactions.

Materials and Methods

The research site was located at the University of Nebraska Agricultural Research and Development Center near Mead, Neb. The soil is a Sharpsburg silty clay loam (fine montmorillonitic mesic Typic Argiudoll) derived from loess materials.

In 1986, 'Pawnee' big bluestem, 'Nebraska 54' indiangrass, and 'Trailblazer' switchgrass were planted as monocultures in nine 5 × 44-m plots allowing for 3 replications of each treatment arranged in a randomized complete block design. In 1988, each monoculture main plot was divided into four, 5 × 9-m subplots with 1.5-m borders separating the subplots. Burn treatments were randomly assigned to subplots and included burns conducted in mid-March when plants were still dormant, mid-April with about 1 to 5 cm of new growth, or mid-May with about 15 to 20 cm of new growth. Non-burned subplots were used as controls. The same burning treatments were applied to the same area from 1988 through 1991.

Within each burned subplot, four, 1.5 × 5-m harvest treatment sub-subplots were randomly assigned and included plots not harvested or harvested 1 (June), 2 (June and July), or 3 (June, July, and August) times each summer. Herbage from a 1 × 5-m area in each sub-subplot was removed with each summer harvest using a flail-type forage harvester. The remaining 0.5 m^{-2} was mowed and left on the plot for litter accumulation and fuel for burning. Sub-subplots were harvested to leave a stubble height of 18 cm. After a killing freeze caused above ground growth to cease in October, a 30 × 180-cm area was clipped by hand to a height of 18 cm from non-harvested sub-subplots in 1989 and from all plots in 1990 for an estimate of forage mass. The same harvest treatments were applied to the same sub-subplots each year. Harvest treatments were initiated in 1988 and continued through 1991.

Plant vigor can be measured in a number of ways. Measuring etiolated growth (growth that occurs in the absence of light) is one way to quantify total organic reserves of a plant and thereby quantify plant vigor in grasses (McKendrick and Sharp 1970, Dovrat et al. 1972, Ogden and Loomis 1972, Reece et al. 1988).

Before growth initiation in the spring of 1989, 1990, and 1991, 3 randomly selected plants per sub-subplot were clipped to remove the previous years residue and covered with #10 metal cans (186 cm^2 × 17 cm) to exclude light and thus measure the effect of the previous year's burning and harvest treatments on etiolated growth. Cans were painted white to reduce thermal load. A groove at least 8 cm deep was cut in the soil around the outside edge of the can to sever any shoots or shallow roots that might translocate photosynthates or nutrients to covered tillers. A weight was placed on top of each can to prevent it from being blown over.

Etiolated growth parameters used to estimate plant vigor were biomass and number of tillers. Etiolated growth under each can was measured by clipping all etiolated plant material to a height of 2 cm. Number of etiolated tillers was a count of tillers growing under each can. Sampling was conducted from mid-April when etiolated growth began until etiolated growth ceased in early July. Etiolated growth was sampled 4 times during 1989 and 1991 and 3 times during the same period in 1990. In all 3 years, etiolated growth was clipped 1 day prior to the mid-May burn and 1 day prior to the June harvest to ensure etiolated growth was not destroyed. Clipped biomass was dried in a forced air oven at 60° C for 2 days and weighed. Average mass per etiolated tiller was calculated by dividing the number of etiolated tillers by dried etiolated biomass.

Tiller density of sub-subplots was estimated by counting the number of tillers in 2 randomly placed 30 × 30-cm frames in each plot after the July harvest in 1991. Basal cover was measured in November 1991, using the 10-point frame method (Cook and Stubbendieck 1986) with 60 points per sub-subplot.

The study was designed and analyzed as a split-split plot in time and all statistical procedures were analyzed using procedures of SAS (SAS 1988). The main plot was species, subplot was burn date, and sub-subplot was harvest. All differences reported are significant at $P < 0.05$.

Results and Discussion

Etiolated Biomass

Differences in plant vigor resulting from harvest frequency treatments were observed for all species after only a single year

Table 1. Total etiolated biomass of switchgrass, big bluestem, and indiangrass for 4 harvest frequencies in 3 years averaged across burn treatments.

Grass species	Su harvest frequency[1]	Year 1989	1990	1991
		($g\ m^{-2}$)		
Switchgrass	0	187	174	211
	1	148	119	168
	2	121	126	151
	3	85	70	125
Big bluestem	0	490	460	419
	1	339	330	301
	2	365	317	287
	3	313	225	282
Indiangrass	0	148	120	256
	1	152	129	232
	2	124	116	236
	3	127	92	143
LSD (0.05)		39	46	75

[1] Summer harvest frequency
0=Not harvested
1=June harvest
2=June and July harvests
3=June, July, and August harvests

of applying treatments (1988; Table 1). However, cumulative harvest frequency effects were not observed following 2 more years of harvest. In each year, and averaged across the study, big bluestem produced more etiolated spring growth (344 g m^{-2}) than switchgrass (141 g m^{-2}) and indiangrass (154 g m^{-2}).

Indiangrass was less vigorous in non-harvested plots than switchgrass or big bluestem (except compared with switchgrass in 1991). However, indiangrass was less adversely affected by increasing harvest frequency than the other species (Table 1). For example, in 1989 etiolated biomass from indiangrass plots harvested 3 times was 86% of the non-harvested indiangrass, whereas big bluestem and switchgrass harvested 3 times produced 64 and 45% as much etiolated biomass as non-harvested plots, respectively.

In general, plants tended to be less vigorous as harvest frequency increased. Etiolated biomass averaged across all species and years was 274, 213, 205, and 162 g m^{-2} for non-harvested plots and plots harvested 1, 2, and 3 times per summer, respectively. However, 2 summer harvests (June and July) resulted in similar vigor as a single summer harvest (July; Table 1). Both once- and twice-harvested plots had the same late summer rest period (from July until fall dormancy). This apparently was adequate to replenish energy lost due to the June harvest. These results are similar to those of Owensby et al. (1977) who reported that decreased energy reserves from intensive early-season defoliation could be overcome by a rest period late in the growing season. Other researchers also found early-season grazing was less likely to reduce stored energy in grasses than later-season defoliations (Trlica and Cook 1971, Drawe et al. 1972). An explanation was provided by Anderson et al. (1989), who found that defoliation had a greater impact on energy reserves when apical meristems were removed. The June harvest in the present study was taken before apical meristems were elevated. Reduced plant vigor which occurred with an additional third harvest per growing season is similar to the response found by Peterson (1962), Buwai and Trlica (1977), and Reece et al. (1988) who found plant vigor reduced following frequent or heavy defoliation.

Burning had little effect on plant vigor. All burns were conducted by mid-May in this study, so plants had nearly the entire growing season to replenish any organic reserves lost as a result of burning. Ehrenreich and Aikmann (1957) concluded for Iowa prairies, 4 to 6 years without burning was needed to develop a mulch capable of suppressing warm-season grass growth. This suggests that the current study may not have been long enough to suppress plant vigor due to mulch accumulation on non-burned plots.

Etiolated Tiller Density

As with etiolated biomass, big bluestem had greater etiolated tiller density when averaged across treatments(5,300 tillers m^{-2}) than switchgrass or indiangrass (2,080, and 2,700 tillers m^{-2}, respectively). Harvest frequency, averaged across all species and burn dates did not affect etiolated tiller density (3,320, 3,370, 3,480, and 3,280 tillers m^{-2}, for non-harvested plots and plots harvested 1, 2, and 3 times per summer, respectively). This contrasts with results reported by McKendrick and Sharp (1970) in which etiolated tiller numbers per unit area were reduced by heavy grazing.

Burning did not affect etiolated tiller density. Average etiolated tiller density was 3,330, 3,350, 3,180, and 3,620 m^{-2} for non-burned, March, April, and May burn treatments, respectively.

Etiolated Tiller Mass

The relatively constant etiolated tiller density regardless of burn date or harvest frequency suggests that these plants partition energy to achieve a certain tiller density which varies among species. Initial changes in plant vigor therefore, may best be expressed as weight of individual etiolated tillers.

Harvest frequency interactions with burn treatment and species for etiolated tiller mass were the result of weight of individual etiolated tillers being most affected by harvest frequency and a general decline in etiolated tiller mass as harvest frequency increased (Tables 2 and 3)

Table 2. Average etiolated tiller mass for 4 burn treatments at 4 harvest frequencies averaged across species and years.

	Summer harvest frequency			
Burn date	0	1	2	3
	(mg $tiller^{-1}$)			
Non-burned	304[1]	189	185	127
March	230	196	167	161
April	236	167	150	127
May	196	164	163	146

[1]LSD (at 0.05 = 36) value is suitable for comparisons within and between columns.

Etiolated tiller weight was reduced in non-harvested/burned plants but not in harvested/burned plants (Table 2). This was the result of greater etiolated tiller weights for non-harvested/non-burned plants when compared with all other treatment combinations. In this study, except for the April burn, burning impacted etiolated tiller mass similarly to a single growing-season harvest.

Harvest frequency by species interactions indicated non-harvested switchgrass and big bluestem plants had more vigorous tillers than indiangrass (Table 3). However, average etiolated tiller mass of indiangrass was not reduced as much by harvesting as was that of switchgrass and big bluestem. This appears to be in contrast to indiangrasses classification as a decreaser in tallgrass prairie plant communities (Nichols et al. 1984). One explanation may be that in mixed tallgrass prairie stands indiangrass is preferentially grazed, and therefore has greater defoliation stress than competing species.

Table 3. Average etiolated tiller mass of 3 warm-season grasses at 4 harvest frequencies averaged across burn treatments and years.

	Summer harvest frequency			
Species	0	1	2	3
	(mg $tiller^{-1}$)			
Switchgrass	250[1]	177	186	135
Big bluestem	265	188	163	140
Indiangrass	174	157	151	138

[1]LSD (at 0.05 = 31) value is suitable for comparisons within and between columns.

Species by burn date interactions suggested that individual species responded differently to burn dates (Table 4). Big bluestem etiolated tiller mass was not adversely affected by burning except with the May burn date, whereas indiangrass was most adversely affected by March burning. Switchgrass; however, was not affected by burn date. The adverse effect of the March burn on indiangrass may have occurred because indiangrass has live biennial tillers present above ground in March (McKendrick et al.

Table 4. Average etiolated tiller mass of 3 warm-season grasses for 4 burn treatments averaged across harvest frequency treatments and years.

Species	Burn treatment Non-burned	March	April	May
	(mg tiller^{-1})			
Switchgrass	198[1]	198	167	185
Big bluestem	195	209	197	155
Indiangrass	180	136	146	157

[1] LSD (at 0.05 = 49) value is suitable for comparisons within and between columns.

1975) which are subject to injury by early burning. Although indiangrass appeared damaged by burning in this study, it has been reported that indiangrass populations decline rapidly without burning in mixed species plant communities (Hulbert and Wilson 1983, Towne and Owensby 1984).

Stand Basal Cover

Treatment interactions were not detected for basal cover and basal cover was only affected by harvest frequency. Plots harvested twice per summer had greater basal cover (11.4%; L.S.D. at 0.05 = 1.2) than non-harvested plots (9.9%) or plots harvested 3 times per summer (10.0%), and similar basal cover to plots harvested 1 time per summer (11.0%). Basal cover among species was 9.6% for switchgrass, 11.0% for big bluestem, and 11.1% for indiangrass. Basal cover among burn treatments was 10.1, 10.8, 10.5, and 10.0% for non-burned, March, April, and May burn dates, respectively. With respect to burning, these results differ from those reported by others. In mixed stands basal cover of the species used in the present study tend to increase with burning compared with competing species (Anderson et al. 1970, Kucera and Koelling 1964). With the monocultures used in this study, only treatments enhancing plant vigor of the individual species would increase basal cover.

Stand Tiller Density

Interactions among treatments were not identified for stand tiller density, but stand tiller density differed for species, for some burn dates, and for some harvest frequencies (Table 5). Big bluestem produced the most tillers and switchgrass the least. However, when harvested to a stubble height of 18 cm, big bluestem produced less forage mass than switchgrass (Cuomo et al. 1996). Switchgrass produced more erect tillers and heavier reproductive tillers (personal observation), whereas big bluestem produced many vegetative tillers which never grew above the 18-cm harvest height. These shorter tillers produced no harvested herbage, but did provide photosynthetically active tissue. This intact photosynthetic tissue may have enabled big bluestem to produce more photosynthates, and therefore, allocate more energy to storage tissue. This would enhance its ability to grow vigorously the next spring.

Table 5. Final stand tiller density in July 1991 for 3 warm-season grasses, 4 burn treatments, and 4 harvest frequencies.

Species	Tillers	Burn treatment	Tillers	Summer harvest frequency	Tillers
	(m^{-2})		(m^{-2})		(m^{-2})
Switchgrass	567	Non-burned	671	0	656
Big bluestem	1,108	March	942	1	811
Indiangrass	830	April	920	2	921
		May	806	3	952
LSD (0.05)	95		144		116

Stand tiller density increased as harvest frequency increased (average across all species and burn dates; Table 5). This concurred with other research (Peterson 1962, Reece et al. 1988) and has been attributed to increased light penetration and soil temperature (Rice and Parenti 1978). In this study, even though stand tiller density increased as harvest frequency increased, plant vigor decreased (Tables 1, 2 and 3). This result suggests that as harvest frequency increases, tillering occurs rather than energy storage (Tables 2, 3, and 5). Eventually, the increase in tillering, as opposed to energy storage with frequent harvests, would lead to low vigor and non-competitive plants. Other research supports the suggestion that stand vigor declines with long term heavy use (Heinrichs and Clark 1961, McKendrick and Sharp 1970, Buwai and Trlica 1977).

For all species and harvest treatments combined, burning increased tillering 32%. Increased tillering following burning has been reported by Rice and Parenti (1978), Hulbert (1984), and Svejcar and Browning (1988). Svejcar and Browning (1988) attributed increased big bluestem tillering to the release of dormant buds with burning.

Conclusions

Big bluestem had the most vigorous spring growth whether measured by etiolated tiller mass, number of etiolated tillers, or stand tiller density. However in this study, big bluestem did not produce as much forage mass as switchgrass (Cuomo et al. 1996). Thus, vigor may not always be related to forage production. Vigorous early-season growth by big bluestem may enhance its competitive status and may partially explain its dominance in ecosystems to which it is adapted.

Effects of harvest management on the plant vigor of these species occurred after 1 growing season. Further effects were not detected in 2 subsequent growing seasons. Two harvests before apical meristems elongated, coupled with an end-of-growing season rest, did not reduce plant vigor below that of a single harvest.

Burning did not affect plant vigor as measured in this study, but decreased productivity (Cuomo et al. 1996). Therefore, when developing grazing strategies plant vigor can be maintained with different spring burning management if adjustments in stocking rate are made to accommodate changes in productivity associated with burning.

Short term changes in plant vigor are often difficult to detect and measure in grasslands. In this study, mass of etiolated tillers gave an early indication of plant vigor and may provide a method for early identification of trends in plant vigor.

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Statement of Ownership, Management, and Circulation

(Act. of August 12, 1970, Sec. 3685, Title 39, United States Code)

1. *Title of Publication*: Journal of Range Management
2. *Date of Filing:* September 23, 1997
3. *Frequency of Issue*: Bimonthly
4. *Location of Office of Publication:* 1839 York Street, Denver, Colo. 80206
5. *Location of General Business Office:* Same
6. *Name and Address of:*
   Publisher: Society for Range Management, 1839 York Street, Denver, Colo. 80206
   Editor: Gary Frasier, 7820 Stag Hallow Road, Loveland, Colo. 80538
   Managing Editor: Craig Whittekiend, 1839 York Street, Denver, Colo. 80206
7. *Owner:* Society for Range Management, 1839 York Street, Denver, Colo. 80206
8. *Known Bondholders, Mortgages, etc.:* Membership
9. *For Completion by Nonprofit Organizations Authorized to Mail at Special Rates:* The purpose, function, and nonprofit status of this organization and the exempt status for Federal income tax purposes have not changed during preceding 12 months.
10. *Extent and Nature of Circulation*

	Avg. for 12 months	Actual for issue nearest filing date
A. *Total copies printed*	3,709	3,101
B. *Paid Circulation*		
1. *Dealers, counter sales*	0	0
2. *Mail subscriptions*	3,303	2,761
C. *Total paid circulation*	3,303	2,761
D. *Free distribution*	14	14
E. *Total distribution*	3,317	2,775
F. *Copies not distributed*	392	326
G. *Total*	3,709	3,101

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