Bulletin of the Torrey Botanical Club 123(4), 1996, pp. 304–308

Effects of fire frequency on plant species in oak savanna in east-central Minnesota[1]

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TESTER, J. R. (Department of Ecology, Evolution and Behavior, University of Minnesota, St. Paul, MN 55108). Effects of fire frequency on plant species in oak savanna in east-central Minnesota. Bull. Torrey Bot. Club 123: 304–308. 1996.—From 1964 through 1984, nine forest sites, ranging in size from 2.6 to 27.5 ha, were each burned from two to 19 times. Percent cover of 13 of 14 true-prairie grasses was positively correlated with burn frequency. Of these, eight have C4 and six have C3 photosynthetic pathways. Cover of 34 of 39 true-prairie forbs, and of *Amorpha canescens,* increased with frequency of burning. All except *Aster oolentangiensis* are C3 species. Cover of six of seven native, not prairie, species, all C3, decreased with increasing burn frequency. These data suggest that the adaptation of true-prairie species to repeated burning outweighs the effects of their photosynthetic pathways.

Key words: oak savanna, prescribed burning, prairie plants.

The role of fire in maintenance of tallgrass prairie and savanna ecosystems is well documented (reviewed in Collins and Wallace 1990; Hulbert 1986; Johnson 1993). In general, fire suppresses shrubs and trees and favors native prairie species. Responses of plant species to burning, however, are related to season of burning (Howe 1994a, 1994b), intensity and frequency of fires (Gibson 1988; Tester 1989; White 1986). However, plant species respond in an indivdualistic manner. Thus, use of prescribed burning by resource managers must be based on knowledge of how individual species will respond to the treatment. This paper reports on the response of certain plant species over a 20-year period to a program of prescribed fires that was implemented in 1964 at the Cedar Creek Natural History Area to restore oak savanna from oak forest.

Methods. In 1964, nine forest sites, ranging in size from 2.6 to 27.5 ha, were established and randomly assigned for the application of different frequencies of prescribed burns (Irving 1970). The number of burns at a given site for the 20-year period ranged from two to 19. Dates, characteristics of burns, and design limitations are given in Tester (1989). Unfortunately, no data were collected on these nine sites prior to initiation of the burning regimen in 1964.

These sites plus three unburned sites in adjacent oak forest believed to be typical of the entire study area were used for the present study. All 12 sites are within a 320-ha block and have similar topography. In 1984, percent cover of litter, bare ground, and each shrub and herb species was visually estimated in 24 1.0-m × 0.5-m quadrats, spaced uniformly in the sample area, following Inouye et al. (1987). Each species was placed in one of three categories; (1) typically occurring in true (tallgrass) prairie, (2) native to North America but not typically found in prairie, or (3) introduced from another continent, using data from Gleason and Cronquist (1963), Curtis (1959), and personal communications with E. Cushing, B. Delaney, and T. Morley. Species also were categorized by photosynthetic pathways following Waller and Lewis (1979) and E. Wardenaar (pers. comm.). Nomenclature follows Ownbey and Morley (1991). Regression analyses were performed with number of burns as the independent variable and average of percent cover as the dependent variable. No a priori criteria were available to identify outliers; therefore, all data points were included for all species.

Results and Discussion. Litter comprised from 28.9 to 85.0 percent of the cover in the 12 plots and bare ground varied from <1.0 to 38.5 percent. A total of 104 shrub and herb species were identified on the study area. Cover estimates of 13 of 14 true-prairie grasses were positively correlated with burn frequency (Table 1), with the highest significance levels noted for *Panicum praecocious, Sorghastrum nutans* (Fig. 1), *Stipa spartea, Bouteloua hirsuta, Schizachyrium scoparius, Panicum virgatum,* and *An-*

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[1] This study was supported by National Science Foundation Grant DEB 8114302 for Long Term Ecological Research at Cedar Creek Natural History Area. I thank D. Tilman for suggestions on the manuscript.

Received for publication October 13, 1995, and in revised form June 19, 1996

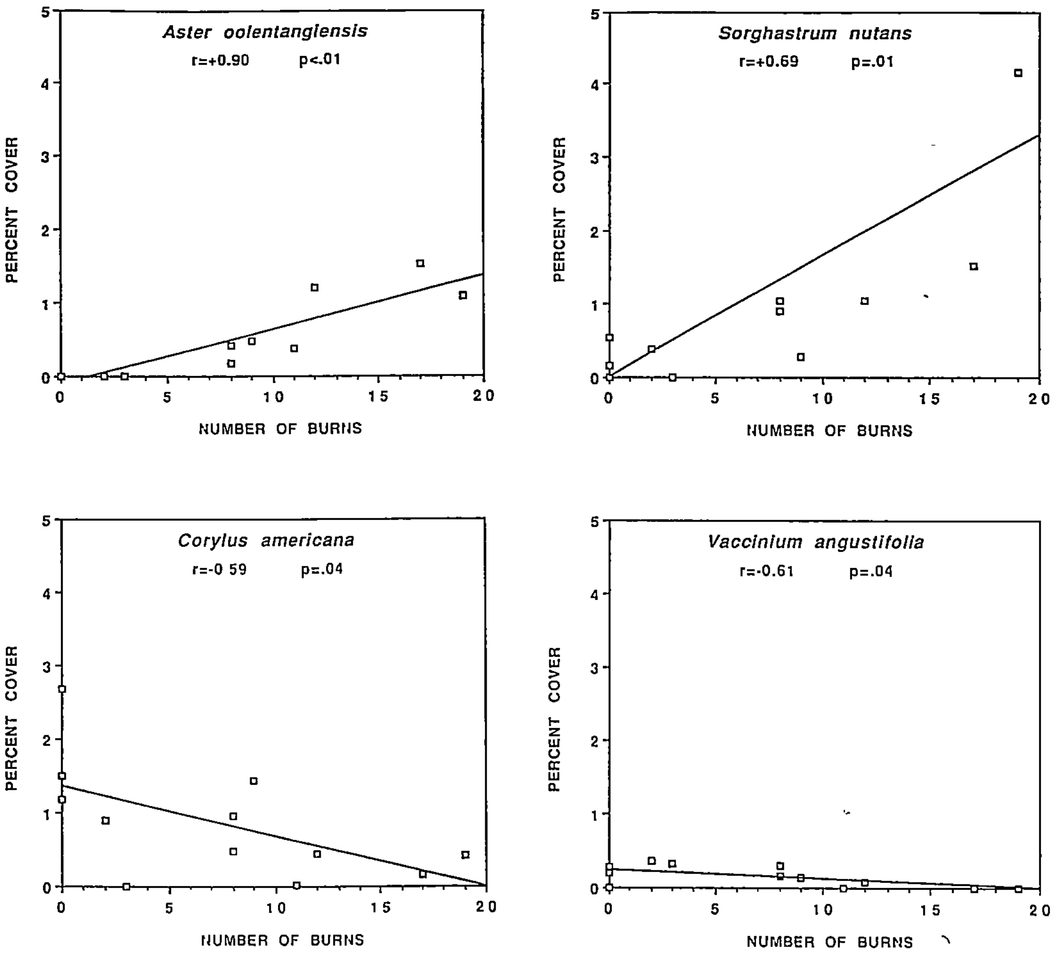

Fig. 1. Linear regressions showing effect of number of burns on percent cover of *Aster oolentangiensis, Sorghastrum nutans, Corylus americana,* and *Vaccinium angustifolia.*

dropogon gerardi. Six have C3 and eight have C4 photosynthetic pathways.

Increase in C4 grasses has been reported from numerous studies (Gibson 1989; Hadley and Kieckhefer 1963; Svedarsky et al. 1986; and others). However, increased cover of C3 grasses is somewhat surprising. Anderson et al. (1970), Gibson and Hulbert (1987), and Glenn-Lewin et al. (1990) stated that C3 grasses generally decreased after spring fire, and Howe (1994a, 1994b) emphasized that spring burns are likely to suppress C3 and favor C4 species. Anderson and Bailey (1980) reported that annual burning for 24 years reduced cover of *Stipa spartea,* a C3 species, in Alberta.

Cover of two introduced grasses, *Poa pratensis* (C3) and *Setaria lutescens* (C4), showed increases in cover with burn frequency and two other introduced species, *Agropyron repens* (C3) and *Bromus inermus* (C3), showed decreases. However, none of the *P*-values were less than 0.23.

Linear regressions showing the effect of number of fires on percent cover of *Corylus americana* and *Vaccinium angustifolia* are shown in Fig. 1. Cover estimates of six of the seven native, non-prairie species with $P < 0.10$, including the above, were negatively correlated with burn frequency. This result is not surprising since these species are typical of Minnesota forests where fire would have been less frequent (Tester 1995). I cannot explain the one exception, *Parthenocissus vitacea,* which significantly increased with burn frequency. All native, non-prairie species in Table 1 have C3 photosynthetic pathways.

Table 1. Linear regression showing effects of burn frequency on percent cover of shrubs and herbs. Ecological origin, photosynthetic pathway, and life form are given for each species.

	Origin[a]	Photo-synthetic pathway	Life form[b]	r	*P*	*P* < 0.10
Achillea millefolium	T	C3	F	0.028	0.931	
Agropyron repens	I	C3	G	−0.372	0.233	
Ambrosia coronopifolia	T	C3	F	0.334	0.288	
Amorpha canescens	T	C3	SH	0.572	0.052	*
Amphicarpa bracteata	N	C3	F	0.141	0.663	
Andropogon gerardi	T	C4	G	0.578	0.049	*
Anemone cylindrica	T	C3	F	0.179	0.577	
Antenaria plantagenifolia	T	C3	F	0.281	0.376	
Apocynum cannabinum	N	C3	SH	−0.355	0.258	
Arenaria lateriflora	N	C3	F	−0.377	0.227	
Artemisia caudata	T	C3	F	0.171	0.594	
Artemisia ludoviciana	T	C3	F	0.464	0.129	
Asclepias syriaca	N	C3	F	−0.208	0.516	
Asclepias tuberosa	T	C3	F	0.201	0.531	
Aster oolentangiensis	T	C4	F	0.898	0.000	*
Bouteloua hirsuta	T	C4	G	0.596	0.041	*
Bromus inermus	I	C3	G	−0.002	0.995	
Calamagrostis canadensis	T	C3	G	0.223	0.486	
Calamovilfa longifolia	T	C4	G	0.478	0.116	
Campanula rotundifolia	T	C3	F	0.219	0.494	
Ceanothus americanus	T	C3	SH	0.028	0.931	
Celastrus scandens	N	C3	SH	0.209	0.514	
Chenopodium alba	I	C3	F	−0.351	0.264	
Commandra richardsiana	T	C3	F	0.383	0.219	
Coreopsis palmata	N	C3	F	0.460	0.133	
Cornus racemosa	N	C3	SH	0.028	0.931	
Cornus stolonifera	N	C3	SH	−0.233	0.467	
Corylus americana	N	C3	SH	−0.588	0.044	*
Crepis tectorum	I	?	F	0.342	0.277	
Desmodium canadense	N	C3	F	−0.005	0.989	
Elymus canadensis	T	C3	G	0.028	0.931	
Equisetum laevigatum	T	C3	N	−0.285	0.369	
Eragrostis spectabilis	T	C4	G	−0.038	0.908	
Erigeron candensis	N	C3	F	0.307	0.332	
Erigeron strigosus	N	C3	F	0.458	0.134	
Euphorbia corollata	T	C3	F	0.458	0.134	
Fragaria virginiana	T	C3	F	−0.132	0.682	
Galium aparine	T	C3	F	0.076	0.815	
Galium boreale	N	C3	F	0.121	0.707	
Galium triflorum	N	C3	F	−0.515	0.086	*
Helianthemum bicknellii	T	C3	F	0.694	0.012	*
Helianthus laetiflorus	T	C3	F	0.567	0.055	*
Juniperus communis	T	C3	SH	−0.470	0.124	
Lactuca canadensis	T	C3	F	0.009	0.977	
Lathyrus venosus	N	C3	F	0.075	0.818	
Lechea stricta	T	C3	F	−0.089	0.782	
Lespedeza capitata	T	C3	F	0.224	0.485	
Lithospermum canescens	T	C3	F	0.615	0.033	*
Lithospermum carolinense	T	C3	F	−0.005	0.989	
Lychnis alba	I	C3	F	0.268	0.399	
Lysimachia ciliata	N	C3	F	0.028	0.931	
Maianthemum canadense	N	C3	F	−0.220	0.493	
Monarda fistulosa	N	C3	F	−0.292	0.357	
Muhlenbergia racemosa	T	C4	G	0.038	0.907	
Oenothera biennis	T	C3	F	0.355	0.258	
Oxybaphus hirsutus	T	C3	F	0.193	0.548	
Panicum oligosanthes	T	C3	G	0.524	0.080	*
Panicum perlongum	T	C3	G	0.548	0.065	*
Panicum praecocious	T	C3	G	0.765	0.004	*
Panicum virgatum	T	C4	G	0.585	0.046	*
Parthenocissus inserta	N	C3	SH	0.391	0.209	
Parthenocissus vitacea	N	C3	SH	0.678	0.015	*

Table 1. Continued

	Origin[a]	Photo-synthetic pathway	Life form[b]	r	P	$P < 0.10$
Pedicularis canadensis	T	C3	F	0.219	0.494	
Physalis virginiana	T	C3	F	0.406	0.190	
Poa pratensis	I	C3	G	0.169	0.600	
Polygala polygama	T	C3	F	0.587	0.045	*
Polygonatum biflorum	N	C3	F	0.079	0.807	
Polygonum convolvulus	I	C3	F	0.029	0.930	
Potentilla simplex	N	C3	F	0.083	0.799	
Prunus americana	N	C3	SH	−0.355	0.258	
Prunus virginiana	N	C3	SH	−0.512	0.089	*
Ranunculus rhomboideus	T	C3	F	0.137	0.671	
Rhus glabra	T	C3	SH	0.130	0.688	
Rhus radicans	T	C3	SH	0.390	0.210	
Rosa arkansana	T	C3	SH	0.232	0.468	
Rubus sp	N	C3	SH	0.068	0.835	
Rudbeckia serotina	T	C3	F	0.045	0.890	
Rumex acetosella	I	C3	F	−0.131	0.685	
Salix sp	T	C3	SH	−0.179	0.578	
Schizachyrium scoparius	T	C4	G	0.590	0.044	*
Scutellaria parvula	T	C3	F	0.687	0.014	*
Senecio pauperculus	T	C3	F	0.488	0.108	
Setaria lutescens	I	C4	G	0.246	0.441	
Sisyrinchium campestre	T	C3	F	0.554	0.062	*
Smilacina racemosa	N	C3	F	0.007	0.984	
Smilacina stellata	T	C3	F	0.188	0.559	
Smilax herbacea	N	C3	F	0.259	0.416	
Solanum dalcamara	I	C3	F	−0.211	0.510	
Solidago gigantea	T	C3	F	−0.016	0.959	
Solidago graminifolia	T	C3	F	0.455	0.137	
Solidago missouriensis	T	C3	F	0.438	0.155	
Solidago nemoralis	T	C3	F	0.560	0.058	*
Solidago rigida	T	C3	F	0.142	0.661	
Sorghastrum nutans	T	C4	G	0.694	0.012	*
Stachys palustris	T	C3	F	0.173	0.590	
Stellaria longifolia	N	C3	F	−0.355	0.258	
Stipa spartea	T	C3	G	0.834	0.001	*
Trientalis borealis	N	C3	F	−0.529	0.077	*
Trifolium sp	I	C3	F	−0.211	0.510	
Uvularia sessifolia	N	C3	F	−0.355	0.258	
Vaccinium angustifolia	N	C3	SH	−0.605	0.037	*
Viola pedatifida	T	C3	F	0.033	0.918	
Viola sagittata	T	C3	F	−0.350	0.264	
Vitis riparia	N	C3	SH	−0.508	0.092	*

[a] T—true prairie, N—native, non-prairie, I—introduced.
[b] F—forb, G—grass, N—non-vascular, SH—shrub.

All true-prairie forbs with $P < 0.10$, 34 of the 39 true-prairie forbs listed in Table 1, and *Amorpha canescens,* a true-prairie shrub, increased with burn frequency. All except *Aster oolentangiensis* (Fig. 1) are C3. Increase in *Amorpha canescens* was reported by Abrams and Hulbert (1987), but Gibson et al. (1993) found that cover of *Amorpha canescens* was reduced by burning. Gibson et al. (1993) reported that cover of forbs was reduced by burning and Gibson and Hulbert (1987) indicated that C3 species were reduced and C4 species favored by spring burning. Published information on the response of most forbs listed in Table 1 to fire frequency is lacking. However, Kline (1986) found that *Solidago nemoralis* decreased under annual burning.

Management of tallgrass prairie is dependent on knowledge of how individual species will respond to treatments such as prescribed burning. Data presented here on the response of selected native true-prairie and native, non-prairie species to fire frequency indicate that the true prairie species are well adapted to fire, and that this adaptation appears to outweigh the effects of the photosynthetic pathway on response of the individual species.

Literature Cited

ABRAMS, M. D. AND L. C. HULBERT. 1987. Effect of topographic position and fire on species in tallgrass prairie in northeast Kansas. Amer. Midland Nat. 117: 442–445.

ANDERSON, H. G. AND A. W. BAILEY. 1980. Effects of annual burning on grassland in the aspen parkland of east-central Alberta. Can. J. Bot. 58: 985–996.

ANDERSON, K. L., E. F. SMITH, AND C. E. OWENSBY. 1970. Burning bluestem range. J. Range Manag. 23: 81–91.

COLLINS, S. L. 1992. Fire frequency and community heterogeneity in tallgrass prairie vegetation. Ecology 73: 2001–2006.

——— AND L. L. WALLACE. 1990. Fire in North American tallgrass prairies. Univ. Oklahoma Press, Norman.

GIBSON, D. J. 1988. Regeneration and fluctuation of tallgrass prairie vegetation in response to burning frequency. Bull. Torrey Bot. Club 115: 1–12.

———. 1989. Hulbert's study of factors effecting botanical composition of tallgrass prairie, pp. 115–133. *In:* Proc. Eleventh North American Prairie Conf., T. B. Bragg, and J. Stubbendieck [eds.], Lincoln, NB.

——— AND L. C. HULBERT. 1987. Effects of fire, topography and year-to-year climatic variation on species composition in tallgrass prairie. Vegetatio 72: 175–185.

———, T. R. SEASTEDT AND J. M. BRIGGS. 1993. Management practices in tallgrass prairie: Large- and small-scale experimental effects on species composition. J. Applied Ecol. 30: 247–255.

HADLEY, E. B. AND B. J. KIECKHEFER. 1963. Productivity of two prairie grasses in relation to fire frequency. Ecology 50: 389–395.

HOWE, H. F. 1994a. Managing species diversity in tallgrass prairie: Assumptions and implications. Conservation Biology 8: 691–704.

———. 1994b. Response of early- and late-flowering plants to fire season in experimental prairies. Ecological Applications 4: 121–133.

HULBERT, L. C. 1986. Fire effects on tallgrass prairie, pp. 138–142. *In:* Proc. Ninth North American Prairie Conf. G. K. Clambey, and R. H. Pemble [eds.], Fargo, N. D.

INOUYE, R. S., N. J. HUNTLEY, D. TILMAN, J. R. TESTER, M. STILLWELL AND K. C. ZINNELL. 1987. Old field succession on a Minnesota sandplain. Ecology 68: 12–26.

JOHNSON, P. S. 1993. Perspectives on the ecology and silviculture of oak-dominated forests in the central and eastern states. General Tech. Rept. NC-153. USDA, North Central For. Exp. Sta., St. Paul, MN. 28 p.

OWNBEY, G. B. AND T. MORLEY. 1991. Vascular plants of Minnesota. University of Minnesota Press, MN.

SVEDARSKY, W. D., P. E. BUCKLEY AND T. A. FEIRO. 1986. The effect of 13 years of annual burning on an aspen-prairie ecotone in northwestern Minnesota, pp. 118–122. *In:* Proc. Ninth North American Prairie Conf. G. K. Clambey and R. H. Pemble [eds.], Fargo, N. D.

TESTER, J. R. 1989. Effects of fire frequency on oak savanna in east-central Minnesota. Bull. Torrey Bot. Club 116: 134–144.

———. 1995. Minnesota's Natural Heritage: An ecological perspective. University of Minnesota Press, MN.

TILMAN, D. 1987. Secondary succession and the pattern of plant dominance along experimental nitrogen gradients. Ecol. Monogr. 57: 189–214.

WALLER, S. S. AND J. K. LEWIS. 1979. Occurrence of C3 and C4 photosynthetic pathways in North American grasses. J. Range Manag. 32: 12–28.

WHITE, A. S. 1986. Prescribed burning for oak savanna restoration in central Minnesota. Research Paper NC-266. USDA, North Central For. Exp. Sta., St. Paul, MN. 12 p.