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HULBERT'S STUDY OF FACTORS EFFECTING BOTANICAL COMPOSITION OF TALLGRASS PRAIRIE

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Abstract. Lloyd Hulbert's death in May 1986 left a wealth of unfinished projects as well as the legacy of Konza Prairie Research Natural Area, Kansas. One of these was an incomplete manuscript on fire, mowing, and soil effects on the tallgrass prairie, in which canopy cover and frequency in 27 soil-treatment combinations from Konza Prairie were reported. Treatments included unburned and April burned at 1-, 2-, and 4-year intervals, annual burning during three seasons, and mowing during two seasons. Soils ranged from deep and non-rocky to shallow, rocky, silty clay loams. Late April burning favored tall C₄ grasses at the expense of most forbs, whereas autumn and March burning allowed many forbs to do well. More species occurred on shallow, rocky soils than on deep soils. Annuals and biennials succeeded in mowed areas but not in burned areas. Tables of partially summarized data are included with this report so that other researchers may make use of them.

Key Words. tallgrass prairie, fire, mowing, soil, plant communities, species richness, Kansas

INTRODUCTION

Burning frequency and soil type were major determinants of the plant species composition of tallgrass prairie (Abrams and Hulbert 1987, Gibson and Hulbert 1987, Gibson 1988). The season in the year that burning occurs also had an important impact on the prairie (Aldous 1934, Owensby and Anderson 1967, Adams *et al.* 1982, Towne and Owensby 1984). Fire removed accumulated litter (Knapp and Seastedt 1986), allowed the soil surface to become warmer

during the early part of the growing season (Hulbert 1988), and may lead to a more productive (Abrams *et al.* 1986), lower diversity, structurally more uniform grassland. The importance of soil type upon the composition of the prairie lies, in part, in the differential texture and water-holding capacities of various soils (Barnes and Harrison 1982, Archer 1984). Mowing for hay and to control certain undesirable range plants is a common management practice in the prairie that also affects species composition in a manner similar to burning (Crockett 1966, Christiansen 1972, Zimmerman and Kucera 1977, Hover and Bragg 1981). Although several studies have been conducted on one or more aspects of the effects of fire, mowing, and soil type on tallgrass prairie species composition, none have considered the effects of all three factors at a single site.

In 1983, Lloyd C. Hulbert sampled the plant species composition in 27 soil treatment combinations on Konza Prairie Research Natural Area, Riley and Geary counties, Kansas. Treatments included unburned and April burned at 1-, 2-, and 4-year intervals, annual burning at 3 seasons, mowing at 3 seasons and 5 soil types (Table 1). Before his death in May 1986 (Platt 1988), Hulbert summarized these data in tabular form and started to write a manuscript. These data are presented in this report (Tables 2, 3 and 4). The dissemination of these data will hopefully provide a resource- and database for other workers in this area of prairie research.

Table 1. Summary of soil characteristics and 27 soil-treatment combinations sampled by Hulbert to determine the effects of fire, mowing and soil type in tallgrass prairie vegetation. Figures indicate the number of replicate sample sites per soil-treatment combination. Soil characteristics from Jantz *et al.* (1975).

Soil characteristics and Plot combinations	Soil type				
	Florence	Sogn	Benfield	Irwin	Tully
Depth (cm)	25	23	15	28	25
Topography	upper rim of slopes	slopes	ridge tops	ridge tops	foot slopes
Slope	level	5-20%	level	4-8%	4-8%
texture (all loams)	cherty silt	silty clay	silty clay	silty clay	silty clay
Treatment Combinations					
Annual burn: March	1				2
late April	3			1	5 ¹
November	1				2
Two year cycle	3				3
Four year cycle	2				2
Unburned	3	1	1	2	2
Mowed and baled: March	1				
Mowed and left: July		1			1
Mowed and baled: July	1				2
Mowed and left: November					1
Mowed and baled: November				1	

¹Includes 1 replicate sample site each of burned with and against the prevailing wind.

Table 2. Canopy coverage/frequency of plant species on Tully soil based on twenty 10 m² plots per replication. Number of replications in parentheses. Nomenclature follows the Great Plains Flora Association (1986), where authorities for scientific names may be found.

Species	Annually burned			2-year burns (3)	4-year burns (2)	Unburned (2)	July mowed & removed (2)	July mowed & left (1)	Nov. mowed & left (1)
	Nov. (2)	March (2)	late Apr. (3)						
Tall Warm-Season Perennial Grasses:									
<i>Andropogon gerardii</i> big bluestem	98/100	97/100	98/100	98/100	98/100	96/100	97/100	83/100	98/100
<i>Sorghastrum nutans</i> indiangrass	35/100	54/100	43/83	39/100	36/100	14/88	59/100	50/100	23/95
<i>Panicum virgatum</i> switchgrass	6/40	23/70	7.5/38	2.6/18	5.6/42	18/72	2.8/30	15/75	
Total cover, above 3 grasses	139	174	148	140	140	128	159	133	136
Medium-Tall Warm-Season Grasses:									
<i>Andropogon scoparius</i> little bluestem	74/100	68/100	22/93	30/98	10/85	1.7/50	8.5/68	25/100	29/100
<i>Bouteloua curtipendula</i> sideoats grama	0.5/50	0.6/60	0.1/27	0.4/35	0.02/5	0.02/5	0.6/22	1.2/75	0.4/45
<i>Sporobolus asper</i> var. <i>asper</i> tall dropseed	13/72	25/95	0.2/10	0.9/17	15/65	3.0/25	2.0/20	6.9/65	34/100
<i>Sporobolus heterolepis</i> prairie dropseed		0.1/2		0.6/22	0.4/2				2.0/55
<i>Eragrostis spectabilis</i> prairie lovegrass		0.02/5		0.1/15	0.1/2				
<i>Leptoloma cognatum</i> fall witchgrass						0.01/2		0.8/70	
<i>Muhlenbergia racemosa</i> green muhly						1.0/5			
<i>Tridens flavus</i> purpletop							0.4/38	0.08/15	
Total cover, above 8 grasses	88	94	22	32	25	5.8	12	34	65
Short Warm-Season Perennial Grasses:									
<i>Bouteloua hirsuta</i> hairy grama								0.02/5	
Cool-Season Perennial Grasses:									
<i>Poa pratensis</i> Kentucky bluegrass ¹	0.2/5			0.1/15	29/50	47/100	80/100	82/100	27/100
<i>Dicanthelium oligosanthes</i> var. <i>scribnerianum</i> , scribner panicum	0.6/95	1.0/88	0.4/62	0.6/78	0.6/85	0.7/85	0.6/95	1.6/100	0.2/40
<i>D. acuminatum</i> var. <i>villo-</i> <i>sissimum</i> , early panicum	0.01/2	0.04/8		0.8/52	0.2/12	0.01/2	0.01/2	0.02/5	
<i>Koeleria pyramidata</i> prairie junegrass	1.4/88	0.2/45		0.1/27	0.02/5	0.06/12	0.01/2	0.05/10	0.4/55
<i>Sphenopholis obtusata</i> prairie wedgescale				0.07/7	0.04/8	0.3/28	1.6/40	1.6/80	0.02/5
<i>Elymus canadensis</i> Canada wildrye						0.1/5	0.1/5	0.02/5	0.4/25
Total cover, above 6 grasses	2.2	1.2	0.4	1.7	30	48	82	85	28
Introduced Cool-Season Perennial Grasses:									
<i>Bromus inermis</i> smooth brome grass ¹							1.4/22	0.02/5	
<i>Festuca arundinacea</i> tall fescue ¹							0.1/5		
Cyperaceae and Juncaceae:									
<i>Carex brevior</i> straw sedge	3.6/100	0.8/50	0.02/3	0.2/37	0.5/58	0.2/22	0.06/15		
<i>Carex gravida</i> var. <i>lupulina</i> hop sedge	0.02/5	0.01/2	0.01/2	0.02/15	1.0/48	0.8/55		0.6/85	0.05/10
<i>Carex heliophyla</i> pennsylvania sedge	0.2/28	0.6/48	0.01/2	0.03/5	0.01/2				
<i>Carex meadii</i> mead sedge	42/100	38/100	0.07/17	26/87	5.8/70	0.9/58	0.1/30	0.2/30	64/100

Table 2. Continued

<i>Species</i>	<i>Annually Nov. (2)</i>	<i>March (2)</i>	<i>burned late Apr. (3)</i>	<i>2-year burns (3)</i>	<i>4-year burns (2)</i>	<i>Unburned (2)</i>	<i>July mowed & removed (2)</i>	<i>July mowed & left (1)</i>	<i>Nov. mowed & left (1)</i>
<i>Carex</i> spp.			0.07/10				0.1/8		
<i>Cyperus lupulinus</i> spp. lupulinus, fern flatsedge			0.03/5	0.02/5					
<i>Eleocharis compressa</i> flatstem spikesedge	0.04/8	0.01/2		0.1/8					
<i>Juncus interior</i> inland rush				0.03/5					
Total cover, Cyperaceae and Juncaceae	46	38	0.2	27	7.3	1.9	0.3	0.8	64
Annual Grasses:									
<i>Bromus japonicus</i> Japanese brome ¹							46/100	0.1/20	
Perennial Forbs:									
<i>Achillea millifolium</i> var. lanulosa, western yarrow	0.06/15	0.04/8	0.01/2	0.09/20	0.1/18	0.5/32	0.2/40	0.6/85	0.1/25
<i>Ambrosia psilostachya</i> western ragweed	5.2/92	12/98	13/88	3.6/98	3.2/100	2.0/100	0.04/8	0.2/30	2.8/100
<i>Antennaria neglecta</i> var. neglecta, field pussytoes	0.05/10	0.2/15		0.2/18				0.05/10	0.05/10
<i>Apocynum cannabinum</i> hemp dogbane					0.01/2				
<i>Artemisia ludoviciana</i> Louisiana sagewort	1.5/75	0.4/42		0.05/10	1.2/40	1.9/82	0.2/28	0.7/95	
<i>Asclepias stenophylla</i> narrowleaf milkweed		0.01/2		0.01/2		0.02/5			
<i>Asclepias syriaca</i> common milkweed			0.01/2						
<i>Asclepias tuberosa</i> ssp. interior, butterfly milkweed	0.01/2		0.07/5		0.01/2				
<i>Asclepias verticillata</i> whorled milkweed		0.05/10	0.5/40	0.03/5	0.5/20	0.09/18	0.3/40	0.1/20	0.6/65
<i>Asclepias viridiflora</i> green milkweed		0.01/2		0.01/3					
<i>Asclepias viridis</i> green antelopehorn	0.5/32	0.2/25	0.2/22	0.3/33	0.5/40	0.7/40	0.6/48	0.7/60	0.2/20
<i>Aster ericoides</i> heath aster	19/100	18/100	0.3/22	13/98	9.3/98	2.7/95	0.7/98	0.8/100	25/100
<i>Aster laevis</i> smooth aster					0.02/5				
<i>Aster oblongifolius</i> aromatic aster									0.3/15
<i>Aster sericeus</i> silky aster									0.2/10
<i>Astragalus crassicaerpus</i> groundplum milkvetch	0.01/2								0.6/35
<i>Baptisia australis</i> var. minor, blue wildindigo		0.8/12		0.4/7	0.2/12	0.01/2			0.3/10
<i>Baptisia bracteata</i> plains wildindigo	0.6/30	0.4/25	0.2/15	0.4/27	0.01/2	0.4/20	1.2/45	0.08/15	2.0/60
<i>Cacalia plantaginea</i> tuberous indianplantain					0.01/2			0.02/5	
<i>Callirhoe involucrata</i> purple poppymallow						0.1/8			
<i>Cirsium altissimum</i> tall thistle					0.01/2	0.02/5			
<i>Cirsium undulatum</i> wavyleaf thistle		0.04/8		0.04/10	0.01/2	0.01/2	0.02/5	0.02/5	
<i>Convolvulus arvensis</i> field bindweed ¹					0.01/2				
<i>Dalea candida</i> white prairieclover	3.7/62	1.6/32	0.3/12	0.6/32	0.04/8	0.2/15	0.2/15	0.2/5	0.4/30

Table 2. Continued

Species	Annual Nov. (2)	March (2)	burned late Apr. (3)	2-year burns (3)	4-year burns (2)	Unburned (2)	July mowed & removed (2)	July mowed & left (1)	Nov. mowed & left (1)
<i>Dalea multiflora</i> roundheaded prairieclover	0.01/2								0.02/5
<i>Dalea purpurea</i> var. <i>purpurea</i> purple prairieclover	1.4/50	0.5/35	0.1/12	0.04/8	0.2/10	0.4/5	0.2/15	0.4/50	0.6/50
<i>Desmodium illinoense</i> Illinois tickclover	0.6/18	0.3/25	0.5/17	0.3/7	0.1/5	0.02/5	0.09/20		0.1/20
<i>Equisetum laevigatum</i> smooth horsetail			0.2/33				0.4/50		
<i>Hedyotis nigricans</i> narrowleaf bluets								0.05/10	
<i>Kuhnia eupatorioides</i> var. <i>corymbulosa</i> , false boneset	0.2/20	0.1/8	0.3/27	0.2/20	0.2/32	0.02/5	0.04/8	0.08/15	0.5/50
<i>Lespedeza capitata</i> roundhead lespedeza	0.9/48	0.9/25	0.5/28	0.3/10	0.2/10	0.2/8	0.04/8	0.02/5	0.05/10
<i>Lespedeza violacea</i> violet lespedeza ¹	0.5/8	0.1/2	0.9/5	2.7/13	0.4/5	0.1/2	0.01/2		1.0/10
<i>Liatris punctata</i> dotted gayfeather					0.2/10				
<i>Lithospermum incisum</i> narrowleaf gromwell					0.01/2				
<i>Monarda fistulosa</i> var. <i>fistulosa</i> , mintleaf beebalm						0.4/2			
<i>Oenothera speciosa</i> white eveningprimrose					0.1/8	0.02/5	0.1/5	0.08/15	
<i>Oxalis violacea</i> violet woodsorrel oxalis		0.01/2	0.3/8	0.1/25	0.04/8	0.06/12		0.2/20	0.2/45
<i>Physalis heterophylla</i> clammy groundcherry						0.1/5	0.02/5		
<i>Physalis pumila</i> prairie groundcherry		0.05/10	0.07/5	0.01/2	0.04/8	1.5/15	0.4/40	0.08/15	0.02/5
<i>Physalis virginiana</i> Virginia groundcherry	0.09/18	0.1/20	0.07/15	0.2/28	0.8/40	0.7/45	0.05/10	0.1/25	0.2/40
<i>Psoralea argophylla</i> silverleaf scurfpea		0.05/10		0.07/2	0.2/10		1.5/12		
<i>Psoralea esculenta</i> common breadroot scurfpea	0.04/8			0.03/5			0.01/2		0.1/25
<i>Psoralea tenuiflora</i> manyflower scurfpea	0.8/20	0.4/5	0.2/8		0.02/5	0.3/28	0.1/22	2.9/70	
<i>Ratibida columnifera</i> upright prairieconeflower	0.02/5	0.01/2	0.01/3	0.03/7	0.01/2			0.08/15	0.02/5
<i>Ruellia humilis</i> fringeleaf ruellia	0.2/28	0.1/20	0.3/52	0.2/35	0.2/32	0.2/30	0.1/20	0.05/10	0.2/40
<i>Salvia azurea</i> Pitcher sage	0.1/2		0.04/10	0.1/22	0.2/12	0.7/28	0.1/8	0.02/5	0.1/25
<i>Schrankia nuttallii</i> catclaw sensitivebriar		0.4/2	0.07/2	0.3/2		0.01/2			
<i>Senecio plattensis</i> prairie groundsel	0.05/12	0.01/2		0.02/5	0.02/5		0.01/2	0.05/10	0.02/5
<i>Silphium integrifolium</i> wholeleaf rosinweed							0.1/5		
<i>Sisyrinchium campestre</i> prairie blueeyedgrass	0.9/92	0.8/100	0.02/52	0.2/43	0.2/25	0.2/32	0.02/5	0.7/85	0.1/25
<i>Solanum carolinense</i> horsenettle			0.01/2			0.01/2	0.6/22		
<i>Solidago canadensis</i> var. <i>scabra</i> , Canada goldenrod		1.0/5	0.07/2	0.01/2	0.4/8	4.6/18	0.01/2		1.7/20
<i>Solidago missouriensis</i> var. <i>fasciculata</i> , Missouri goldenrod	0.8/8	3.8/20	0.2/25	2.1/42	8.6/45	0.1/12		0.2/40	3.8/25
<i>Solidago mollis</i> ashy goldenrod						0.1/2			
<i>Solidago rigida</i> var. <i>humilis</i> stiff goldenrod		0.02/5	0.01/2		0.01/2				0.05/10

Table 2. Continued

Species	Annual Nov. (2)	March (2)	burned late Apr. (3)	2-year burns (3)	4-year burns (2)	Unburned (2)	July mowed & removed (2)	July mowed & left (1)	Nov. mowed & left (1)
<i>Spiranthes vernalis</i> upland ladiestresses		0.01/2	0.03/5	0.01/2					
<i>Taraxacum officinale</i> common dandelion ¹							0.02/5		
<i>Teuchrium canadense</i> var. <i>virginiana</i> American germander			0.02/3		0.01/2	0.1/5			
<i>Verbena stricta</i> woolly verbena	0.01/2	0.05/10	0.05/10	0.01/2		0.04/8		0.05/10	0.08/15
<i>Vernonia valdwini</i> var. <i>interior</i> , inland ironweed	0.7/88	0.8/75	2.2/97	1.7/90	1.5/80	6.3/100	8.2/100	2.5/100	0.8/100
<i>Vicia americana</i> American vetch							0.6/12	0.05/10	0.2/35
<i>Viola pedatifida</i> prairie violet				0.1/22					0.2/50
<i>Viola pratincola</i> blue prairie violet									0.08/15
<i>Zizia aurea</i> golden zizia									1.1/30
Total cover, perennial forbs	38	43	20	27	29	25	16	11	44
Woody Plants:									
<i>Amorpha canescens</i> leadplant	1.9/38	2.9/35	10/37	11/77	21/95	0.4/22	0.02/5	0.02/5	7.2/95
<i>Prunus americana</i> American plum							0.01/2		
<i>Rhus glabra</i> smooth sumac			0.01/2						
<i>Rosa arkansana</i> Arkansas rose			0.07/3						
<i>Symphoricarpos orbiculatus</i> buckbrush	0.01/2		0.01/2	0.01/2	0.2/8	1.4/12	0.2/15		0.02/5
Total cover, woody plants	1.9	2.9	10	11	21	1.8 0.2	0.02	7.2	
Annual and Biennial Forbs:									
<i>Ambrosia artemisiifolia</i> common ragweed			0.01/2	0.01/3					
<i>Conyza canadensis</i> horseweed				0.01/2				0.02/5	
<i>Erigeron strigosus</i> var. <i>strigosus</i> , daisy fleabane	0.01/2		0.01/2	0.06/12		0.05/10	0.4/52	0.3/60	
<i>Euphorbia marginata</i> snow-on-the-mountain		0.01/2	0.02/5		0.01/2	0.04/8	0.01/2		0.02/5
<i>Euphorbia spathulata</i> wartly spurge						0.02/5			
<i>Helianthus annuus</i> common sunflower			0.03/7	0.01/2					
<i>Hymenopappus scabiosaeus</i> whitebract hymenopappus								0.02/5	
<i>Lactuca</i> spp. wild lettuces ¹				0.02/3	0.01/2	0.1/25	0.01/2	0.3/65	0.02/5
<i>Linum sulcatum</i> grooved flax	0.02/5	0.02/5	0.01/2	0.07/17	0.1/22	0.01/2		0.02/5	0.05/10
<i>Medicago lupulina</i> black medic ¹							0.4/20		
<i>Melilotus</i> spp. sweetclovers ¹	20/38	0.2/10	0.01/2				37/100	0.3/10	0.02/5
<i>Oenothera villosa</i> spp. <i>villosa</i> , eveningprimrose					0.01/2				
<i>Oxalis stricta</i> common yellow oxalis				0.02/5	0.06/12	0.04/8	0.06/12	0.2/40	

Table 2. Continued

Species	Annually burned			2-year burns (3)	4-year burns (2)	Unburned (2)	July	July	Nov.
	Nov. (2)	March (2)	late Apr. (3)				mowed & removed (2)	mowed & left (1)	mowed & left (1)
<i>Plantago rhodosperma</i> redseed plantain				0.01/2		0.01/2			
<i>Spermolepis inermis</i> spreading spermolepis							0.01/2	0.05/10	
<i>Strophostyles leiosperma</i> smoothseed wildbean	0.01/2	0.4/8	0.03/7						
<i>Tragopogon dubius</i> western salsify ¹			0.01/2	0.01/2		0.01/2	0.2/35	0.6/40	
<i>Triodanis perfoliata</i> clasping venus lookingglass					0.01/2			0.02/5	
<i>Veronica arvensis</i> common speedwell ¹							0.01/2		
<i>Viola rafinesquii</i> johnnyjumpup				0.02/3		0.02/5			
Total cover, annual and biennial forbs	20	0.6	0.1	0.2	0.2	0.3	38	1.8	0.1
Total cover, all plants	335	354	201	239	252	211	355	266	344
Average number of native species	38.5	39.5	34.3	45.0	47.5	48.0	40.0	54	53
Average number of exotic species	1.5	1.0	1.3	1.3	1.5	2.0	8.0	5	3
Shannon-Weaver diversity index, H', av.	2.01	2.08	1.46	1.80	2.00	1.81	1.91	1.78	2.27

¹Exotic species

Table 3. Canopy coverage/frequency of plant species on Florence soil based on twenty 10 m² plots per replication. Number of replications in parentheses. Nomenclature follows the Great Plains Flora Association (1986), where authorities for scientific names may be found.

Species	Annually burned			2-year burns (3)	4-year burns (2)	Unburned (3)	July mowed & removed (1)	March mowed & removed (1)
	Nov. (1)	March (1)	late Apr. (3)					
Tall Warm-Season Perennial Grasses:								
<i>Andropogon gerardii</i> big bluestem	69/100	77/100	94/100	93/100	94/100	93/100	94/100	90/100
<i>Sorghastrum nutans</i> indiangrass	35/100	21/100	43/95	53/100	34/95	34/100	57/100	26/75
<i>Panicum virgatum</i> switchgrass	2.3/40	7.5/60	3.5/17	3.5/18	0.2/10	2.8/17	9.0/30	4.3/25
Total cover, above 3 grasses	106	106	140	150	128	130	160	120
Medium-Tall Warm-Season Perennial Grasses:								
<i>Andropogon scoparius</i> little bluestem	67/100	63/100	28/95	31/100	36/100	38/100	51/100	25/95
<i>Bouteloua curtipendula</i> sideoats grama	0.9/100	1.5/100	6.4/100	1.8/95	2.8/95	0.4/38	11/100	5.7/95
<i>Sporobolus asper</i> var. <i>asper</i> tall dropseed	24/100	22/90	5.5/28	0.2/7	2.2/28	0.7/15	18/95	29/60
<i>Sporobolus heterolepis</i> prairie dropseed	6.1/75	6.2/75	0.3/15	1.0/37	2.8/52	1.0/13	2.4/45	5.4/70
<i>Eragrostis spectabilis</i> Prairie lovegrass			0.01/3			0.2/3	1.4/30	
<i>Leptoloma cognatum</i> fall witchgrass			0.06/13					
<i>Muhlenbergia cuspidata</i> plains muhly	2.4/50	1.6/40		0.07/8	0.7/22	0.8/15	0.2/25	0.7/45
<i>Sporobolus cryptandrus</i>		0.02/5	0.02/3	0.1/3	0.2/5			
Total cover, above 8 grasses	100	94	40	34	45	41	84	66
Short Warm-Season Perennial Grasses:								
<i>Bouteloua gracilis</i> blue grama	2.1/95	1.5/100	1.2/62	0.4/32	0.5/18	0.2/3	0.2/5	0.02/5
<i>Bouteloua hirsuta</i> hairy grama	1.6/100	1.6/95	0.3/23	0.1/15	0.1/5	0.1/3		
<i>Buchloe dactyloides</i> buffalograss	0.3/35	0.4/30	0.01/3		0.1/2			
Total cover, above 3 grasses	4.0	3.5	1.5	0.5	0.7	0.03	0.2	0.02
Cool-Season Perennial Grasses:								
<i>Poa pratensis</i> Kentucky bluegrass ¹		0.02/5	0.04/8	0.1/12	37/68	37/67	36/95	75/100
<i>Dicanthelium oligosanthes</i> var. <i>scribnerianum</i> , scribner panicum	0.2/30	0.4/45	0.2/37	0.3/38	0.4/78	1.0/72	4.6/90	0.2/45
<i>D. acuminatum</i> var. <i>villo-</i> <i>sissimum</i> , early panicum			0.01/2	0.02/5	0.05/10	0.02/5	0.3/35	
<i>D. linearifolium</i> slimleaf panicum		0.02/5	0.03/5	0.01/2				
<i>Koeleria pyramidata</i> prairie junegrass	1.6/100	1.4/95	0.6/47	0.7/70	0.2/42	0.2/28	0.1/25	0.1/25
<i>Sphenopholis obtusata</i> prairie wedgescale					0.01/2	0.03/7	12/95	
<i>Elymus canadensis</i> Canada wildrye	0.05/10		0.02/3			0.1/8		0.4/45
Total cover, above 7 grasses	1.8	1.8	0.9	1.1	38	38	53	76
Introduced Cool-Season Perennial Grasses:								
<i>Bromus inermis</i> smooth brome grass ¹	0.08/15						3.4/25	0.6/50

Table 3. Continued

Species	Annually burned			2-year burns (3)	4-year burns (2)	Unburned (3)	July mowed & removed (1)	March mowed & removed (1)
	Nov. (1)	March (1)	late Apr. (3)					
Cyperaceae and Juncaceae:								
<i>Carex brevior</i> straw sedge			0.4/62	0.09/7	0.2/22	0.4/33	0.5/10	
<i>Carex gravida</i> var. <i>lupulina</i> hop sedge			0.2/13	0.1/12	0.9/40	0.2/17		
<i>Carex heliophila</i> pennsylvania sedge	5.2/100	1.0/100	0.02/3	0.3/38	0.3/40	0.2/22	0.2/30	
<i>Carex meadii</i> mead sedge	1.1/65	0.5/75	0.09/7	1.3/13	2.0/25	1.1/18	17/70	0.4/20
<i>Cyperus lupulinus</i> spp <i>lupulinus</i> , fern flatsedge		0.05/10	0.1/28	0.1/30	0.01/2	2.2/33		
<i>Syperus schweinitzii</i> schweinitz flatsedge			0.01/2					
Total cover, Cyperaceae and Juncaceae	6.3	1.5	0.8	1.9	3.4	4.1	18	0.4
Annual Grasses:								
<i>Bromus japonicus</i> Japanese brome ¹				0.01/2	3.0/15	0.4/22	15/100	12/100
Perennial Forbs:								
<i>Achillea millefolium</i> var. <i>lanulosa</i> , western yarrow			0.1/15	0.2/32	0.4/40	0.5/52	0.4/85	0.1/20
<i>Ambrosia psilostachya</i> western ragweed	0.2/30	0.4/50	0.9/77	1.4/87	1.2/80	4.5/93	0.3/40	0.2/40
<i>Antennaria neglecta</i> var. <i>neglecta</i> , field pussytoes	0.2/20	0.4/45	0.01/2	0.07/15	0.05/12	0.01/2	0.8/55	0.02/55
<i>Artemisia ludoviciana</i> Louisiana sagewort	0.5/70	0.2/40	0.3/17	7.5/63	3.6/40	4.1/32	0.1/20	12/85
<i>Argemone polyanthemus</i> pricklypoppy						0.07/2		
<i>Asclepias stenophylla</i> narrowleaf milkweed		0.02/5	0.04/8	0.03/7	0.02/5	0.04/8	0.2/30	
<i>Asclepias verticillata</i> whorled milkweed		0.05/10		0.01/2	0.02/5	0.01/2	0.2/40	0.1/20
<i>Aslepias viridiflora</i> green milkweed	0.2/30	0.3/65	0.08/18	0.2/23	0.1/22	0.1/27	0.2/30	0.1/20
<i>Asclepias viridis</i> green antelopehorn	0.4/25	0.05/10	0.3/35	0.07/8	0.04/8	0.08/12	0.5/20	0.2/20
<i>Aster ericoides</i> heath aster	0.5/70	0.4/90	0.1/27	0.2/42	1.6/95	3.4/88	0.4/80	5.1/100
<i>Aster laevis</i> smooth aster						0.01/2		
<i>Aster oblongifolius</i> aromatic aster	5.0/100	0.7/65	0.1/12	3.1/62	24/85	12/47	0.4/30	7.4/75
<i>Aster sericeus</i> silky aster	0.05/10	0.08/15	0.1/15	0.2/42	1.7/88	0.8/45	0.2/45	0.9/75
<i>Astragalus crassicaarpus</i> groundplum milkvetch	2.7/90	0.3/35	0.01/2	0.02/3	0.01/2	0.01/2	0.5/20	0.7/40
<i>Baptisia australis</i> var. <i>minor</i> blue wildindigo	0.3/10	0.5/30	0.01/2	0.9/28	0.5/25	0.09/7	3.9/75	0.02/5
<i>Baptisia bracteata</i> plains wildindigo	0.02/5	0.4/20	0.3/23	0.5/27	0.1/15	0.5/27		0.7/40
<i>Cacalia plantaginea</i> tuberous indianplantain							0.02/5	
<i>Callirhoe alceoides</i> pale poppymallow								0.02/5
<i>Cirsium undulatum</i> wavyleaf thistle	0.2/35	0.4/65	0.3/35	0.1/15	0.4/34	0.3/22	0.2/30	0.08/15
<i>Commandra umbellata</i> var. <i>pallida</i> , pale comandra						0.01/2	0.02/5	

Table 3. Continued

Species	Annually burned			2-year burns (3)	4-year burns (2)	Unburned (3)	July mowed & removed (1)	March mowed & removed (1)
	Nov. (1)	March (1)	late Apr. (3)					
<i>Corypantha missouriensis</i> Missouri mamillaria			0.01/2		0.01/2			
<i>Dalea candida</i> white prairieclover	1.3/35	0.2/25	0.1/8	0.1/12	0.1/5	0.1/7	0.8/50	0.02/5
<i>Dalea multiflora</i> roundheaded prairieclover	0.05/10	0.08/7	0.02/5	0.06/12	0.2/5			
<i>Dalea purpurea</i> var. <i>purpurea</i> purple prairieclover	19/100	20/95	2.3/73	1.2/88	0.4/58	0.4/60	0.8/50	0.3/60
<i>Delphinium carolinianum</i> plains larkspur				0.01/2		0.01/3		
<i>Desmodium illinoense</i> Illinois tickclover			0.02/3	0.01/2				
<i>Echinacea augustifolia</i> blacksampson echinacea	0.2/25	0.4/20	0.07/7	0.07/5	0.2/22	0.04/8	0.05/10	
<i>Hieracium longipilum</i> longbeard hawkweed				0.02/3		0.01/2		
<i>Hybanthus verticillatus</i> North American calceolaria	0.02/5		0.7/23		0.1/2	0.07/3		
<i>Kuhnia eupatorioides</i> var. <i>corymbulosa</i> , false boneset	0.2/35	0.3/40	0.5/30	2.0/70	1.0/58	1.0/78	0.7/70	1.0/55
<i>Lespedeza capitata</i> roundhead lespedeza			0.05/10	0.07/12	0.1/10	0.7/13	0.08/15	
<i>Lespedeza violacea</i> violet lespedeza'				0.07/2				
<i>Liatris punctata</i> dotted gayfeather				0.01/2	0.01/2	0.2/10		
<i>Lithospermum incisum</i> narrowleaf gromwell		0.02/5	0.01/2		0.03/7		0.02/5	
<i>Lomatium foeniculaceum</i> carrotleaf lomatium			0.03/7	0.5/53	0.01/2	0.07/17	4.0/50	0.08/15
<i>Mirabilis linearis</i> narrowleaf four-o'clock			0.02/3					
<i>Opuntia macrorhiza</i> var. <i>macrorhiza</i> bigroot pricklypear					0.01/2			
<i>Oxalis violacea</i> violet woodsorrel oxalis						0.08/5		
<i>Penstemon cobaea</i> cobaea penstemon	0.02/5	0.1/20		0.01/2		0.01/2		
<i>Penstemon grandiflorus</i> shell-leaf penstemon			0.02/5	0.1/15				
<i>Physalis pumila</i> prairie groundcherry	0.2/10	0.08/15	0.3/27	0.1/8	1.0/8	0.5/22	0.2/15	
<i>Physalis virginiana</i> Virginia groundcherry			0.02/3	0.01/3	0.05/10	0.01/2	0.1/25	0.2/10
<i>Psoralea esculenta</i> common breadroot scurfpea		0.05/10	0.05/10	0.1/17	0.06/12	0.04/8	0.2/20	0.2/30
<i>Psoralea tenuiflora</i> manyflower scurfpea				0.3/5	0.1/5	0.01/2		
<i>Ratibida columnifera</i> upright prairieconeflower	0.02/5	0.08/15	0.02/30	0.6/37	0.8/50	0.3/27	0.08/15	0.08/15
<i>Ruellia humilis</i> fringeleaf ruellia	0.1/20	0.08/15	0.3/43	0.04/8	0.1/22	0.2/38	0.2/45	0.08/15
<i>Salvia azurea</i> Pitcher sage	3.8/95	5.8/80	20/87	2.9/62	1.8/70	1.0/60	1.0/55	3.2/70
<i>Schrankia nuttallii</i> catclaw sensitivebriar	0.9/15	0.4/15	1.2/13	1.8/33	1.6/20	1.4/33		0.4/15
<i>Senecio plattensis</i> prairie groundsel	0.05/10	0.1/25	0.02/5	0.04/8		0.07/13	0.08/15	
<i>Sisyrinchium campestre</i> prairie blueeyedgrass	0.4/80	1.2/100	0.2/37	0.3/50	0.2/35	0.01/2	1.4/100	0.3/60
<i>Solidago missouriensis</i> var. <i>fasciculata</i> , Missouri goldenrod	0.2/45	0.2/30	0.4/30	0.3/48	1.4/52	1.3/22	3.4/60	0.9/35

Table 3. Continued

Species	Annually burned			2-year burns (3)	4-year burns (2)	Unburned (3)	July mowed & removed (1)	March mowed & removed (1)
	Nov. (1)	March (1)	late Apr. (3)					
<i>Solidago rigida</i> var. <i>humilis</i> stiff goldenrod						0.02/3	0.2/10	
<i>Stenosiphon linifolius</i> stenosiphon						0.02/3		
<i>Tragia betonicifolia</i> nettleleaf noseburn			0.2/25	0.3/32	0.4/38	0.02/3		0.1/25
<i>Verbena canadensis</i> rose verbena				0.01/2				
<i>Verbena stricta</i> woolly verbena		0.02/5	0.02/3	0.01/2		0.03/7	0.02/5	
<i>Vernonia baldwinii</i> var. <i>interior</i> , inland ironweed	0.08/15	0.4/45	1.9/95	0.4/63	1.0/55	1.1/78	0.4/50	0.5/70
Total cover, perennial forbs	37	34	31	26	44	35	22	35
Woody Plants:								
<i>Amorpha canescens</i> leadplant	10/100	4.1/100	1.9/85	6.0/90	5.0/98	1.7/65	3.1/100	7.6/80
<i>Ceanothus herbaceus</i> var. <i>pubescens</i> , inland ceanothus	0.02/5		4.3/42	1.4/12	0.7/12	1.9/40	0.02/5	
<i>Rosa arkansana</i> Arkansas rose					0.02/5			
<i>Symphoricarpos orbiculatus</i> buckbrush						0.1/7		
Total cover, woody plants	10	4.1	6.2	7.4	5.7	3.7	3.1	7.6
Annual and Biennial Forbs:								
<i>Androsace occidentalis</i> western rockjasmine					0.01/2			
<i>Conyza canadensis</i> horseweed					0.01/2			
<i>Descurainia pinnata</i> pinnate tansymustard						0.06/12		
<i>Erigeron strigosus</i> var. <i>strigosus</i> , daisy fleabane	0.02/5		0.04/8	0.2/30	0.2/38	0.1/28	0.02/5	0.02/5
<i>Euphorbia marginata</i> snow-on-the-mountain			0.01/2		0.02/5			
<i>Euphorbia spathulata</i> wartly spurge						0.06/12		
<i>Hedeoma hispidum</i> rough falsepennyroyal				0.02/3				
<i>Hymenopappus scabiosaeus</i> whitebract hymenopappus			0.03/7	0.04/10	0.1/22	0.03/7	0.1/25	
<i>Lactuca spp.</i> wild lettuces ¹				0.04/8	0.05/10	0.2/35	0.08/15	0.05/10
<i>Lepidium densiflorum</i> peppergrass ¹					0.2/45	0.01/2	0.02/5	
<i>Linum sulcatum</i> grooved flax			0.2/32	0.2/33		0.07/13	0.4/70	
<i>Melilotus spp.</i> sweetclovers ¹	0.8/60	0.1/20		0.03/7			6.3/85	18/75
<i>Oxalis stricta</i> common yellow oxalis			0.01/2	0.03/5	0.3/52	0.1/23	0.4/85	0.02/5
<i>Silene antirrhina</i> sleepy catchfly				0.02/3	0.01/2	0.03/5		
<i>Spermolepis inermis</i> spreading spermolepis				0.01/2		0.02/5	0.02/5	
<i>Strophostyles leiosperma</i> smoothseed wildbean							0.02/5	
<i>Tragopogon dubius</i> salsify ¹			0.01/2	0.04/10	0.05/10	0.08/17	0.2/30	0.2/30

Table 3. Continued

Species	Annually burned			2-year burns (3)	4-year burns (2)	Unburned (3)	July	March
	Nov. (1)	March (1)	late Apr. (3)				mowed & removed (1)	mowed & removed (1)
<i>Triodanis leptocarpa</i> slimpod venus lookingglass				0.02/3	0.02/5	0.07/15		
<i>Triodanis perfoliata</i> clasping venus lookingglass				0.01/2	0.01/2	0.02/3		
<i>Verbascum blattaria</i> moth mullein ¹							0.02/5	
<i>Viola rafinesquii</i> johnnyjumpup						0.01/2		
Total cover, annual and biennial forbs	0.8	0.1	0.3	0.7	1.0	0.9	7.6	18
Total cover, all plants	266	245	221	222	269	253	366	336
Number of native species	46	51	54	53	58.5	59.3	61	48
Number of exotic species	2	1	1	2.7	1	2.7	7	5
Shannon-Weaver diversity index, H', av.	2.25	2.13	1.85	1.82	2.09	1.96	2.53	2.36

¹Exotic species

Table 4. Canopy coverage/frequency of plant species on Irwin, Sogn, Benfield and Tully soils, based on twenty 10 m² plots per replication. Number of replications in parentheses. Nomenclature follows the Great Plains Flora Association (1986), where authorities for scientific names may be found.

Species	Irwin					Sogn		Benfield	Tully	
	Burned annually (1)	Unburned (2)	July mowed & left (1)	July mowed & removed (1)	Nov. mowed & removed (1)	Unburned (1)	July mowed & left (1)	Unburned (1)	Burned against wind (1)	Burned with wind (1)
Tall Warm-Season Perennial Grasses:										
<i>Andropogon gerardii</i> big bluestem	94/100	96/100	91/100	96/100	93/100	92/100	91/100	98/100	98/100	96/100
<i>Sorghastrum nutans</i> indiangrass	13/40	14/70	56/95	72/100	30/90	39/100	28/95	18/95	39/100	43/100
<i>Panicum virgatum</i> switchgrass	6.4/20	0.6/18	6.8/65	0.9/15	5.2/20	13/70	5.3/40	4.3/25	10/60	12/55
Total cover, above 3 grasses	113	111	154	169	128	144	124	120	147	151
Medium-Tall Warm-Season Perennial Grasses:										
<i>Agropyron scoparius</i> little bluestem	25/95	2.6/58	1.0/35	44/100	4.9/70	2.2/60	0.9/35	23/100	38/100	58/100
<i>Bouteloua curtipendula</i> sideoats grama	1.8/80	0.2/15	0.08/15	7.0/95	0.4/30	7.4/90	5.2/100	0.2/50	0.4/45	0.7/85
<i>Sporobolus asper</i> var. <i>asper</i> tall dropseed	7.2/65	29/85	15/85	33/100	72/100	45/100	22/85	0.2/15	6.0/75	3.9/90
<i>Sporobolus heterolepis</i> prairie dropseed	0.2/10	4.1/18						0.3/10		
<i>Eragrostis spectabilis</i> prairie lovegrass		0.1/2		0.05/10		0.2/5	0.2/15	0.2/5	0.3/40	0.2/30
<i>Leptoloma cognatum</i> fall witchgrass		0.01/2								
<i>Tridens flavus</i> purpletop		0.01/2	1.7/20							
Total cover, above 7 grasses	34	36	18	84	77	55	28	24	45	63
Short Warm-Season Grasses:										
<i>Bouteloua gracilis</i> blue grama	0.02/5									
<i>Bouteloua hirsuta</i> hairy grama						0.2/5				
<i>Buchloe dactyloides</i> buffalograss						0.2/5				
Total cover, above 3 grasses	0.02					0.4				
Cool-Season Perennial Grasses:										
<i>Poa pratensis</i> Kentucky bluegrass ¹		46/75	98/100	78/100	98/100	35/100	91/100	4.6/30		
<i>Dicanthelium oligosanthos</i> var. <i>scribnerianum</i> , scribner panicum	0.6/85	1.1/78	0.6/90	1.5/100	0.5/55	0.2/35	0.05/10	4.5/100	1.0/100	0.6/100
<i>D. acuminatum</i> var. <i>villosissimum</i> , early panicum								0.05/10	0.08/15	0.05/10
<i>Koeleria pyramidata</i> prairie junegrass	0.05/10	0.1/18		0.02/5	0.02/5	0.02/5				0.02/5
<i>Spenopholis obtusata</i> prairie wedgescale		0.02/5		0.2/10				0.05/10		
<i>Elymus canadensis</i> Canada wildrye		1.0/5	0.1/20	0.02/5	0.5/50	0.6/30	0.4/60			
<i>Elymus virginicus</i> Virginia wildrye					0.02/5					
Total cover, above 7 grasses	0.6	48	99	80	99	36	91	9.2	1.1	0.7
Introduced Cool-Season Grasses:										
<i>Bromus inermis</i> spp. <i>inermis</i> smooth brome grass ¹			3.2/10	0.08/15	0.8/5		3.2/10			

Table 4. Continued

Species			Irwin			Sogn		Benfield	Tully	
	Burned annually (1)	Unburned (2)	July mowed & left (1)	July mowed & removed (1)	Nov. mowed & removed (1)	Unburned (1)	July mowed & left (1)	Unburned (1)	Burned against wind (1)	Burned with wind (1)
Cyperaceae and Juncaceae:										
<i>Carex brevior</i> straw sedge		0.06/15	0.2/40	0.1/20	1.9/85	0.02/5	0.08/15	0.02/5	0.3/30	0.2/30
<i>Carex gravida</i> var. <i>lupulina</i> hop sedge	0.2/5	1.0/55	2.0/85	1.2/65	2.4/95	0.1/25	0.1/20		0.02/5	
<i>Carex heliophila</i> pennsylvania sedge				0.1/20						
<i>Carex meadii</i> mead sedge		11/48	2.0/95	0.6/80	42/95	9.6/90	0.6/60	6.4/80	1.4/55	8.2/85
<i>Cyperus lupulinus</i> spp. <i>lupulinus</i> , fern flatsedge	0.02/5								0.02/5	0.05/10
<i>Eleocharis compressa</i> flatstem spikesedge									0.02/5	
Total cover, Cyperaceae & Juncaceae	0.2	12	4.2	2.0	46	9.7	0.8	6.4	1.8	8.4
Annual Grasses:										
<i>Bromus japonicus</i> Japanese brome ¹		0.01/2	13/90	23/100	0.05/10		0.02/5			
Perennial Forbs:										
<i>Achillea millefolium</i> var. <i>lanulosa</i> , western yarrow		0.9/40	0.8/75	0.4/75	0.4/55	0.3/35	0.6/75	0.5/30		
<i>Ambrosia psilostachya</i> western ragweed	8.8/85	3.0/70	0.4/50	0.5/70	1.1/100	0.6/75	0.3/55	5.2/100	19/100	2.7/100
<i>Antennaria neglecta</i> var. <i>neglecta</i> , field pussytoes				0.05/10					0.02/5	
<i>Artemisia ludoviciana</i> Louisiana sagewort	0.02/5	3.6/90	1.9/90	0.3/55	0.9/80	8.6/100	2.6/90	0.02/5	0.1/25	0.2/40
<i>Asclepias stenophylla</i> narrowleaf milkweed		0.05/10			0.02/5			0.02/5	0.05/10	0.02/5
<i>Asclepias verticillata</i> whorled milkweed	2.0/25	0.2/38	4.2/30	0.05/10	0.5/70			0.1/25	0.05/10	0.1/25
<i>Asclepias viridiflora</i> green milkweed	0.02/5	0.02/5					0.05/10	0.05/10		
<i>Asclepias viridis</i> green antelopehorn	0.05/10	0.01/18	0.2/35	0.6/55	1.0/70	0.4/35	0.05/10	0.2/20	0.6/50	0.4/60
<i>Aster ericoides</i> heath aster	0.05/10	4.4/90	0.8/85	0.4/85	0.4/90	4.1/85	0.5/100	19/100	4.9/100	5.7/100
<i>Aster laevis</i> smooth aster		0.01/2					0.2/5			
<i>Aster oblongifolius</i> aromatic aster						9.9/75	0.1/20	0.8/5		
<i>Aster sericeus</i> silky aster								0.5/25		
<i>Astragalus crassicaulus</i> groundplum milkvetch	0.05/10	0.1/5		0.02/5		0.1/20	0.02/5	0.02/5		
<i>Astragalus missouriensis</i> Missouri milkvetch				0.02/5						
<i>Baptisia australis</i> var. <i>minor</i> , blue wildindigo		0.1/5		0.3/10		1.0/20	0.4/20	0.2/5		
<i>Baptisia bracteata</i> plains wildindigo		0.02/5	0.2/5	0.5/25	0.2/5	0.02/5	0.2/5	1.0/45	0.05/10	0.2/25
<i>Cacalia plantaginea</i> tuberous indianplantain							0.08/15			
<i>Callirhoe involucrata</i> purple poppymallow		0.1/8		0.02/5						
<i>Cirsium undulatum</i> wavyleaf thistle				0.08/15		0.3/40	0.7/45			
<i>Dalea candida</i> white prairieclover	0.5/30	0.2/20			0.05/10		0.02/5	0.3/30	1.5/50	0.1/20

Table 4. Continued

Species			Irwin			Sogn		Benfield	Tully	
	Burned annually (1)	Unburned (2)	July mowed & left (1)	July mowed & removed (1)	Nov. mowed & removed (1)	Unburned (1)	July mowed & left (1)	Unburned (1)	Burned against wind (1)	Burned with wind (1)
<i>Dalea multiflora</i> roundheaded prairieclover								0.05/10		
<i>Dalea purpurea</i> var. <i>purpurea</i> purple prairieclover	0.02/5	0.1/5	0.02/5	0.2/5	0.08/15	0.3/55	0.2/25	0.1/25	0.1/25	0.4/25
<i>Delphinium carolinianum</i> plains larkspur						0.05/10				
<i>Desmodium illinoense</i> Illinois tickclover	0.2/10				0.2/10				0.8/15	0.2/10
<i>Echinachea angustifolia</i> blacksampson echinachea							0.05/10			
<i>Hieracium longipilum</i> longbeard hawkweed										0.05/10
<i>Kuhnia eupatorioides</i> var. <i>corymbulosa</i> , falseboneset	0.1/20	0.02/5	0.02/5	0.02/5		0.7/60	3.6/90	0.5/75	0.2/30	
<i>Lespedeza capitata</i> roundhead lespedeza			0.02/5		0.05/10		0.02/5	0.2/45	1.0/35	1.0/25
<i>Lespedeza violacea</i> violet lespedeza ¹		0.01/2							8.6/35	
<i>Lithospermum incisum</i> narrowleaf gromwell				0.02/5			0.02/5			
<i>Lomatium foeniculaceum</i> carrotleaf lomatium						0.02/5				
<i>Oenothera macrocarpa</i> ssp. <i>macrocarpa</i> , Missouri eveningprimrose						0.05/10				
<i>Oenothera speciosa</i> white eveningprimrose		0.1/5	0.08/15		0.02/5	0.02/5				
<i>Onosmodium molle</i> var. <i>occidentale</i> , western marbledseed						0.2/5				
<i>Oxalis violacea</i> violet woodsorrel oxalis	0.1/20	0.01/2					0.02/5			0.02/5
<i>Physalis heterophylla</i> clammy groundcherry		0.1/2								
<i>Physalis pumila</i> prairie groundcherry		2.5/25	0.5/30	0.02/5	1.0/35	1.8/30	0.6/35	0.05/10		0.02/5
<i>Physalis virginiana</i> Virginia groundcherry	0.05/10	1.3/50	0.6/75	0.2/30	0.02/5	0.05/10	0.2/25		0.2/40	0.2/45
<i>Psoralea argophylla</i> silverleaf scurfpea				0.02/5						
<i>Psoralea esculenta</i> common breadroot scurfpea							0.05/10	0.02/5	0.02/5	
<i>Psoralea tenuiflora</i> manyflower scurfpea		0.2/5	0.5/30	3.4/60	1.3/35	3.5/70	4.3/75		2.3/50	3.2/80
<i>Ratibida columnifera</i> upright prairieconeflower	0.02/5		0.02/5	0.08/15	0.02/5	0.2/45	0.4/40	0.05/10		
<i>Ruellia humilis</i> fringeleaf ruellia	0.5/55	0.4/70	0.3/65	0.2/45	0.3/60	0.2/35	0.2/35	0.5/80	0.2/40	0.3/60
<i>Salvia azurea</i> Pitcher sage	0.4/20	0.1/15	0.05/10	0.3/15	0.02/5	1.1/30	0.2/35	0.4/35	0.02/5	
<i>Schrankia nuttallii</i> catclaw sensitivebriar	0.2/10	1.4/8						2.6/25		
<i>Senecio plattensis</i> prairie groundsel				0.02/5			0.02/5	0.1/20		
<i>Sisyrinchium campestre</i> prairie blueeyedgrass	0.2/40	0.2/30	0.3/60	0.2/45	0.05/10	0.2/35	0.4/60	0.2/30	0.4/85	0.3/65
<i>Solanum carolinense</i> horsenettle			0.4/30							
<i>Solidago canadensis</i> var. <i>scabra</i> , Canada goldenrod		1.3/5	0.02/5	0.05/10	0.02/5					
<i>Solidago missouriensis</i> var. <i>fasciculata</i> , Missouri goldenrod	0.02/5	11/40	0.4/55	0.2/35		1.6/85	0.6/50	1.9/5	6.8/45	0.08/15

Table 4. Continued

Species	Irwin		Sogn		Benfield		Tully			
	Burned annually (1)	Unburned (2)	July mowed & left (1)	July mowed & removed (1)	Nov. mowed & removed (1)	Unburned (1)	July mowed & left (1)	Unburned (1)	Burned against wind (1)	Burned with wind (1)
<i>Solidago mollis</i> ashy roldenrod							0.02/5			
<i>Solidago rigida</i> var. <i>humilis</i> stiff goldenrod				0.05/10						
<i>Spiranthes vernalis</i> upland ladiestresses										0.05/10
<i>Taraxacum officinale</i> common dandelion ¹			0.1/25	0.02/5						
<i>Teuchrium canadense</i> var. <i>virginiana</i> . American germander		0.3/22			0.4/20					
<i>Tragia betonicifolia</i> nettleleaf noseburn								0.02/5		
<i>Verbena canadensis</i> rose verbena						0.05/10				
<i>Verbena stricta</i> woolly verbena		0.01/2	0.2/25			0.02/5			0.1/20	0.1/20
<i>Vernonia baldwinii</i> var. <i>interior</i> , inland ironweed		2.6/50	11/100	1.8/95	12/100	3.3/100	4.8/100	0.8/85	1.0/95	1.4/95
<i>Vicia americana</i> American vetch				0.05/10	0.02/5					
<i>Viola pratincola</i> blue prairie violet							0.2/35			
Total cover, perennial forbs	13	34	23	10	20	39	22	36	48	17
Woody Plants:										
<i>Amorpha canescens</i> leadplant	16/80	7.1/50		0.02/5	0.02/5	0.5/20	0.1/20	4.3/95	0.6/35	0.1/25
<i>Ceanothus herbaceus</i> var. <i>pubescens</i> , inland ceanothus						0.2/5		2.0/45		
<i>Gymnocladus dioica</i> Kentucky coffeetree		0.01/2			0.02/5					
<i>Rosa arkansana</i> Arkansas rose		2.2/18								0.2/5
<i>Symphoricarpos orbiculatus</i> buckbrush		0.4/12	0.4/40		3.1/35		0.2/25	0.05/10	0.02/5	
Total cover, woody plants	16	9.7	0.4	0.02	3.1	0.7	0.3	6.4	0.6	0.3
Annual and Biennial Forbs:										
<i>Ambrosia artemisiifolia</i> common ragweed					0.02/5					
<i>Erigeron strigosus</i> var. <i>strigosus</i> , daisy fleabane	0.02/5		0.1/25	0.2/50	0.02/5	0.1/25	0.2/30	0.02/5	0.02/5	0.02/5
<i>Euphorbia marginata</i> snow-on-the-mountain								0.02/5	0.02/5	
<i>Euphorbia spathulata</i> wartly spurge						0.05/10				
<i>Galium aparine</i> catchweed bedstraw		0.02/5	0.02/5							
<i>Hymenopappus scabiosaeus</i> whitebract hymenopappus						0.05/10	0.08/15			
<i>Lactuca</i> spp. wild lettuces ¹			0.08/15	0.05/10	0.3/30	0.1/25	0.6/70	0.1/20		
<i>Linum sulcatum</i> grooved flax		0.02/5		0.2/45	0.02/5	0.02/5		0.08/15	0.05/10	0.02/5
<i>Melilotus</i> sweetclovers ¹				0.2/5						
<i>Oxalis stricta</i> common yellow oxalis		0.02/5	0.2/30	0.3/65			0.05/10		0.02/5	
<i>Plantago rhodosperma</i> redseed plantain				0.05/10						

Table 4. Continued

Species	Irwin		Sogn			Benfield		Tully		
	Burned annually (1)	Unburned (2)	July mowed & left (1)	July mowed & removed (1)	Nov. mowed & removed (1)	Unburned (1)	July mowed & left (1)	Unburned (1)	Burned against wind (1)	Burned with wind (1)
<i>Spermolepis inermis</i> spreading spermolepis		0.01/2		0.02/5		0.08/15				
<i>Strophostyles leiosperma</i> smoothseed wildbean									0.2/30	0.05/10
<i>Tragopogon dubius</i> western salsify ¹		0.01/2	4.9/100	0.6/50	0.02/5	0.1/20	1.5/95	0.02/5		
<i>Triodanis perfoliat</i> clasping venus lookingglass		0.01/2								
<i>Verbascum blattaria</i> moth mullein ¹			0.02/5							
<i>Viola rafinesquii</i> Johnnyjumpup		0.02/5		0.08/15						
Total cover, Annual & Biennial forbs	0.02	0.1	5.3	1.7	0.4	0.5	2.4	0.2	0.3	0.09
Total cover, all plants	177	251	320	370	374	285	272	202	244	240
Number of native species	33	42	53	40	43	51	50	50	43	41
Number of exotic species	0	1.5	6	6	4	2	4	2	1	0
Shannon-Weaver diversity index, H', av.	1.65	2.03	1.99	1.97	1.97	2.22	1.88	1.98		

¹Exotic species

STUDY AREA

The study was conducted in the Geary County, "Old Konza Prairie", portion of Konza Prairie Research Natural Area in the Flint Hills of northeast Kansas (Hulbert 1985). Konza Prairie is a 3,487 ha tallgrass prairie site acquired by The Nature Conservancy in late 1971 and is leased to Kansas State University. A management plan, initiated in 1972, included prescribed burning in early April of watershed units at 1-, 2-, 4-, and 10-year intervals, as well as unburned units (Hulbert 1973). The area was never been plowed, except in a few lowland areas, and had been grazed by cattle since settlement. The sites studied by Hulbert were last grazed in 1971. Experimental mowing in March, July, and November began in 1971, with the hay removed on part and left on part of the mowed areas. With the acquisition of additional land in Riley County in 1977, Konza Prairie was much enlarged. Subsequently, some of the experimental treatments were modified in 1978 (Hulbert 1985).

METHODS

The relative cover of all vascular plant species was recorded in 1983 in twenty circular plots (10 m²) in each of 27 soil-treatment combinations (Table 1). The plots were evenly distributed over each soil-treatment area. Each soil-treatment area was sampled in late spring, mid-summer, and late summer. Cover was estimated ocularly according to a modified Daubenmire (1959) scale (Abrams and Hulbert 1987). The maximum cover value attained for each species in each plot over the three dates was retained for subsequent analysis.

RESULTS AND DISCUSSION

In his unfinished manuscript, Hulbert pointed out that the six to ten years of treatments were insufficient to remove all effects of prior grazing and burning. In an analysis of other Konza Prairie data, Gibson (1988) came to a similar conclusion for watersheds subjected to a four-year burning cycle. Hulbert pointed out that rigorous statistical analyses would likely yield a number of significant differences between treatments that were not biologically useful. Furthermore, in spite of the many hours spent gathering data, the number of replicate samples per soil-treatment combination was small ($n = 1$ to 5). Thus, for this report, only differences that occurred consistently between soil-treatment combinations were considered.

Effect of Season of Burning

Annual burning in March or November resulted in the highest total cover of warm-season grasses and perennial forbs (Figures 1b and 1c). In contrast, burning in late April led to a comparatively lower cover of these types of plants. Of the individual species, little bluestem (*Andropogon scoparius* Michx.) and tall dropseed [*Sporobolus asper* (Michx.) Kunth] were favored especially on Tully soils by burning in March compared with late April. In contrast, big bluestem (*Andropogon gerardii* Vitman) and indian-grass [*Sorghastrum nutans* (L.) Nash] were favored on Florence soils by burning in late April compared with March (Table 2). These results are comparable to those reported by Towne and Owensby (1984). Although the difference between burning in March or late April was only a few days, it apparently was critical because it coincided with the emergence of the warm-season perennial grasses (Aldous 1934, Towne and Owensby 1984).

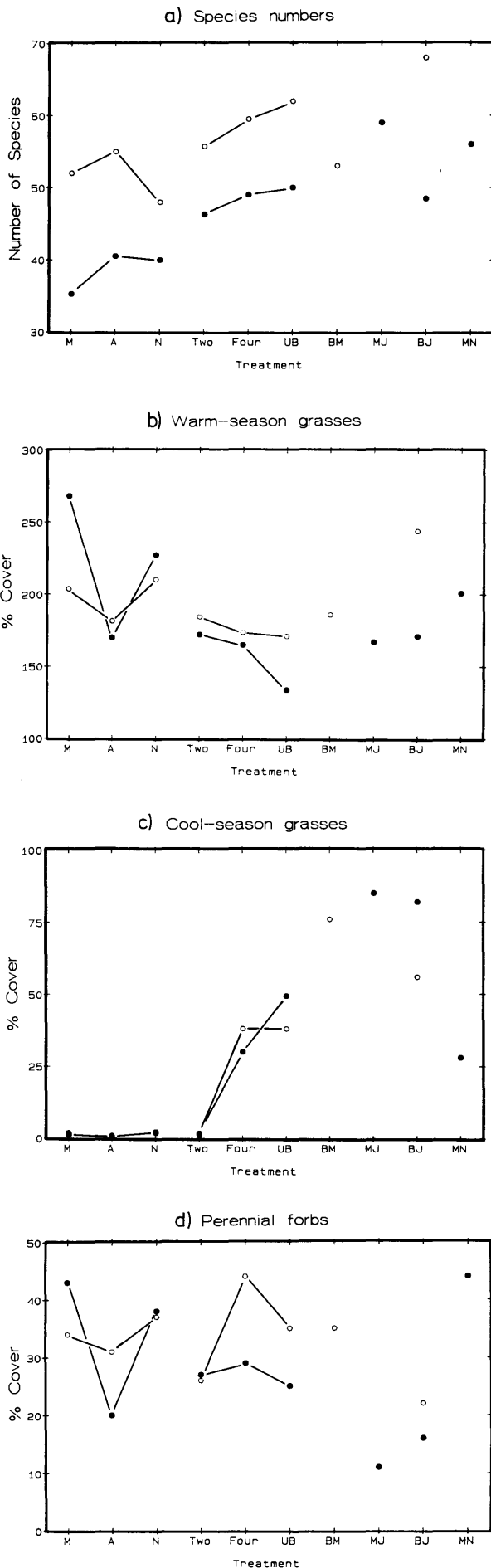


FIG. 1. a) Mean number of species, and b-e) percentage cover of different plant life forms according to different burning and mowing treatments on Florence (open circles) and Tully (solid circles) soils. M = burned annually in March, A = burned annually in April, N = burned annually in November, Two = burned every two years in April, Four = burned every four years in April, UB = unburned, BM = mowed and baled in March, MJ = mowed and left in July, BJ = mowed and baled in July, and MN = mowed and left in November.

Effect of Frequency of Burning

With more frequent burning, growth (cover) of warm-season grasses was favored (Figure 1a). Cool-season grasses and species richness increased with less frequent burning (Figures 1a and 1b). Of the cool-season grasses favored by less frequent burning, Kentucky bluegrass (*Poa pratensis* L.) showed a particularly strong response as it had in other studies (Towne and Owensby 1984, Abrams and Hulbert 1987). As a group, perennial forbs did not show a clear response to burning frequency (Figure 1d), although on Tully soils western ragweed (*Ambrosia psilostachya* DC.), and on Florence soils Canada goldenrod (*Solidago canadensis* var. *scabra* T. & G.) and inland ironweed [*Vernonia baldwinii* var. *interior* (Small) Faust] had highest cover values in less frequently burned areas. As shown in other studies (Gibson and Hulbert 1987), big bluestem showed little response to burning frequency, whereas indiagrass and little bluestem were most abundant under conditions of frequent burning.

Effect of Mowing

The effect of mowing was varied and depended on the season and whether or not the hay was removed. Annual and biennial forbs were favored by mowing and reached 38% cover on Florence soils in sites that had been mowed and baled in July. This was primarily due to the success of sweetclovers (*Melilotus* spp. P. Mill.), an exotic biennial species (Table 2). Japanese brome (*Bromus japonicus* Thunb. ex Murr.), an exotic annual grass, also reached maximum cover on sites that had been mowed in July (Tables 2 and 3). In the absence of mowing, annual species were normally most abundant on sites of animal disturbances (Collins and Glenn 1988, Gibson 1989). The maximum number of species was also recorded on Florence soils in sites that had been mowed and baled in July (Figure 1e). This reflected a large number (8) of exotic species (Table 2). Mowing and baling removed vegetative cover, and had the effect of increasing light levels at the soil surface. Increased surface light intensity was one of the factors which, in combination with higher soil temperatures, accounted for increased productivity following burning (Hulbert 1988). In this sense, mowing was similar to burning. However, an increase in species richness and cover of annual species was not noted in the burned sites in this study. Whereas burning killed seedlings and favored rapidly resprouting perennials, mowing allowed and favored annual species.

Effect of Soil Type

The different soils sampled by Hulbert represented an indirect gradient from the shallow soils of prairie ridge tops (Florence and Benfield series), down slope on thin rocky soils (Sogn and Irwin series), to lowland foot slopes (Tully series) (Jantz *et al.* 1975). The most thoroughly sampled portion on this gradient was on the Florence and Tully series. This gradient of moisture availability was severe enough that there were differences between the flora of the two extremes. Silky aster (*Aster sericeus* Vent.), aromatic aster (*Aster oblongifolius* Nutt.), sleepy catchfly (*Silene antirrhina* L.), and slimpod venus-looking glass [*Triodanis perfoliata* (L.) Nieuw.] were absent from Tully soils. Smoothseed wildbean [*Strophostyles leiosperma* T. & G.] Piper, clammy groundcherry (*Physalis heterophylla* Nees), Virginia groundcherry (*Physalis virginiana* P. Mill.), Canada goldenrod (*Solidago canadensis* L.), upland ladies'-tresses (*Spiranthes vernalis* Engelm. & Gray), and American germander (*Teucrium canadense* L.) were absent from Florence soils. Overall, more species occurred on Florence soils than on either Tully or Irwin soils irrespective of burning or mowing treatment (Figure 2). Other species showed quantitative differences in abundance on different soil types. For example, big bluestem, the dominant plant overall, was more abundant on Tully soils than on Florence soils under all burning and mowing treatments. Many species showed an interaction between a combination of burning, mowing, and soil type. For example, wild lettuces (*Lactuca* spp. L.) were more abundant on Florence soils compared with Tully soils when in treatments burned on a less frequent than annual burning regime. Prairie coneflower [*Ratibida columnifera* (Nutt.) Woot. & Standl.] was infrequent on Tully soils irrespective of burning treatment, but was more abundant on Florence soil that had been either left unburned or burned only every few years.

The unburned treatments allowed a comparison across all five soil series (Table 1). However, the variability in these data were large, in particular the mean cover of particular life form classes, such as cool- and warm-season grass cover (Figure 2). This variation reflects Hulbert's assertion and Gibson's (1988) observation, that influence from prior management may still be evident after several years of known management.

CONCLUSIONS

Hulbert's data represent a valuable resource for understanding plant community interactions on the tallgrass prairie with respect to burning, mowing, and soil type. Previous studies have considered these factors, but not in such a large number of treatment combinations. Prior management and landscape effects were clearly evident in these data and increased the variance of each treatment effect. Nevertheless, a number of consistent trends emerged. For example, spring burning favored warm-season grasses at the expense of cool-season grasses and forbs, annual and biennial plants were able to establish under the mowing treatments, and the number of species was highest on the soils of level uplands. More subtle effects and trends would be likely revealed using multivariate and other statistical procedures, and the data are provided (Tables 2 to 4) so that other researchers might have this opportunity.

ACKNOWLEDGEMENTS

This report is written in tribute to the late Lloyd Hulbert who undertook the field work. The original field notes, other partial summaries of these data and Hulbert's original unfinished manuscript are stored in the Konza Prairie Office, Kansas State University, Manhattan, Kansas 66506. J. M. Briggs is thanked for critically reviewing an early draft of the manuscript, and for giving the oral presentation. Manuscript preparation was partially funded by NSF Grant BSR-8514327 for Long-Term Ecological Research to Kansas State University. This is contribution number 89-31-A, Division of Biology, Kansas Agricultural Experiment Station, Kansas State University. The author was formerly with the Division of Biology, Kansas State University.

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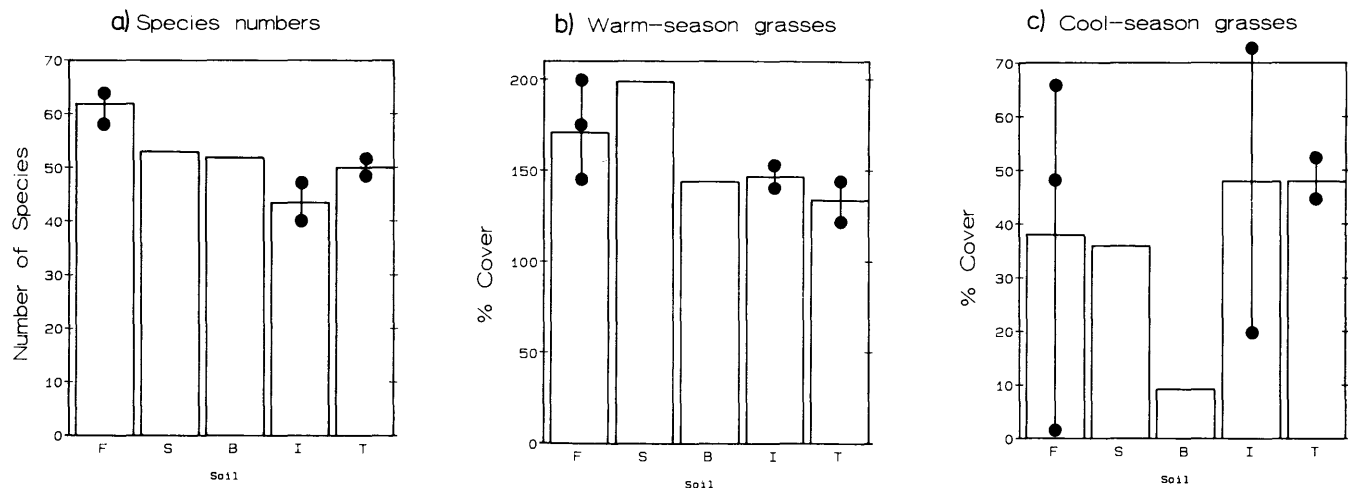


FIG. 2. Mean a) number of species, and percentage cover of b) warm-season and c) cool-season grasses in unburned sites on Florence (F), Sogn (S), Benfield (B), Irwin (I), and Tully (T) soils. The bars indicate mean values over all replicate sites, the solid circles indicate the mean values for each replicate site (e.g. three replicate sites on Florence soil). One site was sampled on Sogn and Benfield soils and so just the bars are drawn. The line joining the highest and lowest value indicates the range of means.

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