Mixed-grass Vegetation Response to Grazing Management Strategies in Kentucky Bluegrass-invaded Pastures

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The response of vegetation to seasonlong (SL), patch-burn (PB) and early intensive (EI) grazing and idle management strategies is being analyzed on Kentucky bluegrass (Poa pratensis L.)-invaded pastures in the mixed-grass prairie of the northern Great Plains. Research has shown that burning alone can reduce Kentucky bluegrass for a year, but a return to preburn levels the following year suggests that additional disturbance is necessary.

Burning followed by grazing may control Kentucky bluegrass proliferation by removing senescent material and promoting fire-tolerant grasses and forbs. Early grazing also may control Kentucky bluegrass by disturbing it during active growth, and promote native grasses and forbs by removing livestock before the grasses and forbs have received significant grazing pressure.

Results from 2017 suggest that plant communities under PB and EI grazing management have less Kentucky bluegrass, increased diversity and higher annual forage production than SL and idle plant communities. Analysis between study years is necessary to reveal if these trends are consistent and to confirm the mechanisms behind differences in the plant communities. Before these management strategies can be recommended for control of Kentucky bluegrass in invaded communities, additional research is required to evaluate their effects on livestock production.

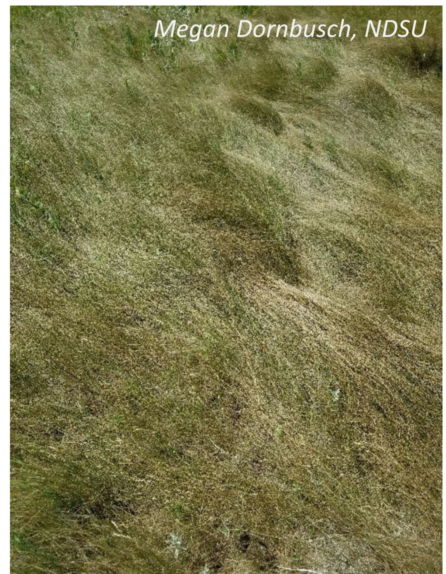
Introduction

The influence of grazing and fire on the evolution of the Great Plains grassland ecosystem is widely recognized (Fuhlendorf et al., 2009; Samson et al., 2004). These disturbances had complex spatial and temporal interactions that, when coupled with climatic variability, resulted in structurally and compositionally diverse plant communities across the landscape consisting of patches with varying degrees of disturbance (Fuhlendorf and Engle, 2004).

As European colonization replaced bison with domestic cattle, suppressed natural wildfires and introduced new species, the composition of the landscape changed dramatically (Samson and Knopf, 1994). Intensive agricultural production in North America has further impaired grassland communities by fragmenting the landscape and reducing their land area to small fractions of their native range.

Prairie fragments that remain today are increasingly threatened by overgrazing, lack of fire and exotic invasive species (Bahm et al., 2011). Outdated land management strategies further threaten prairie integrity by promoting homogeneity and invasive species spread (Fuhlendorf and Engle, 2004; Toledo et al., 2014).

Kentucky bluegrass (*Poa pratensis* L.) invasion in the mixed-grass prairie of the northern Great Plains has accelerated rapidly during the past 30 years but only recently has received attention (Toledo et al., 2014). Kentucky bluegrass is a cool-season, perennial grass native to northern Europe that is displacing mixed-grass prairie species and altering ecosystem properties by filling a previously unoccupied phenological niche and developing a dense root and thatch layer (Toledo et al., 2014).



Kentucky bluegrass monoculture in an idle pasture.

Thatch, a layer of live and dead plant material between the soil surface and canopy not only restricts the growth and establishment of native species by limiting their access to light but also alters surface hydrology (Taylor and Blake, 1982), soil structure (Herrick et al., 2001) and nutrient cycling (Badra et al., 2005). The forage quality of Kentucky bluegrass is high in the spring during active growth but decreases as dormancy occurs with heat and water stress experienced during summer, unlike native warm-season species (Hockensmith et al., 1997).

Grassland ecosystems managed for livestock production typically utilize grazing systems that promote uniform distribution and forage utilization (Fuhlendorf and Engle, 2001, 2004) such as seasonlong or rotational grazing (Bailey et al., 1998). Uniform disturbances promote homogeneity because they do not allow the development of areas with varying levels of disturbance intensity or frequency (Bailey et al., 1998; Fuhlendorf and Engle, 2004).

Kentucky bluegrass has the ability to regenerate quickly by rhizomes, and often develops a monoculture with a dense root and thatch layer that prevents the establishment of other species (Toledo et al., 2014). Traditional seasonlong grazing results in an increase in Kentucky bluegrass, implying that its invasion expands under uniform disturbance regimes (Smith and Owensby, 1978). Alternative grazing regimes are necessary to control

Kentucky bluegrass invasion but have yet to be developed and tested empirically (Toledo et al., 2014).

High-intensity grazing in early spring during active Kentucky bluegrass growth may have the potential to reduce its competitive pressure on later-emerging native species when grazing is absent. Research on early intensive grazing indicates that it can decrease or stabilize populations of Kentucky bluegrass, along with other nondesirable cool-season species in a warm-season prairie (Smith and Owensby, 1978).

Preliminary research on the effect of prescribed burns on Kentucky bluegrass invasion suggests fire may be an effective management tool. Studies in the Kansas Flint Hills (Anderson et al., 1970; Owensby and Smith, 1979) and South Dakota (Bahm et al., 2011; Engle and Bultsma, 1984) indicate that burning has the potential to decrease Kentucky bluegrass and other cool-season species cover.

Bahm et al. (2011) found that fire substantially reduced Kentucky bluegrass cover in the first year post-fire but its cover returned to pretreatment levels in the second year. Additional disturbance, therefore, is necessary to maintain the long-term benefits of burning for Kentucky bluegrass management (Bahm et al., 2011).

Furthermore, a study in the tallgrass prairie of Oklahoma found patch-burn grazing management to be effective for the suppression of sericea lespedeza (*Lespedeza cuneate*), an exotic invasive legume, because focused post-fire grazing maintained the plant at a young maturity level (Cummings et al., 2007). Patch-burn grazing not only should remove Kentucky bluegrass thatch and allow other species to move in, but it also should increase the carbon-to-nitrogen ratio and favor native grassland species, which have a competitive advantage in coping with low nitrogen (Wedin and Tilman, 1990).

To our knowledge, research comparing the effects of traditional seasonlong grazing management with alternative grazing management approaches on Kentucky bluegrass-invaded plant communities is lacking. By making these comparisons, our goal is to elucidate management strategies that not only promote diversity but also promote the functionality of invaded ecosystems for livestock production in the face of extensive Kentucky bluegrass invasion.

The objectives of this study were to:

- Determine the effects of idle, seasonlong, patch-burn and early intensive grazing management strategies on plant community composition
- Evaluate the effects of each management strategy on forage production

Grazing Treatment	Year	Average Head/Pasture	Date On	Date Off	Days Grazed	Stocking Rate (AUM/acre)
Early intensive (EI)	2011	41.7	May 2	June 6	35	0.98
	2012	46.0	April 13	May 24	41	1.26
	2013	50.0	May 6	June 7	32	1.10
	2014	43.6	April 30	June 6	37	1.19
	2015	44.7	April 23	June 2	40	1.27
	2016	41.3	May 12	June 7	26	0.72
	2017	33.0	May 2	June 10	39	0.86
Seasonlong (SL)	2011	15.0	May 13	Sept. 15	125	1.30
	2012	18.3	May 9	Sept. 21	135	1.85
	2013	15.7	May 23	Aug. 28	97	0.96
	2014	13.3	April 30	Sept. 2	125	1.23
	2015	13.0	April 23	Aug. 27	126	1.20
	2016	12.3	May 12	Sept. 1	112	0.92
	2017	9.7	May 2	Sept. 5	126	0.81
Patch-burn (PB)	2015	13.7	April 23	Aug. 27	126	1.22
	2016	13.0	May 12	Sept. 1	112	0.94
	2017	9.7	May 2	Sept. 5	126	0.79

Table 1. Stocking history of the early intensive (EI) and seasonlong (SL) grazing treatments for 2011 to 2017 and patch-burn (PB) treatments for 2015 to 2017 at the Central Grasslands Research Extension Center, Streeter, N.D.

Methods

This study is being conducted in the mixed-grass prairie of the northern Great Plains at the Central Grasslands Research Extension Center in Stutsman County northwest of Streeter, N.D. Various grazing experiments have occurred on the study site in previous years, but the site received only light summer grazing in 2009 and 2010 prior to the initiation of management strategies associated with this study.

In 2011, six of 12 pastures of roughly 30 to 40 acres each were assigned seasonlong (SL) grazing, while the other six were assigned early intensive (EI) grazing. In 2014, patch-burn (PB)

Treatment	Litter	Bare Ground	Kentucky Bluegrass	Smooth Brome	Western Snowberry	Western Wheatgrass	Green Needlegrass
Idle	92.9 ± 0.6	0.2 ± 0.1	46.8 ± 3.2	1.8 ± 0.6	5.3 ± 1.0	0.2 ± 0.1	0.5 ± 0.1
Seasonlong	96.7 ± 0.6	0.1 ± 0.1	47.8 ± 3.9	0.8 ± 0.3	3.2 ± 0.1	0.1 ± 0.1	0.8 ± 0.1
Patch-burn	90.2 ± 3.9	1.8 ± 1.7	27.0 ± 2.3	2.8 ± 0.3	3.7 ± 0.6	0.4 ± 0.2	1.3 ± 0.8
Early intensive	96.6 ± 0.6	0.2 ± 0.1	29.8 ± 0.7	2.8 ± 1.0	7.4 ± 1.8	0.1 ± 0.1	0.5 ± 0.4

Table 2. Relative canopy cover of litter, bare ground, Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), western snowberry (*Symphoricarpos occidentalis*), western wheatgrass (*Pascopyrum smithii*) and green needlegrass (*Nassella viridula*) in 2017. Values reflect percent relative canopy cover plus or minus the standard error of mean.

grazing was assigned to three of the 12 pastures, with three others assigned as idle pastures not to be grazed. The six pastures remaining were assigned to continue their original seasonlong or early intensive grazing treatments. Livestock are not rotated among pastures, and each pasture receives the same treatment each year.

SL-grazed pastures receive moderate stocking rates and are grazed mid-May through August. EI pastures receive similar stocking rates but are grazed at triple stock density for the first 1.2 months of the grazing season and then the cattle are removed. PB-grazed pastures receive the same stocking rate and grazing duration as SL pastures, but a patch-burn treatment is incorporated.

Beginning in 2014, a different fourth of each pasture has been burned annually when vegetation is dormant. Table 1 details the grazing start and end dates, average head per pasture, number of days grazed and stocking rate for each grazing treatment since 2011.

Prescribed burn on a patch-burn grazed pasture.

Vegetation response data have been collected July through early August each year since 2014. Due to differences in sampling procedures, we are able to report findings only from 2017 at this time.

We obtained information on plant community composition by sampling the relative canopy cover of all plant species, litter, bare ground, rock and fecal pat in 20 0.5- by 0.5-meter frames along 40-meter transects at four locations within each pasture. Canopy cover was estimated utilizing a modified Daubenmire cover class (1 = trace to 1 percent, 2 = 1 to 2 percent, 3 = 2 to 5 percent, 4 = 5 to 10 percent, 5 = 10 to 20 percent, etc.) and midpoint values were used for analysis (Daubenmire, 1959).

Species richness, evenness, and Simpson's and Shannon's diversity indices were determined for each pasture using ANOVA (analysis of variance) procedures. Mean species composition was analyzed with nonmetric multidimensional scaling (NMS) in PC-ORD 6.22 after compiling data from the 20 quadrats in each transect and averaging across the four transects for each pasture.

Annual forage production is determined for each pasture by clipping standing forage at peak production (mid to late July) from the interior of three caged grazing enclosures at four locations within each pasture. Harvested samples were oven-dried to constant weight and averaged across the three cages, four locations and three pastures for each treatment for analysis with ANOVA.

2017 Results

Relative Canopy Cover

We recorded a total of 89 plant species across the study's 12 pastures in 2017. Average relative cover of Kentucky bluegrass was higher in idle (46.8 ± 3.2 percent) and SL-grazed pastures (47.8 ± 3.9 percent) than EI (29.8 ± 0.7 percent) and PB (27.0 ± 2.3 percent). Table 2 details additional relative canopy cover information for litter (standing and basal litter combined) and bare ground, along with native and invasive species of interest.

Richness, evenness and diversity analyses for 2017 are detailed in Figure 1. Plant species richness averages the highest for patch-burn (S = 58, SE = 1) and early intensive (S = 56.67, SE = 2.73) grazed pastures, while richness was similar for seasonlong (S = 48.67, SE = 6.67) grazed and idle (S = 49, SE = 3) pastures. Average evenness and diversity indices were the highest for patch-burn grazed pastures followed by early intensive, seasonlong and idle treatments, respectively (see Figure 1).

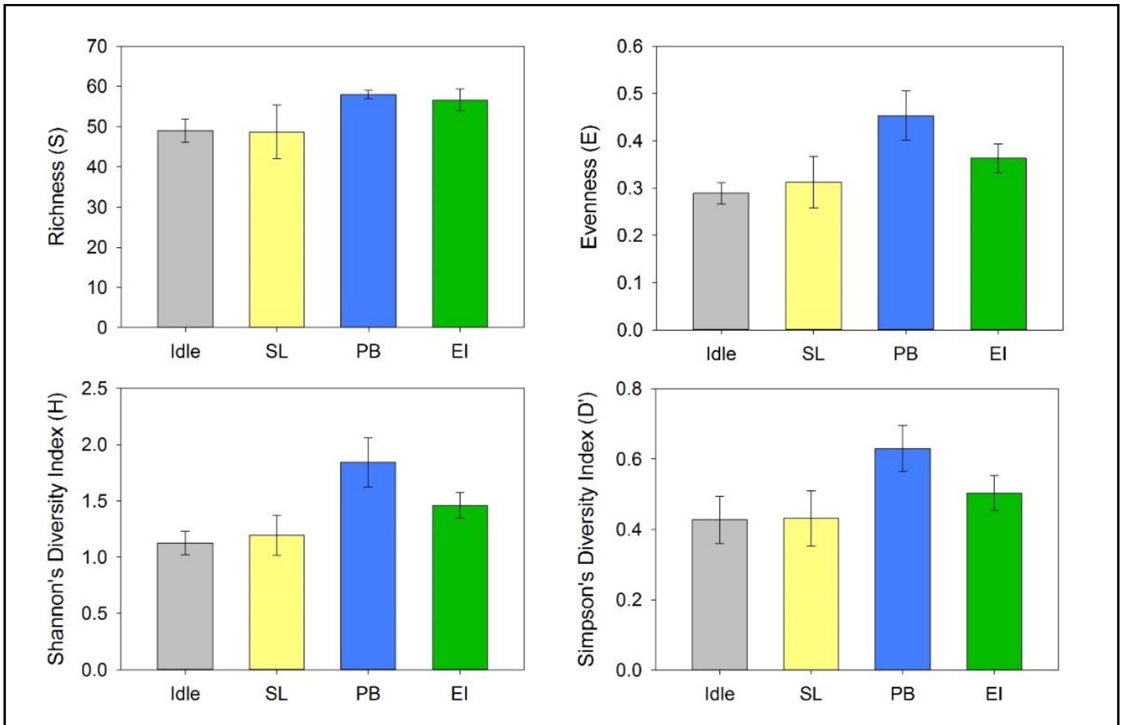


Figure 1. Richness, evenness, Shannon's Diversity and Simpson's Diversity indices on idle, seasonlong (SL), patch-burn (PB) and early intensive (EI) pastures from 2017. Error bars represent standard error of mean.

The NMS analysis on 2017 data indicate that the species composition of SL and idle treatments were similar to one another and different from EI and PB, which also were similar to one another (see Figure 2, next page). While Kentucky bluegrass was present at all sites in 2017, it was the most highly correlated with idle and SL treatments with values of 0.98 and 0.99, respectively. Native western wheatgrass and green needlegrass were the species most highly correlated with PB and EI treatments.

Annual Forage Production

Figure 3 details the results of annual forage production sampling for SL, PB, EI and idle pastures in 2017 ($p \leq 0.05$). The idle treatment (control) produced the lowest average standing biomass among all grazing treatments, while the early intensive treatment produced the highest and most variable average standing biomass among pastures. Biomass production was similar for seasonlong and patch-burn treatments.

Discussion

At this stage of the project, Kentucky bluegrass remains dominant in each pasture. However, PB and EI grazing management appear to control its dominance in the plant community and promote the diversity of other grasses and forbs.

As cattle select for recently burned areas of high nutritive value (Fuhlendorf and Engle, 2004), we expect that increased grazing pressure, coupled with the removal of senescent vegetation, mostly Kentucky bluegrass thatch, is controlling the proliferation of Kentucky bluegrass in PB pastures.

Removal of senescent vegetation also may permit increased annual forage production because it provides all plants with more access to light and space resources. We expect that early grazing may control Kentucky bluegrass proliferation by disturbing it during its early active growth. Further analysis of past years' data will reveal if these treatments have reduced or controlled Kentucky bluegrass dominance throughout the study.

This year also was marked by higher average biomass production in EI-grazed pastures than in PB, SL and ID, respectively. Although increased forage production is attractive for livestock, this measure does not account for differences in early and late-season production.

Furthermore, the EI treatment was marked by high western snowberry and litter cover, which are nondesirables that typically don't contribute to forage available for livestock. PB-grazed pastures, on the other hand, had slightly lower average annual forage production but also had the lowest average relative cover of litter and lower western snowberry cover, compared with EI-grazed and ID pastures.

While patch-burn and early intensive grazing management may be effective strategies to control Kentucky bluegrass dominance, livestock performance should be considered. Kentucky bluegrass production can vary widely, and experiences reduced nutritive value and annual production during dry or drought years (Hockensmith et al., 1997; Toledo et al., 2014).

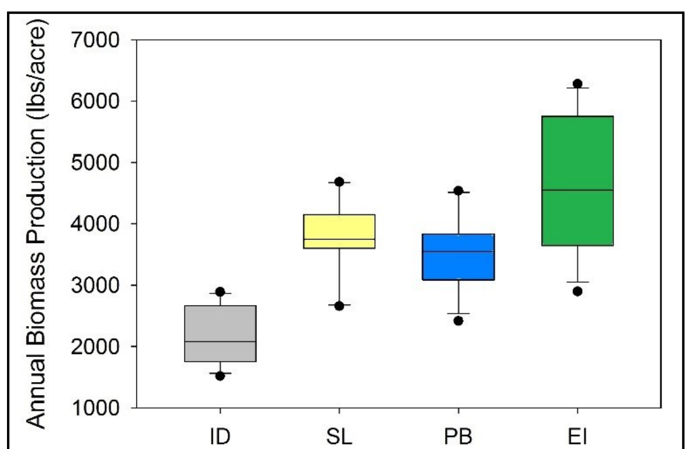


Figure 3. Annual biomass production (pounds/acre) for idle (ID), seasonlong (SL), patch-burn (PB) and early intensive (EI) pastures in 2017.

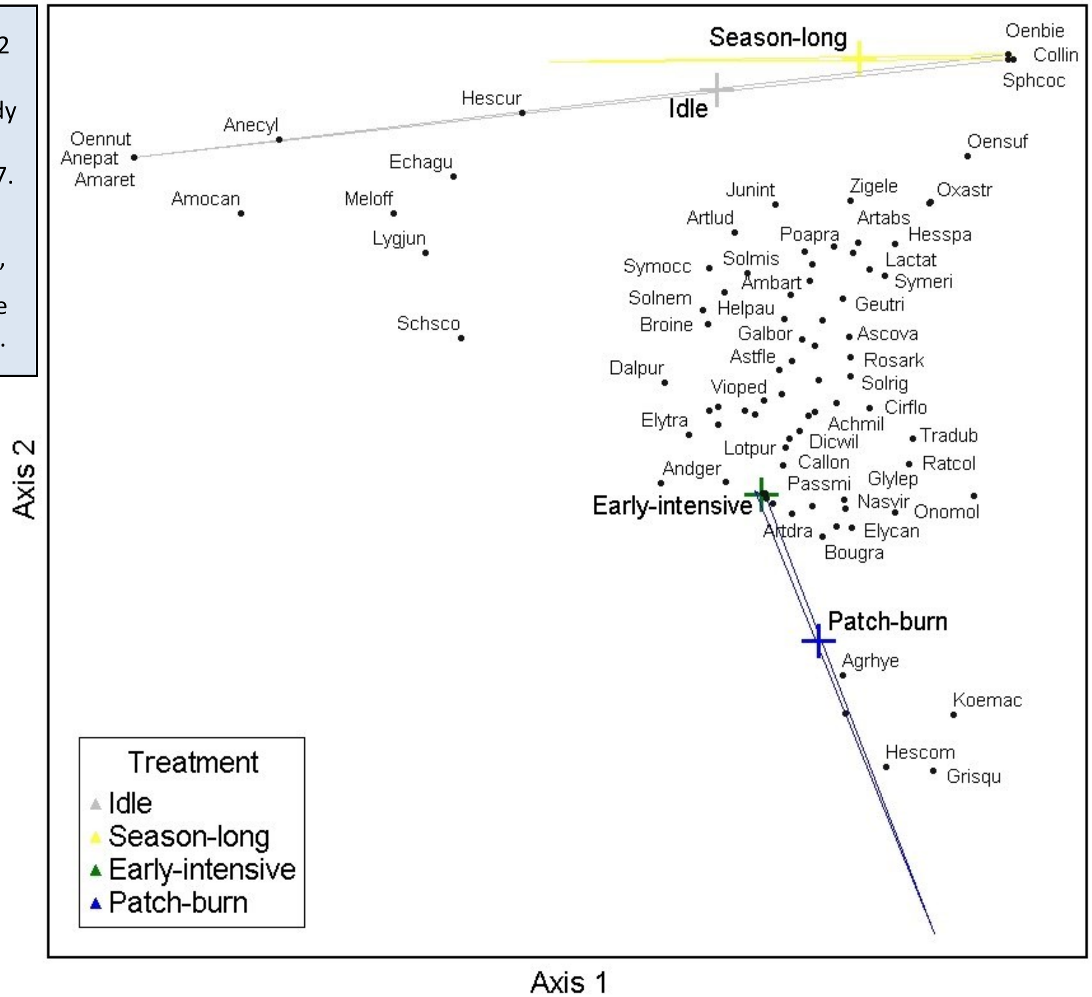


Figure 2. NMS ordination of axes 1 and 2 with regard to treatment, pastures and mean vegetation composition from study sites at the Central Grasslands Research Extension Center, Streeter, N.D., in 2017. Colored polygons represent treatments while individual points represent plant species; refer to table below for species' code names. Crosshairs indicate average species composition for each treatment.

Code	Scientific Name	Common Name
Achmil	*Achillea millefolium*	western yarrow
Amaret	*Amaranthus retroflexus*	rough pigweed
Ambart	*Ambrosia artemisiifolia*	common ragweed
Amocan	*Amorpha canescens*	leadplant
Andger	*Andropogon gerardii*	big bluestem
Anecyl	*Anemone cylindrica*	candle anemone
Anepat	*Anemone patens*	pasque flower
Arghye	*Agrostis hyemalis*	tickle grass
Artabs	*Artemisia absinthium*	wormwood
Artdra	*Artemisia dracunculus*	green sagewort
Artlud	*Artemisia ludoviciana*	cudweed sagewort
Ascova	*Asclepias ovalifolia*	ovalleaf milkweed
Astfle	*Astragalus flexuosus*	slender milk-vetch
Bougra	*Bouteloua gracilis*	blue grama
Broine	*Bromus inermis*	smooth brome
Callon	*Calamovilfa longifolia*	prairie sandreed
Cirflo	*Cirsium flodmanii*	Flodman's thistle
Collin	*Collomia linearis*	collomia
Dalpur	*Dalea purpurea*	purple prairie-clover
Dicwil	*Dichanthelium wilcoxianum*	Wilcox's panic grass
Elycan	*Elymus caninus*	bearded wheatgrass
Elytra	*Elymus trachycaulus*	slender wheatgrass
Galbor	*Galium boreale*	northern bedstraw
Geutri	*Geum triflorum*	prairie smoke
Glylep	*Glycyrrhiza lepidota*	wild licorice
Grisqu	*Grindelia squarrosa*	curly-cup gumweed
Helpau	*Helianthus pauciflorus*	stiff sunflower
Hescom	*Hesperostipa comata*	needle-and-thread

Code	Scientific Name	Common Name
Hescur	*Hesperostipa curtiseta*	western porcupine grass
Hesspa	*Hesperostipa spartea*	porcupine-grass
Junint	*Juncus interior*	inland rush
Koemac	*Koeleria macrantha*	prairie Junegrass
Lactat	*Lactuca tatarica*	blue lettuce
Lotpur	*Lotus purshianus*	deer vetch
Lygjun	*Lygodesmia juncea*	skeletonweed
Meloff	*Melilotus officinalis*	yellow sweetclover
Nasvir	*Nassella viridula*	green needlegrass
Oenbie	*Oenothera biennis*	common evening primrose
Oennut	*Oenothera nuttallii*	Nuttall's evening primrose
Oensuf	*Oenothera suffrutescens*	scarlet gaura
Onomol	*Onosmodium molle*	false gromwell
Oxastr	*Oxalis stricta*	yellow wood sorrel
Passmi	*Pascopyrum smithii*	western wheatgrass
Poapra	*Poa pratensis*	Kentucky bluegrass
Ratcol	*Ratibida columnifera*	prairie coneflower
Rosark	*Rosa arkansana*	prairie rose
Schsco	*Schizachyrium scoparium*	little bluestem
Solmis	*Solidago mollis*	soft goldenrod
Solnem	*Solidago nemoralis*	gray goldenrod
Solrig	*Solidago rigida*	stiff goldenrod
Sphcoc	*Sphaeralcea coccinea*	scarlet globe mallow
Symeri	*Symphyotrichum ericoides*	white aster, heath aster
Symocc	*Symphoricarpos occidentalis*	western snowberry, buckbrush
Tradub	*Tragopogon dubius*	goat's beard
Vioped	*Viola pedatifida*	larkspur violet
Zigele	*Zigadenus elegans*	death camas, white camas

Although burning initially removes all standing forage, post-fire conditions typically provide increased forage quality because most native species are fire-tolerant and have nutritious regrowth. For example, research has shown that little bluestem (*Schizachyrium scoparium*), a native warm-season forage species, does not experience adverse effects from burning (Limb et al., 2011a).

Furthermore, research indicates that cattle performance responds the same under PB grazing management as traditional SL stocking (Limb et al. 2011b). Consequently, further research is required to evaluate cattle performance differences among SL, PB and EI grazing management in Kentucky bluegrass-invaded rangelands.

Further analysis of all study years combined will reveal overall responses of vegetation composition and annual production to each grazing treatment. Although we expect Kentucky bluegrass to persist as the dominant plant species, PB and EI grazing management may control its proliferation enough to promote the abundance and diversity of other grasses and forbs. Without active land management, the invasion of Kentucky bluegrass in the mixed-grass prairie likely will result in homogeneous plant communities with impaired forage quality and production across the landscape.

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Cattle on a recently burned patch.