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Five Years of Annual Prairie Burns

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Abstract. A prairie site at Pipestone National Monument in southwestern Minnesota was burned each spring from 1983-1987. During the past century of use, much of the site had been invaded by various, non-native, cool-season grasses and broadleaf weeds. Also, various woody species have invaded parts of the site. Annual burns generally induced positive changes in native remnants, primarily with big bluestem (*Andropogon gerardii* Vitman) and prairie dropseed (*Sporobolus heterolepis* A. Gray) increasing cover from 6.4 to 21.0%. Cover of native forbs also increased, from 6.5 to 12.8%, due to increased vigor of existing plants and establishment of new individuals. While some tree and shrub species were permanently damaged, wild plum (*Prunus americana* Marsh), chokecherry (*Prunus virginiana* L.), and smooth sumac (*Rhus glabra* L.) re-sprouted from underground parts each year and were able to maintain or slightly increase pre-burn cover levels, although stature was reduced. Dense stands of quackgrass (*Agropyron repens* Beauv.) were reduced in height and vigor, but, unlike stands dominated by other species, were not open to establishment of prairie species. In general, while prescribed burning triggered increases of diversity, cover, and vigor of native prairie species, this was not a uniform effect across the site as most changes occurred within and along the edges of existing prairie remnants. Essentially no changes were observed within the large stands of quackgrass in which additional suppression of the sod is required, which could be accomplished by delay of spring burning, summer mowing, and plantings of native plant materials.

Key Words. prairie restoration, prescribed burning, Pipestone National Monument, Minnesota

INTRODUCTION

The value of fire in prairie management has been recognized at Pipestone National Monument since 1971 when a wildfire induced positive effects on a native prairie tract. Later, a prairie management plan was developed by the U.S. National Park Service (Landers 1975) in order to restore prairie vegetation in parts of the Park which had been subject to various disturbances, including alien plant invasions. Spring burns, varying in frequency from one in three years to one in four years, were considered to be an integral part of the plan. Due to various constraints and concerns, however, the restoration work was not accomplished, and the National Park Service later funded a more extensive prairie investigation from 1982-1985. As part of this effort, prescribed burning trials were conducted on a small, degraded prairie tract from 1983-1987. The purpose was to determine if annual, long-term spring burns could be used as a measure to accomplish the objectives of (1) controlling alien woody and herbaceous plants; and (2) improving native plant diversity, abundance and cover on the site (Becker *et al.* 1986).

STUDY AREA

Pipestone National Monument is located in southwestern Minnesota within a hilly, elevated region known as the Prairie Coteau. The Park consists of about 114 ha located within a glacially-formed valley just north of the city of Pipestone. A wide variety of vegetation types occur on the Park landscapes including dry, mesic, and wet grassland, shrubland, and woodland. A quartzite escarpment bisects the area in a northwest-southeast direction, and is a topographically prominent feature. The study was conducted on 5.1 ha contained within the Circle Trail (Figure 1). This area is bounded by the escarpment on the east and the visitor center on the west. Lake Hiawatha, a shallow impoundment, and Pipestone Creek are located within the area, and a small drainageway (woody draw) crosses the area about 90 m downslope and west of the escarpment. There are no records of the site being burned since the time of settlement. Original prairie vegetation upslope of the draw developed on shallow and rocky soils and was dominated by short and mid grasses while the deeper soils downslope of the draw supported tallgrass prairie. The site has been managed for various recreational activities during the past century by local and Federal interests. Both upslope and downslope prairie types have been extensively degraded by the invasion of numerous non-native cool-season grasses leaving only isolated remnants of native prairie sod. These remnants occupied less than 25% percent of the area prior to initiation of the study. Invading grasses were Kentucky bluegrass (*Poa pratensis* L.), smooth brome (*Bromus inermis* Leyss.), and quackgrass (*Agropyron repens* Beauv.). Also, closed stands of snowberry (*Symphoricarpos occidentalis* Hook.) developed on deeper soils. Small patches of Canada thistle [*Cirsium arvense* (L.) Scop.] and field bindweed (*Convolvulus sepium* L.) were occasionally found within the snowberry stands. In the woody draw, mixed stands of buckthorn (*Rhamnus cathartica* L.), tatarian honeysuckle (*Lonicera tatarica* L.), green ash (*Fraxinus pennsylvanica* Marsh), and other woody species had developed, overtopping and suppressing prairie species. In other parts of the prairie, only isolated green ash trees or small patches of chokecherry (*Prunus virginiana* L.), smooth sumac (*Rhus glabra* L.), wild plum (*Prunus americana* Marsh), or buckthorn had established.

Most native cover within the prairie remnants prior to the study was composed of prairie dropseed (*Sporobolus heterolepis* A. Gray) and big bluestem (*Andropogon gerardii* Vitman). The former was most abundant in the rock outcrop prairie, while the latter was confined to the deeper soil prairie downslope of the woody draw. Native forb cover was sparse in both prairie types, especially spring and early summer forms. Late summer and fall forb flora was more abundant but consisted mostly of goldenrods (*Solidago spp.*).

METHODS

Prescribed spring burns were conducted annually from 1983 through 1987, generally from mid to late April when the cool-season grasses had initiated good growth and were 10-15 cm or less in height. In 1987, however, the growing season arrived earlier and burning was delayed until early May. At that time the cool-season grasses were 15-25 cm in height, and woody plants had considerable foliage. Fire intensity during the study was generally considered to be low to moderate, except during the first year when high fuel levels were present.

Annual pre and post-burn qualitative floristic surveys were conducted to determine site-wide responses, while a quantitative sampling procedure was developed to assess changes in plant communities and to determine the individual responses of each species. The quantitative procedure included use of line transect, quadrat and point methods. A transect, 275 m long, formed the alignment for all methods. It extended from the high quartzite ledge on the east to a lowland area near the visitor center on the west. The transect was divided into nine segments, each 30 m in length. The positions and extent of major plant communities (stands of smooth brome, quackgrass, Kentucky bluegrass, snowberry, big bluestem, prairie dropseed, etc.) were recorded along the transect. Also, percent foliage cover of all bunch-forming grasses and forb species encountered along the transect was determined. For

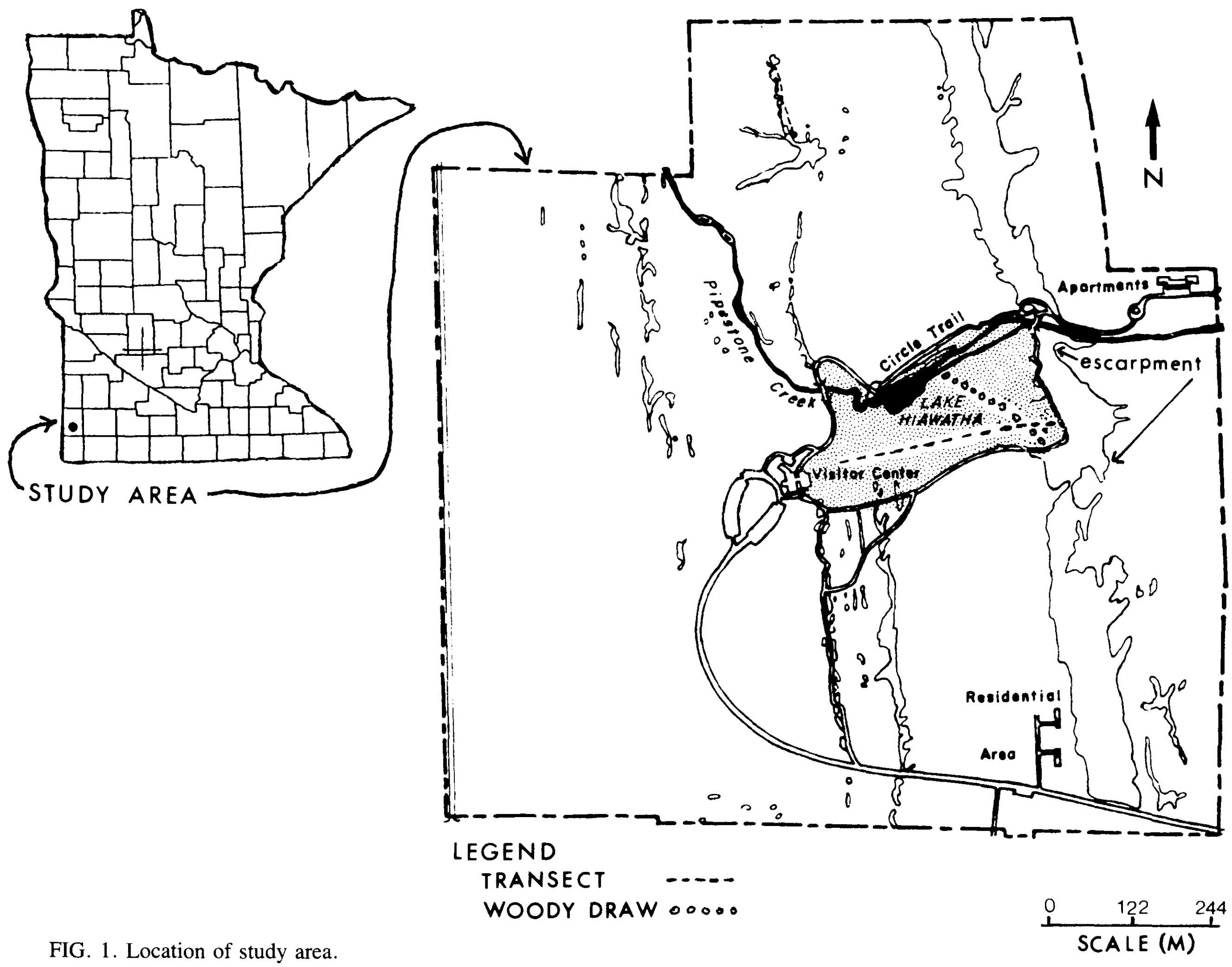

FIG. 1. Location of study area.

single-stalked, cool-season grasses such as Kentucky bluegrass, quackgrass, and smooth brome, 450 uniformly spaced points (0.6 m) along the transect were used to assess percent foliage cover. Each point was projected to the ground from the survey tape and the percent of foliage "hits" was recorded. Ten rectangular quadrats, each 0.10 m^2, were placed at 30-m intervals along the transect, and foliage cover in each plot was estimated by the class interval method of Daubenmire (1959). Heights of the major community dominants were determined within the quadrats. Frequency was determined from presence data obtained within the quadrat and transect microplots.

Within the line transect and quadrat microplots, foliage cover was obtained twice in both early and late season during 1983 and 1984, but only once during 1985 and 1987. Point foliage cover data for the cool-season grasses were taken only in early season during three years (1984, 1985, and 1987). Additional sampling details and a list of plant taxa found is reported in Becker *et al.* (1986). Agradient and soil depth survey was made along the transect in order to define vegetation-soil-slope relationships and is published elsewhere (Becker *et al.* 1986).

RESULTS

Most native remnant stands remained relatively stable during the treatment period, with the exception of those containing snowberry and big bluestem as major or minor components. Big bluestem expanded along the westerly or lower 150 m of the transect (Table 1), invading either 1) adjacent, nearly closed stands of snowberry having only a sparse understory of Kentucky bluegrass, or 2) adjacent, herbaceous stands where smooth brome, Kentucky bluegrass or quackgrass were dominant and formed the canopy. From transect community position and cover data, it was estimated that about 70% of the expansion of big bluestem cover (24.4 m) resulted from invasion of previously open or closed snowberry stands. Dense, monotypic stands of quackgrass, however, remained very persistent despite the annual fires and reduction of vigor. Stand location and limited frequency and foliage cover data indicated that quackgrass even expanded slightly into adjacent stands of snowberry, Kentucky bluegrass, and smooth brome where big bluestem was absent. Patches of broadleaf aliens, such as Canada thistle, decreased over time, while hedge bindweed disappeared (Table 2). Stand location data also suggested that smooth sumac and wild plum invaded slightly into fire-stressed cool-season grass sod. A stand of bur oak (*Quercus macrocarpa* Michx.) also resisted fire, but green ash and tatarian honeysuckle were susceptible to the burns. A few isolated individuals of buckthorn also exhibited sensitivity, but buckthorn thickets in the draw were not exposed to fire.

One of the most striking changes in the prairie was the reduction in shoot and foliage height of both snowberry and the cool-season grasses. Snowberry height decreased from 1 to 0.5 m, Kentucky bluegrass from 0.6 to 0.3 m, quackgrass from 0.6 to 0.3 m, and smooth brome from 0.6 to 0.4 m (Figure 2). Another obvious change was lack of flowering and seed production in the cool-season grasses during this period. Native grass species on the other hand, including big bluestem, prairie dropseed, and Scribner's

Table 1. Increases in linear extent (m) of big bluestem stands during the study period (1983-1987).

Transect	1983	1984		1985	1987	Change
Segment (m)	Summer	Spring	Summer	Spring	Summer	
	m					
0-122	Shallow soil mid-grass prairie and woody draw; big bluestem stands absent.					
122-153	0	0	0	0	0.5	+0.5
153-183	4.7	6.2	12.4	11.5	13.6	+8.9
183-214	0.6	0.6	0.6	0.6	8.4	+7.8
214-244	1.9	5.0	3.1	5.0	6.8	+4.9
244-275	3.3	10.2	5.3	12.4	12.1	+8.8
Total by year	10.5	22.0	21.4	29.5	41.4	+30.9

Table 2. Transect foliage cover (%) in the study area. Nomenclature from Great Plains Flora Association (1986). Dashed lines (——) indicate that this species was not evaluated on the date listed. Trace levels (tr) refer to values less than 0.1% cover.

	Cover					
	1983		1984		1985	1987
Species	Spring	Summer	Spring	Summer	Spring	Summer
	%					
Grasses:						
Agropyron repens	——	——	9.1	——	10.7	26.4[1]
Andropogon gerardii	2.1	2.2	4.8	3.7	8.7	10.7
Andropogon scoparius	0.0	0.1	0.0	0.1	0.0	0.0
Bouteloua curtipendula	tr	0.2	tr	0.3	0.0	0.7
Bouteloua gracilis	0.7	0.2	0.2	0.2	0.8	0.4
Bromus inermis	——	——	21.3	——	22.4	26.4[1]
Dichanthelium oligosanthes	tr	——	0.4	0.2	0.7	1.3
Muhlenbergia cuspidata	0.0	0.0	0.0	0.0	0.0	0.1
Panicum virgatum	0.0	0.0	0.0	0.0	0.0	0.1
Poa pratensis	——	——	32.2	——	15.6	22.0
Spartina pectinata	0.1	0.1	0.1	0.6	0.4	0.4
Sporobolus heterolepis	3.6	3.9	4.3	4.1	6.3	6.8
Stipa spartea	tr	tr	0.6	0.6	0.9	0.3
Forbs:						
Achillea millefolium	tr	tr	tr	tr	0.0	tr
Ambrosia psilostachya	1.6	3.1	4.9	4.0	0.9	5.3
Anenome canadensis	0.1	0.0	0.0	0.0	0.0	0.0
Apocynum sp.	tr	0.0	0.1	0.0	0.0	0.0
Artemisia ludoviciana	0.1	0.2	0.1	0.3	0.4	0.9
Asclepias sp.	0.0	0.1	0.1	0.0	0.0	0.0
Asparagus officinale	0.1	0.1	0.2	0.1	0.0	0.0
Aster ericoides	0.5	0.9	1.3	2.3	1.4	1.9
Aster oblongifolius	0.0	tr	0.0	0.2	0.0	tr
Cirsium arvense	0.1	0.2	0.2	0.1	0.1	0.1
Convolvulus sepium	0.1	0.2	0.1	0.1	0.2	0.0
Conyza canadensis	tr	0.0	0.0	0.0	0.0	0.0
Erigeron sp.	0.1	0.0	0.3	tr	tr	tr
Glycyrrhiza lepidota	0.3	tr	0.1	0.2	0.3	0.4
Helianthus maximiliani	0.0	0.0	0.0	0.0	0.0	0.1
Helianthus rigidus	0.6	1.0	0.8	1.1	1.6	1.0
Heuchera richardsonii	0.1	tr	0.0	0.0	tr	0.0
Lithospermum sp.	0.1	0.0	0.0	0.0	tr	0.0
Medicago lupulina	0.0	0.0	0.1	0.0	0.0	0.0
Monarda fistulosa	0.2	0.1	0.0	0.2	tr	0.2
Physalis sp.	tr	0.0	0.0	0.0	0.0	0.0
Potentilla arguta	0.2	0.1	0.1	0.0	0.3	0.4
Polygonum coccineum	0.1	0.1	0.2	tr	0.2	0.1
Psoralea argophylla	0.1	tr	0.0	0.0	0.2	0.0
Ratibida pinnata	0.0	tr	0.0	0.0	0.0	0.1
Silene antirrhina	0.0	0.0	tr	0.0	0.0	0.0
Solidago canadensis	1.0	1.3	0.9	0.4	[2]	0.2
Solidago missouriensis	1.0	2.4	0.4	1.6	3.3	1.9
Solidago rigida	0.4	0.3	0.2	0.4	[2]	0.4
Thalictrium dasycarpum	0.1	0.0	tr	0.0	0.0	0.0
Tradescantia bracteata	tr	0.0	0.0	0.0	0.2	0.0
Veronicastrum virginicum	0.0	0.1	0.0	tr	0.1	0.1
Vicia americana	0.0	0.0	0.2	0.0	0.0	0.0

Woody Plants:						
Amorpha canescens	2.0	2.5	3.1	2.8	4.1	1.7
Amorpha fruticosa	0.1	0.2	0.1	0.1	0.1	0.1
Fraxinus pennsylvanica	2.8	4.9	1.6	3.0	1.3	2.4
Lonicera tatarica	1.2	1.9	1.2	0.8	0.1	0.0
Parthenocissus inserta	0.4	0.7	——	——	——	——
Prunus americana	0.5	0.4	0.7	1.4	0.6	1.3
Prunus pumila var. *besseyi*	0.3	0.7	0.2	0.7	0.8	0.4
Prunus virginiana	3.5	1.0	3.5	2.7	0.9	1.8
Quercus macrocarpa	2.0	0.9	2.0	0.9	0.9	2.4
Rhamnus cathartica	1.4	2.0	0.9	3.0	2.6	2.4
Rhus glabra	1.7	1.6	1.7	1.4	2.4	3.0
Ribes missouriense	0.2	0.2	0.2	0.2	0.2	——
Rosa arkansana	1.3	2.2	1.4	1.8	2.9	1.6
Rubus occidentalis	tr	0.2	0.1	0.2	0.1	——
Spiraea alba	0.0	0.0	0.0	0.0	0.0	tr
Symphoricarpos occidentalis	3.7	10.0	6.3	9.6	9.5	5.2
Toxicodendron rydbergii	1.6	0.1	0.4	——	0.7	——
Ulmus americana	0.0	0.2	0.6	0.2	0.2	0.0

Other prairie plants (in study area but not sampled):

Aster novae-angliae, Anenome caroliniana, Antennaria neglecta, Galium boreale, Helianthus tuberosus, Liatris punctata, Mentha arvensis var *villosus, Penstemon gracilis, Silphium perfoliatum, Stellaria longifolia, Solidago gigantea, Talinium parviflorum, Taraxacum officinale, Verbena stricta, Verbena hastata, Viola pedatifida*

[1]Data for smooth brome and quackgrass pooled in 1987, as plants in low vigor condition were difficult to differentiate.
[2]Data not collected separately for three species of goldenrods in 1985.

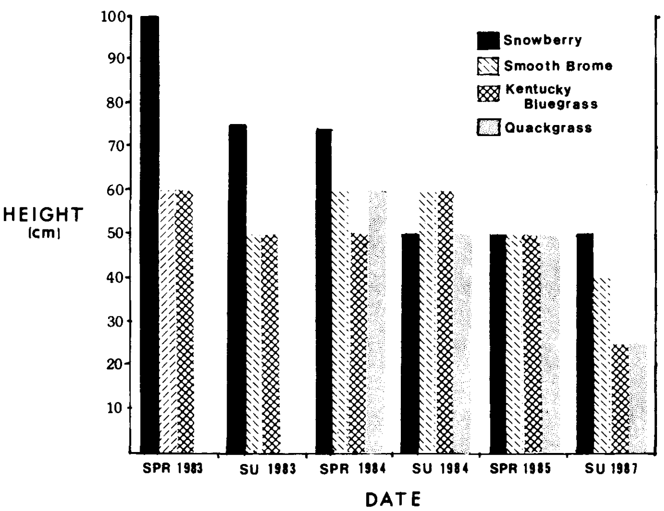

FIG. 2. Height changes of snowberry and some cool-season grasses.

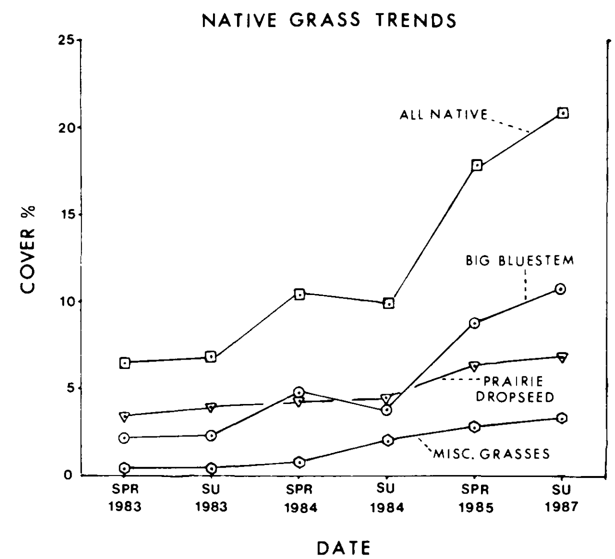

FIG. 3. Native grass cover changes (1983-1987). Miscellaneous grasses referred to include sideoats grama, blue grama, Scribner's panicgrass, porcupine grass, little bluestem, and plains muhly.

panicgrass [*Dichanthelium oligosanthes* (Schult.) Gould var. *scriberianum* (Nash) Gould] exhibited vigorous growth each year, producing numerous flowering culms and apparently viable seed.

Native grass cover increased from 6.4 to 21.0% (Figure 3). Much of this expansion is attributed to spread of the big bluestem community as previously described. Prairie dropseed was the major increaser in the shallow soil prairie, but Scribner's panicgrass, prairie cordgrass (*Spartina pectinata Trin.),* and sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.] also increased. Limited coverage of blue grama [*Bouteloua gracilis* (H.B.K.) Lag. *ex* Griffiths], porcupine grass (*Stipa spartea* Trin.), and little bluestem [*Andropogon scoparius* (Michx.) Nash] were present but no change was apparent (Table 2). All native grasses were in reproductive condition each year, which is considered a favorable response to fire. In 1987 switchgrass (*Panicum virgatum* L.) first appeared on lower slopes along the edge of the woody draw, while plains muhly [*Muhlenbergia cuspidata* (Torr.) Rydb.] was first observed along the upper slopes near the escarpment.

Foliage cover of cool-season grasses decreased only about 10%. This is attributed largely to reduction of Kentucky bluegrass and possibly that of smooth brome (Table 2). Quackgrass increased slightly in cover even though aerial parts exhibited low vigor.

Species richness of prairie forbs increased as a result of the annual fire treatments. Additional species encountered during post burn surveys were Culver's root [*Veronicastrum virginicum* (L.) Farw.], slender penstemon (*Penstemon gracilis* Nutt.), New England aster (*Aster novae-angliae* L.), wild bergamot (*Monarda fistulosa* L.), cup plant (*Silphium perfoliatum* L.), blazing star (*Liatris punctata* Hook.), and fringed loosestrife (*Lysimachia ciliata* L.). Of these species, only Culver's root and wild bergamot were located within the microplots.

Large increases in foliage cover along the transect segments were noted for many late summer flowering composites (Table 2), including western ragweed (*Ambrosia psilostachya* D.C.), prairie sagewort (*Artemisia ludoviciana* Nutt.), and white prairie aster (*Aster ericoides* L.). Other species which increased in cover were wild licorice [*Glycyrrhiza lepidota* (Nutt.) Pursh], prairie cinquefoil (*Potentilla arguta* Pursh), tall coneflower [*Ratibida pinnata* (Vent.) Barnh.], and Maximilian's sunflower (*Helianthus maximilianii* Schrad.). Silver leaf psoralea (*Psoralea argophylla* Pursh), a mid-summer flowering forb, also increased in cover and vigor but was not regularly sampled in late summer, since it is a tumbleweed and blows away. Spring-flowering forbs were nearly absent on the site, except for Carolina anenome (*Anenome caroliniana* Walt.) which flowered profusely two weeks after the late April 1984 burn. It apparently was not harmed by the back-to-back 1983 and 1984 burns.

Forb responses in the quadrat plots were similar to responses observed in the transect plots. Western ragweed increased in two plots where it was encountered in 1983, and later became established in three other plots. Stiff goldenrod (*Solidago rigida* L.), stiff sunflower [*Helianthus rigidus* (Cass.) Desf.], prairie sagewort, and white prairie aster became established in at least one plot and increased in cover as well. Increases in forb cover were generally found in quadrats dominated initially by Kentucky bluegrass or snowberry. Plots dominated by taller grasses such as big bluestem or quackgrass exhibited little change. Forb and shrub seedlings of several species were observed in a quackgrass plot in the wet spring of 1984, but were not observed in either 1985 or 1987. Shading from a nearby green ash tree may have reduced growth capability, and they may also have been affected by a period of dry weather from July-September of 1984. Canada thistle seedlings were first observed within a quadrat dominated by snowberry in spring, 1984. These persisted until 1985, but were absent in 1987. These may have been suppressed or eliminated through the expansion of goldenrod and stiff sunflower cover within the plot.

Total foliage cover of woody species in the prairie remained stable during the period, but seasonal and species specific changes were noted. Smooth sumac cover increased each year, but adverse effects of fire on tatarian honeysuckle, green ash, and buckthorn were noted. Several native prairie shrubs of short stature increased each year until the late 1987 sampling, when a slight drop of foliage cover was recorded. These included lead plant (*Amorpha canescens* Pursh), sand cherry (*Prunus pumilia* L. var. *besseyi* Bailey), and prairie rose (*Rosa arkansana* Porter). It is believed, however, that these lower values reflect drought conditions prior to leaf drop. Snowberry cover fluctuated greatly each year as it was initially set back by the spring burns, but typically recovered well by late summer. Lower cover values in the late summer of 1987 may also be a result of premature leaf drop. The extensive stands of buckthorn and honeysuckle in the woody draw were not subjected to fire during the study due to inadequate levels of herbaceous fuel.

By 1987, site aesthetics had improved greatly, as compared to an adjacent degraded prairie which was managed on a one year in four burn frequency plan. The annually burned prairie became more open each year with the reduction in dominance of snowberry and the tall cool-season grasses, and a concomitant increase in dominance of native grasses and forbs. The flowering shoots of the native plants emerged into the canopy, providing many different hues and textures in a formerly rather drab prairie. Several of the native, broadleaf forbs also had attractive, silvery foliage extending into the canopy.

While the annual rainfall varied considerably both annually and seasonally on the site (Table 3), annual burning had a much greater effect on growth and expansion of native plant cover than did differences in precipitation. As noted above, an adjacent prairie having a low fire frequency did not noticeably change during the five-year period. Details on responses of prairie vegetation to seasonal and yearly differences in precipitation were reported in a previous study (Becker *et al.* 1986).

After 1983, lack of fuel likely reduced the heat intensity of the prescribed burns. This was particularly evident in areas dominated by cool-season grasses or woody plants where herbage production was reduced. This effect may have reduced damage to woody species on site, especially to plant parts located near to the surface.

DISCUSSION

Several studies in the central prairies and plains region of North America have expressed concerns about the undesirable effects of high fire frequency. Increases in weedy forbs and reduction of grass cover have been reported (Aldous 1934, Hopkins *et al.* 1948, Weaver and Rowland 1952). Development of grassland monotypes has also been reported (Kucera and Koelling 1964, Vogl 1974). Kucera (1970) suggested a fire frequency of one in four years to maintain grass dominance and species diversity typical of native tall grass prairies. High frequency burning (annual or biennial) for extended periods of time, however, created favorable results in several studies of northern prairies, including restoration work in Wisconsin (Curtis and Partsch 1948, Anderson 1972, Henderson *et al.* (1982), and maintenance studies of aspen-prairie savannas in northwestern Minnesota (Svedarsky *et al.* 1986) and central Alberta (Anderson and Bailey 1980). Changes observed in the Pipestone study closely paralleled those found in the Wisconsin, Minnesota, and Canadian studies in that increases in both native species richness and foliage cover were observed. Species responding similarly included big bluestem, side oats grama, snowberry, prairie sagewort, white prairie aster, wild bergamot, and various goldenrods.

All species responses at Pipestone, however, were not considered desirable: the increase of western ragweed, the resistance of quackgrass sod to native plant establishment, and the increase and

Table 3. Precipitation (cm) during the 1983-1987 study period[1].

Year	*Jan-Apr.*	*May*	*June*	*July*	*Aug.*	*Sept-Dec.*	*Annual*
	cm						
1983	16.1	6.3	16.7	8.2	6.1	25.4	78.8
1984	21.2	7.8	24.3	7.6	3.0	2.4	66.3
1985	17.3	12.1	4.2	4.0	11.4	21.0	70.0
1986	19.1	9.2	12.9	9.9	7.2	30.8	89.1
1987	10.7	9.8	4.3	10.1	3.3	17.4	55.6
Average (period-of-record)	—	8.8	10.5	7.5	8.6	—	62.0

[1]Data taken from the U.S. Weather Bureau Reporting Station at the city of Pipestone (U.S. Dept. of Commerce, 1983-87). Long term averages for the January-April and September-December periods were not computed.

persistence of native woody species (smooth sumac) are still major concerns. Western ragweed, a native but sometimes weedy perennial, either invaded or increased in five of the quadrats dominated prior to burning by cool-season grasses (smooth brome and Kentucky bluegrass), snowberry, or prairie dropseed. In this respect, western ragweed responded similarly to its behavior under moderate to heavy grazing. Dense quackgrass stands, although curtailed in terms of aerial growth and flowering, were resistent to change and actually expanded slightly into adjacent areas of smooth brome or Kentucky bluegrass sod. This is in contrast with findings in Wisconsin (Curtis and Partch 1948, Anderson 1972), where quackgrass cover was reduced. Because the phenology of this species is somewhat later than for either Kentucky bluegrass or smooth brome, it is likely that prescribed burns at Pipestone were not timed for optimum control. Although shoots of smooth sumac were damaged or killed each year, numerous suckers emerged within the area of the old plant, resulting in slight increases in stand area. This finding is consistent with findings in the Kansas tallgrass prairie (Owensby and Smith 1972). In that study the success of smooth sumac under late spring burning was attributed to its later phenology which paralled that of the warm-season grasses. Control of smooth sumac at Pipestone might be more effective through mowing or cutting of the shoots during its flowering period when carbohydrate reserves of the roots are lower.

The opening of dense, tall stands of snowberry, but not reduction in its areal extent, was previously reported in a three-year study of central Alberta aspen savanna (Anderson and Bailey 1979). The increase of species diversity was attributed to the reduction in competition from shrubs, higher light intensity at the soil surface, warmer soil temperatures, favorable seed bed, and release of nutrients.

At Pipestone no long-term adverse effects on early spring forbs was documented, although more observations are needed since this floral component was poorly represented on the site. Continued monitoring of the prairie is needed. Of particular interest and concern are the responses of quackgrass, woody plants, and early spring forbs over the entire seven-year period. While any specific recommendations are tentative at present, continuation of prescribed burning on a delayed and less frequent basis may be needed, complemented with other restorative measures within the quackgrass stands.

In conclusion, five years of repetitive spring burns significantly improved the structure, composition, and diversity of a severely degraded native prairie site. The procedure may be most effective on sites where native prairie inclusions are large and well-dispersed within a large matrix of degraded sod dominated by brush or alien, cool-season grasses. If dispersion and quality of the inclusions are poor, as at the study site, interplantings of native materials may greatly promote the recovery process.

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