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Growth responses of warm-season tallgrasses to dormant-season management

WALTER H. SCHACHT, ALEXANDER J. SMART, BRUCE E. ANDERSON, LOWELL E. MOSER, AND RICK RASBY

Authors are assistant professor, technologist, professor, and professor, Department of Agronomy, University of Nebraska-Lincoln, Lincoln, Nebr. 68583-0915; and associate professor, Department of Animal Science, University of Nebraska-Lincoln, Lincoln, Nebr. 68583-0908.

Abstract

A study on Conservation Reserve Program (CRP) land was established in southeastern Nebraska to determine the effect of dormant-season management on subsequent-year growth rates and yields of tallgrasses. The purpose of the management practices was removal of standing dead material and litter that negatively impact plant growth and grazing efficiency. Treatments consisted of a control with no residue manipulation and 5 residue manipulation practices including (1) October shredding and leaving residue; (2) October haying; (3) October intensive grazing; (4) March intensive grazing; and (5) spring prescribed burning. The study was conducted in 1994/95 and 1995/96 on a switchgrass (*Panicum virgatum* L.) monoculture and mixed stand of warm-season tallgrasses dominated by big bluestem (*Andropogon gerardii* Vitman) and little bluestem [*Schizachyrium scoparium* (Michx.) Nash]. The manipulation treatments effectively removed standing dead material without reducing yields in the growing season following application. Marked switchgrass tillers on the control plots increased ($P < 0.1$) in height at a more rapid rate than switchgrass on other treatments until late summer in both years. Rate of morphological development was similar ($P > 0.1$) for all treatments in 1995 and 1996. Rate of height increase and morphological development in big and little bluestem on the mixed grass site generally was comparable or slower on the manipulation treatments than the control in both years; however, big and little bluestem tillers grew relatively rapidly at the end of the 1995 growing season. Because the manipulation treatments generally did not increase tiller growth rates of the dominant grass species, potential harvest dates would be similar to those of untreated areas.

Key Words: Conservation Reserve Program, prescribed burning, mowing, high-intensity grazing

About 3.8 million ha of marginal cropland were seeded to perennial grasses in the northern Great Plains since 1985 as a result of the Conservation Reserve Program (CRP) (Osborn et al. 1995). Even with contract renewals, a significant amount of CRP land will come out of retirement in the next several years and as much as 30% of it may remain in grass for livestock grazing or hay production (Osborn et al. 1994). Many of these grass stands, however, will not be ready for grazing or haying the first year following contract expiration because little or no vegetation management (e.g., prescribed burning or grazing) has been applied to these grasslands during the 10 years of retirement.

Long-term nonuse of perennial grass stands commonly results in excessive accumulation of dead plant material and decreased tillering, production, and percentage ground cover (Weaver and Rowland 1952, Tueller and Tower 1979). Methods of rapidly returning such stands to a productive state appropriate for grazing or haying may include prescribed burning, mowing, and (or) intensive grazing. Each method stimulates tillering in warm-season grasses and reduces accumulated plant residue when properly applied (Holechek 1981, McNaughton 1983, Scifres and Hamilton 1993). Application of these residue manipulations modify the growing conditions of the site and potentially affect the growth rate and appropriate harvest dates of warm-season grasses. Numerous studies report that warm-season grasses respond to spring burns by starting growth earlier and growing faster early in the growing season because of increased surface light, soil temperatures, and nutrient availability (Curtis and Partch 1950, Ehrenreich 1959, Hulbert 1988). Effect of dormant-season mowing and grazing on the growth rate of warm-season grasses through the growing season is not well documented (Hulbert 1988). Knowledge of growth rate response of warm-season grasses to residue manipulations is valuable in planning harvest strategies, particularly the initial harvest date.

The purpose of the study was to determine the growth response of warm-season tallgrasses to specific residue manipulations applied in the dormant season prior to the first growing season of use. The objectives were to (1) determine growth rates of switchgrass (*Panicum virgatum* L.) in monocultures and big bluestem (*Andropogon gerardii* Vitman) and little bluestem [*Schizachyrium scoparium* (Michx.) Nash] in mixed grass stands in response to burning, mowing, and grazing in the dormant season and (2) determine the effect of the manipulation treatments on accumulated plant residue and current-year biomass yields.

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Study Area

The study was initiated in August 1994 on 2 sites of CRP land about 5 km south of Virginia, Gage County, Nebr. Average annual precipitation is 824 mm with 75% of the precipitation coming as rain during the growing season. Annual precipitation in 1995 and 1996 was 927 and 906 mm, respectively. Precipitation from April through September was 818 mm in 1995 and 667 mm in 1996. In both years, mean temperature for the growing season was about 1° C higher than the long-term average of 17.2° C. Site 1 was seeded to switchgrass in 1988. The monoculture was vigorous in 1994 with large, scattered switchgrass plants and small amounts of invader species such as common sunflower (*Helianthus annuus* L.) or velvetleaf (*Abutilon theophrasti* Medic.). The dominant soil is Judson silt loam (fine silty, mixed, mesic Cumulic Hapludoll) with 3 to 5% slopes. Site 2 was seeded in 1987 to a 5-way mixture of big bluestem, little bluestem, indiangrass [*Sorhastum nutans* (L.) Nash], switchgrass, and sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.]. In 1994, the site was a mixture of the 5 seeded species and a number of cool-season grasses and forbs, including smooth bromegrass (*Bromus inermis* Leyss.), red clover (*Trifolium pratense* L.), and yellow sweetclover [*Melilotus officinalis* (L.) Pall.]. Big bluestem and little bluestem were co-dominants and accounted for 60% of aboveground yields in August 1994. The site is terraced and soils are Shelby and Burchard clay loams (fine loamy, mixed, mesic Typic Argiudolls) with 8 to 12% slopes.

Methods

Each site was divided into 2 sets of 3 blocks, with slope as the block criterion. Each of 6 treatments were applied randomly to plots within each block. Treatments consisted of a control with no residue manipulation and 5 residue manipulation practices including (1) October shredding with residue left on the soil surface (shred); (2) October mowing with removal of plant material to simulate an end-of-season hay harvest (hay); (3) high-intensity grazing with cattle in October (graze October); (4) high-intensity grazing with cattle in March (graze March); and (5) prescribed burning in late April (burn). Treatments were applied to 1 set of plots at each site in 1994/1995 and to the other set of plots at each site in 1995/96. Dimensions of the plots were 12 X 15 m, except for the grazed plots which were 24 X 15 m.

Mid-October shred and hay treatments were selected to match that date when landowners could first harvest forage from CRP land. Shredding was accomplished using a tractor mounted shredder. Plant material was cut into about 20-cm segments and left on the plots. Haying was conducted using a flail harvester which collects the plant material in removable bags. Contents of the bags were discarded on an adjacent area. Cutting height for the 2 treatments was about 12 cm above ground level.

The graze October treatment also occurred shortly after the time when landowners would have been able to first graze their CRP pasture. A March grazing period coincided with calving for many livestock producers in Nebraska. Tallgrass stands are viewed favorably as calving pasture because of the cover they provide. Grazed plots were fenced and stocked with 3 to 4 dry cows ($\bar{x}$ 550 kg) for 3 to 5 days. Livestock remained on the plots until the standing vegetation was reduced by about 80%. High stocking density (about 100 AU ha^{-1}) was used as a means of approaching even distribution of defoliation, trampling, and manure. Cumulative herbage allowance on the mixed grass site was 2.4 kg dry matter per 100 kg live weight for a 3-day period. For the switchgrass site, cumulative herbage allowance was about 5.1 kg dry matter per 100 kg live weight for a 4.5-day period. The cows had free access to water but no mineral or supplemental feed was available to them while they were on the plots.

The burn plots were mostly backfired to ensure control of the fire. Prescribed burns were conducted on 27 April 1995 and 1 May 1996. Fine fuel loads for the switchgrass site were 18,500 kg ha^{-1} (S.E. = 2,900 kg ha^{-1}) in 1995 and 12,000 kg ha^{-1} (S.E. = 1,150 kg^{-1}) in 1996 whereas fuel loads for the mixed grass site were 6,000 kg ha^{-1} (S.E. - 960 kg ha^{-1}) in 1995 and 6,700 kg ha^{-1} (S.E. = 1,500 kg ha^{-1}) in 1996.

Growth rates of the dominant grass species at both sites were estimated in both years for each treatment. Twenty-five tillers of switchgrass in each plot at the switchgrass site and 25 tillers each of big bluestem and little bluestem per plot at the mixed grass site were randomly located and marked with colored wire at the beginning of the growing season. The height of each tiller was measured and stage of growth (Moore et al. 1991) was determined initially in mid-May and at 1- to 2-week intervals through the growing season.

Above-ground biomass yields were estimated at the end of the first growing season (early September) following application of treatments by collecting all plant material in randomly placed, 0.25-m^2 quadrats. Eight quadrats were sampled in each of the grazed plots and 4 quadrats were used in each of the other plots. Standing vegetation was clipped at ground level, hand-separated into current-year growth and standing dead, oven-dried at 60° C until weight was constant and weighed to the nearest 0.1 g. Litter in each quadrat also was gathered, dried, and weighed. Standing dead material included dead leaves and stems produced in previous years and remaining upright among current-year growth. Litter included all dead leaves and stems on the soil surface. Baseline data on yields of current-year growth, standing dead, and litter also were collected in September of each year prior to application of treatments.

Analysis of variance of the baseline standing crop data in each year indicated few differences among experimental units. Furthermore, the baseline standing crop data used as a covariate was not significant ($P > 0.1$) in the analysis of variance of the above-ground biomass yields in 1995 and 1996. Analysis of plant height and stage of growth was conducted using regression (SAS 1985) on mean plant height and morphological index for each experimental unit over time. Above-ground biomass and coefficients from regression analysis for plant height and morphological index were analzyed by analysis of variance (SAS 1985). Yield data and regression coefficients for each stand type were tested for homogeneity of variance over years to determine if statistical analysis could be conducted on data combined over the 2 years of study. Yield data were combined over years because variances were homogeneous. Variances of the regression coefficients were not homogeneous between years; therefore, regression coefficients were analyzed separately. Means were separated using a Fisher's protected LSD (Steel and Torrie 1980), and they were considered statistically different at $P < 0.1$.

Results and Discussion

Standing Dead Material and Litter

All manipulation treatments effectively removed standing dead material from the switchgrass and mixed grass stands (Table 1). Standing dead material on switchgrass control plots represented 27% of the total standing herbage, but was less than 3% of the total on the manipulated areas. Standing dead on control plots at the mixed grass site was about 15% of the total standing herbage, and less than 2% of the total on the manipulated areas.

Litter distribution within the plots was extremely variable and standard errors generally were very high at both sites. Only the burn and hay treatments reduced the amount of litter below ($P < 0.1$) control levels on the switchgrass site (Table 1). Fire consumed most of the litter and hay removed the standing vegetation which would have added to the litter. Litter amounts were reduced ($P < 0.1$) by the burn, hay, and graze treatments on the mixed grass site. Hoof action on grazed areas incorporated most of the litter into the soil, and also fragmented the dry litter which could have increased the rate of decomposition.

Growth Rates

Table 2 presents fitted polynomial coefficients for each species and treatment for tiller height and growth stage during the 1995 and 1996 growing seasons. Linear and quadratic effects were significant ($P < 0.1$) in most cases for both height and growth stage in 1995 and 1996. Figures 1 through 3 show growth stage and height changes for each species over the 11- to 12-week sampling period in each year.

Switchgrass tillers on control plots increased in height more rapidly in both years than on other treatments until late summer when growth in height of switchgrass was relatively slow for the control (Fig. 1). Switchgrass tillers on the control plots were 10 to 20 cm taller than tillers on manipulated plots by late June in both years. The mechanism(s) controlling this growth response on the control plots was not determined but it is possible that light flux and quality characteristics within the dense canopy of standing residue played a role in eliciting the response. Plant shoots growing in low light intensity commonly are tall and spindly because of accelerated cell division and elongation (Noggle and Fritz 1983). Numerous studies also implicate light quality as a mechanism affecting morphological development, such as tiller elongation rate (Ballare et al. 1991, Casal et al. 1985, 1987). Plant photoreceptors related to tiller elongation appear to respond to different levels of blue, red, or far-red irradiance. Tiller elongation rate

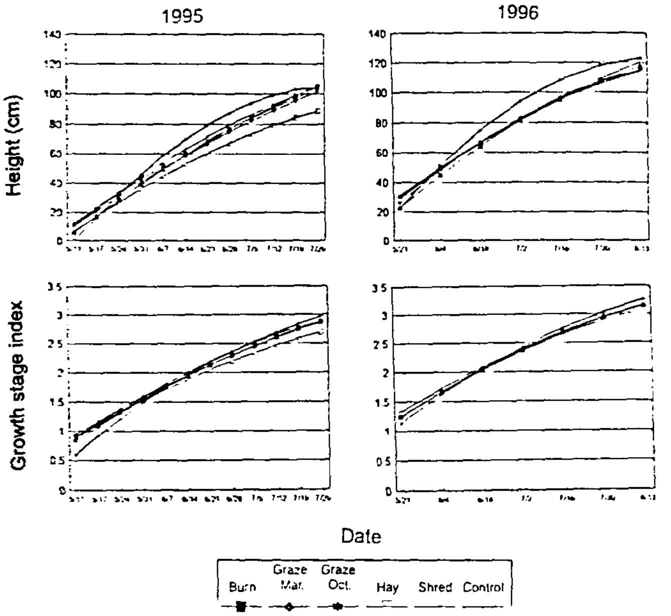

Fig. 1. Fitted curves for height and growth stage index of switchgrass tillers in response to various stand manipulation practices. Tillers were first measured on 11 May 1995 and 21 May 1996.

in grasses is stimulated in dense canopies because of low blue light irradiance (Ballare et al. 1991) or low red:far-red ratios (Casal et al. 1985, 1987).

Switchgrass on the manipulation treatments generally increased in height at a similar rate except in 1996 when growth rates were slower during the first part of the growing season for the graze October and hay treatments than for the other treatments (Table 2). Reasons for slow growth on the graze October and hay treatments were not evident. Growth stage index of switchgrass was similar for all treatments in both 1995 and 1996 (Table 2, Fig. 1).

Growth rate response of big bluestem to treatments was not consistent over the 2 years (Table 2). In 1995, big bluestem on the burn treatment increased in height at a comparable or slower rate than on the other treatments during the early part of the growing season, but grew at a relatively rapid rate toward the end of the season (Table 2, Fig. 2). Big bluestem tillers on the burn treatment in 1995 also developed to an advanced stage of growth more rapidly than they did on the other treatments. Rate of height increase and development of big bluestem in 1996 was similar for all treatments. In both years, average end-of-season height of big

Table 1. Mean yields of components of above-ground plant material in September for the switchgrass and mixed grass sites near Virginia, Nebr. averaged over 1995 and 1996.

Treatment	Switchgrass site: Standing dead	Switchgrass site: Litter	Switchgrass site: Current-year growth	Mixed grass site: Standing dead	Mixed grass site: Litter	Mixed grass site: Current-year growth
	(kg ha)					
Shred	9[b]	6,900[a]	9,590[ab]	0[b]	2,610[ab]	2,820[b]
Hay	0[b]	2,850[cd]	12,090[a]	20[b]	2,150[bc]	2,960[b]
Graze October	120[b]	5,230[ab]	9,760[ab]	10[b]	1,640[c]	3,190[b]
Graze March	320[b]	4,480[bc]	9,990[ab]	50[b]	1,610[c]	2,650[b]
Burn	0[b]	770[b]	10,520[ab]	0[b]	340[d]	4,230[a]
Control	2,870[a]	5,800[ab]	8,150[b]	430[a]	3,490[a]	2,520[b]

[a–c]Means with same letters within columns are not significantly different ($P < 0.10$).

Table 2. Linear and quadratic regression coefficients for tiller height and growth stage index for indicated species and stand manipulation practice when sampled in 1995 and 1996.

		Height						Index					
		1995			1996			1995			1996		
Grass species	Treatment	x	x^2	R^2	x	x^2	R^2	x	x^2	R^2	x	x^2	R^2
Switchgrass	Shred	11.354b	–0.298a	0.95	23.658bc	–1.180ab	0.99	0.23b	–0.006a	0.94	0.485b	–0.022a	0.98
	Hay	12.634b	–0.320a	0.98	21.407c	–0.819a	0.97	0.260b	–0.006a	0.95	0.460b	–0.020a	0.98
	Graze Oct	11.476b	–0.244a	0.99	21.116c	–0.835a	0.99	0.264b	–0.006a	0.95	0.467b	–0.019a	0.98
	Graze Mar	11.258b	–0.227a	0.98	25.776b	–1.376b	0.97	0.235b	–0.005a	0.96	0.501b	–0.023a	0.99
	Burn	12.629b	–0.274a	0.94	25.817b	–1.268b	0.98	0.250b	–0.005a	0.94	0.485b	–0.021a	0.98
	Control	19.435a	–0.756b	0.98	35.490a	–2.355c	0.97	0.351a	–0.011b	0.96	0.588a	–0.026a	0.99
Big bluestem	Shred	7.096ab	–0.293bc	0.97	11.977a	–0.793a	0.76	0.048bc	0.000b	0.79	0.201a	–0.012a	0.72
	Hay	8.086ab	–0.361cd	0.97	12.565a	–0.974a	0.75	0.059a	–0.002b	0.86	0.178a	–0.010a	0.69
	Graze Oct	7.077ab	–0.305bc	0.84	11.327a	–0.865a	0.91	0.045bc	0.000b	0.82	0.209a	–0.018a	0.65
	Graze Mar	6.638bc	–0.249b	0.92	13.717a	–1.122a	0.87	0.044bc	0.000b	0.91	0.146a	–0.006a	0.73
	Burn	5.413c	–0.025a	0.96	13.438a	–1.032a	0.76	0.036c	0.004a	0.94	0.160a	–0.006a	0.69
	Control	8.283a	–0.417d	0.91	12.820a	–1.030a	0.78	0.082a	–0.004c	0.83	0.186a	–0.015a	0.72
Little bluestem	Shred	2.151a	–0.033b	0.93	3.425bc	–0.108a	0.74	–0.012a	0.007a	0.95	0.057a	0.004a	0.59
	Hay	2.696a	–0.051b	0.88	3.957abc	–0.134ab	0.53	–0.017a	0.007a	0.88	0.090a	0.004a	0.53
	Graze Oct	2.825a	–0.096b	0.93	3.798bc	–0.115ab	0.80	0.022a	0.003a	0.88	0.109a	0.000a	0.60
	Graze Mar	2.277a	–0.047b	0.71	2.406c	0.015a	0.79	–0.011a	0.006a	0.76	0.084a	0.001a	0.62
	Burn	1.459a	0.112a	0.94	6.163a	–0.396c	0.77	–0.023a	0.010a	0.93	0.202a	–0.016a	0.59
	Control	3.203a	–0.093b	0.94	4.989ab	–0.334bc	0.53	–0.018a	0.007a	0.93	0.131a	–0.006a	0.62

[a–d]Means with same letters within columns and grass species are not significantly different (P < 0.10).

bluestem was between 40 and 50 cm for each treatment except for the burn treatment in 1995 when mean height of the marked big bluestem tillers was 65 cm. Mean stage index of big bluestem tillers on the burn treatment in 1995 was nearly 2.1 at season's end whereas it was less than 1.6 for other treatments. We were not able to identify factors causing differential growth rates in 1995 for big bluestem tillers from the burn treatment compared to other treatments. Growing conditions were favorable for plant growth during the last part of the 1995 growing season because air temperatures and rainfall in July and August 1995 were above the long-term averages for Virginia, Nebr. Favorable conditions, however, were comparable for all treatments.

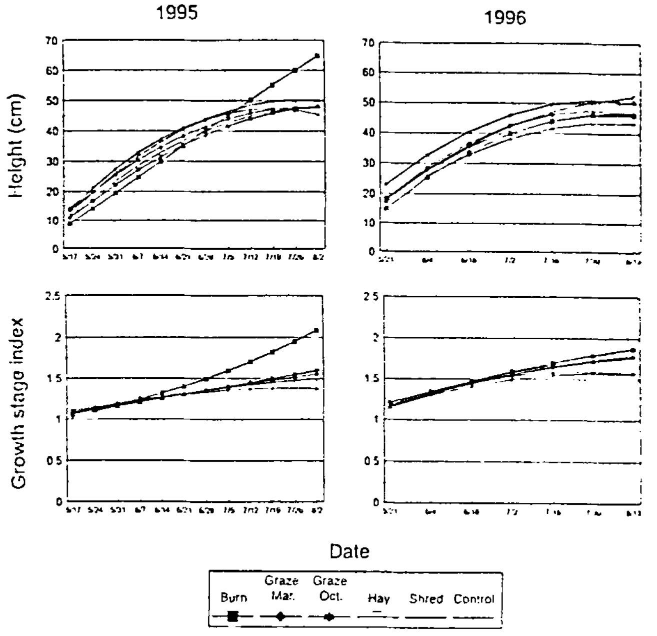

Fig. 2. Fitted curves for height and growth stage index of big bluestem tillers in response to various stand manipulation practices. Tillers were first measured on 17 May 1995 and 21 May 1996.

Little bluestem tillers on the burn plots increased in height during the last part of the 1995 growing season, whereas tiller height did not increase on the other plots (Fig. 3). Height of little bluestem on the burn treatment increased more rapidly than on the graze and shred treatments during the early part of the 1996 growing season; however, height increment dropped off more sharply toward the end of the season for the burn treatment than it did for the other manipulation treatments. Mean stage index of little bluestem was not affected by treatment in either year of this study. Little bluestem plants appeared to be damaged by prescribed burning as they initiated growth later in the spring than did plants on the other treatments; however, once they recovered, they increased in height relatively rapidly during the first part of the growing season in both years.

None of the 3 species responded to late-spring prescribed burning by initiating growth earlier or by increasing rates of morphological development and height increment. Hulbert (1969) reported similar results when comparing big bluestem growth on undisturbed sites and burned areas in Kansas; however, most studies report earlier and more rapid growth of warm-season tallgrasses on burned sites (e.g., Daubenmire 1968, Old 1969). Common reasons given for early and rapid growth are increased light intensity, soil temperature, and nutrient availability. Hulbert (1988) suggests that there are a number of interacting variables related to plant residue removal and soil surface modification which affect growth rate of grasses on recently burned areas, and each combination of variables influence the timing and rate of growth differently.

Yield of Current-Year Growth

Dormant-season application of the manipulation treatments at the 2 sites either did not affect end-of-season yield relative to the control or resulted in higher yields (Table 1). Without periodic removal of standing dead material and litter, tiller recruitment and biomass production of perennial grass stands commonly

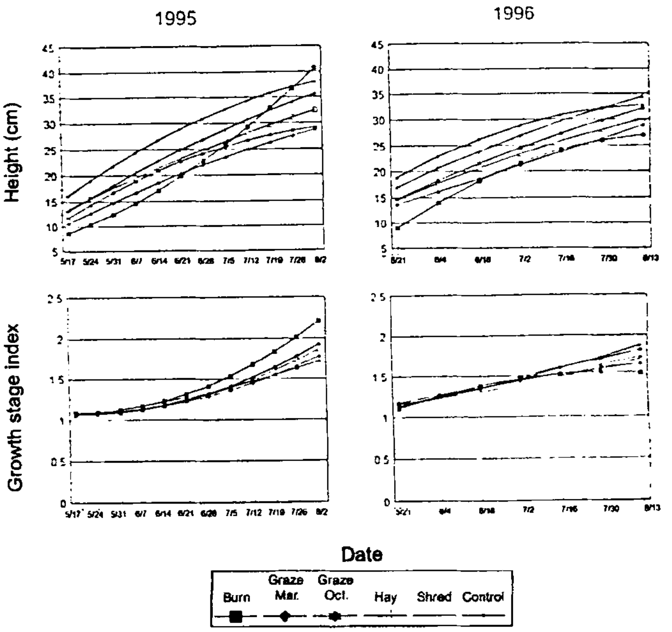

Fig. 3. Fitted curves for height and growth stage index of little bluestem tillers in response to various stand manipulation practices. Tillers were first measured on 17 May 1995 and 21 May 1996.

decline (Weaver and Rowland 1952, Tueller and Tower 1979). High variances associated with the yield estimates of current-year growth on the switchgrass site may have masked actual differences between the manipulation treatments and the control. Only the hay treatment had a higher (($P < 0.1$) yield of current-year growth than the control, although yields were not different ($P .> 0.1$) among manipulation treatments. The reason for the relatively high yields for the hay treatment is not readily apparent. Relative to the control on the mixed grass site, yield responded to burning ($P < 0.1$) but not to the other manipulation treatments. High yields of current-year growth for the burn treatment were largely due to relatively high yields of big bluestem. The favorable response of big bluestem to late-spring burns is well-documented (Towne and Owensby 1984, Hulbert 1986). Lack of yield response to the other manipulation treatments indicates that yield of the mixed grass site was not affected by removal of standing dead material and a 50% reduction of litter.

In conclusion, application of manipulation treatments generally did not increase the growth rate of marked tillers; therefore, potential harvest dates, either by grazing or haying, would be similar to untreated areas. Each treatment would be effective in removing standing dead material and improving potential utilization of forage by grazing animals in the first growing season following termination of CRP contracts. High-intensity grazing proved to be a promising practice and was as effective as the mowing and burning treatments in removing accumulated plant residue. The manipulation treatment selected by landowners to prepare CRP grasslands for future grazing or haying would depend largely on their resources and goals.

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