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Tallgrass Prairie Remnants of Western Iowa Cemeteries.

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Tallgrass Prairie Remnants of Western Iowa Cemeteries

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THESIS ACCEPTANCE

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ABSTRACT

Tallgrass prairie remnants situated in eight western Iowa cemeteries were sampled during 1995 and 1996 to compare both the frequency and season of mowing and burning on plant species composition. Dominant, native tallgrass prairie species, such as big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*) and leadplant (*Amorpha canescens*), generally showed a significant increase with burning, whether mowed or not. Mowing, however, adversely affected other species, including flowering spurge (*Euphorbia corollata*) and porcupine grass (*Stipa spartea*), whether burned or not. Non-native species, in particular smooth brome (*Bromus inermis*) increased with mowing and the absence of fire. Overall, my study suggests the importance of selecting the appropriate type or frequency of management in order to maintain the native tallgrass prairie plant diversity. Further, it supports the appropriate use of fire rather than mowing, both to favor native species and to limit the advance of non-native species.

INTRODUCTION

An estimated 90% of the original 58 M ha of tallgrass prairie (*Andropogon-Panicum-Sorghastrum*) (Küchler 1964, 1985) have been lost with extant prairie remnants occurring mostly in small fragments (Klopatek *et al.* 1979). Regional losses vary from 85% west of the Missouri River to as much as 99.9% in Iowa (Samson and Knopf 1994). Losses are largely a consequence of such factors as cultivation, urban expansion, and alteration of natural fire regime that has exposed prairies to invasion by woody plants (Bragg and Hulbert 1976) or non-native, herbaceous species (Lovell *et al.* 1983).

Tallgrass prairie remnants in Iowa are most commonly found either along roadsides or within the boundaries of old cemeteries (Hanes and Hanes 1947, Kerr and White 1981). In these sites, mowing and burning are the principal management options available to land managers. Which option to apply and the manner (e.g. season and frequency) by which to apply it are dictated by various considerations including prairie location, local expertise, management objectives, and the degree of concern for invasive, native woody species and non-native, herbaceous species, such as smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*) and musk thistle (*Carduus nutans*).

Management of most of Iowa's prairie remnants has involved either mulch-mowing (i.e. mowing and not removing the mulch) or haying (i.e. mowing and removing the mulch). In this study, use of the term *mowing* will refer to mulch-mowing while use of the term *haying* will refer to mowing and removing mulch. Mowing and haying have been noted to have different effects in grasslands. Dale (1983), for example, found that grasses showed better, initial growth on plots where mulch was removed than where mulch remained, probably a response to a warmer soil and more adequate moisture. By mid-July, however, those plots with mulch showed greater growth, probably due to moisture retained in soil by the mulch cover. Over time, however, haying may result in a decline in ecosystem productivity (Ehrenreich and Aikman 1963). Further, repeatedly mowing or haying tallgrass prairie appears to favor some cool-season species, particularly the aggressive eurasian grass, smooth brome, which has the potential to replace native species (Boettcher and Bragg 1989).

More recently, prescribed burning has been used in prairie management, since fire was historically a natural component of the tallgrass prairie ecosystem (Pyne 1982) and since fire can also be a more cost-effective means by which to manage grasslands (Engle 1988). Fire's role in tallgrass prairie is varied (Bragg 1995). Effects of burning include (1) woody plant suppression (Bragg and Hulbert 1976), (2) invigoration of prairie plants and their reproduction through litter removal and increased soil temperature (Hulbert 1969, 1986), and (3) control of invasive, herbaceous species (Lovell *et al.* 1983). In the absence of fire, not only do native woody species invade but so do non-native species such as Kentucky bluegrass and smooth brome (Ross and Vanderpoel 1991).

Comparisons between burning and mowing.- A comparison between burning, a natural process, and mowing, a human process, is necessary in order to assess the degree to which one may be used as a surrogate for the other. In general, mowing and burning are similar in that both (1) may maintain a high diversity of grassland species while controlling woody plant invasion (Mooberry 1984, Solecki and Toney 1986, Fitzgerald and Tanner 1992), (2) may affect either the amount or distribution of standing dead and litter, and (3) typically require planning decisions such as the time and frequency of application and long-term management goals. Some differences, however, are apparent when comparing burning with either haying or mulch-mowing. Haying is more similar to burning than mulch-mowing because both haying and burning remove plant matter, thereby minimizing litter accumulation. Differences, however include that haying does not remove all litter although it does generally remove nutrients from the system.

While there are some similarities, the differences between burning and mowing are more substantial. Most importantly, fire stimulates the tallgrass prairie plant community more than does mowing, although neither all species nor all prairies respond to the same degree (Hadley 1970, Pemble *et al.* 1981). In addition, the blackened surface resulting from burning causes soil temperatures to be higher due to higher absorption of incident solar radiation that may be responsible for spring plant growth being advanced by as much as 2-3 weeks (Ehrenreich 1959, Ehrenreich and Aikman 1963, Hulbert 1969). These differences may also affect microbial responses. Yet another difference is that both haying and mulch-mowing leave a more uniform distribution of plant matter than does burning (Morris 1979). In addition, mowing may remove woody plant cover more completely, particularly that part that is above mowing height, whereas burning may only reduce the amount or extent of woody plant cover and often only temporarily (Evans 1983, Fitzgerald and Tanner 1992).

Certain logistical differences also occur between burning and mowing.

For example, mowing is more easily applied at different seasons than is fire and it can also be applied several times each growing season. On the other hand, burning is usually limited to a single treatment each year, depending on the rate of fuel (litter) accumulation. For example, spring-burned tallgrass prairie accumulates enough fuel so that it can be reburned again in the fall of that year (Bragg 1982) whereas slow litter accumulation in short-grass prairie limits fire frequency to 6-10 years (Leenhouts 1997). The season and frequency of application, thus, are among important variables for both mowing and burning (Aldous 1934, McMurphy and Anderson 1965).

Frequency of treatment.- In general, frequent treatment by either mowing or burning is detrimental to the native tallgrass prairie plant community. Frequent mowing (e.g. annually or several times in a single year), for example, results in both a decline in native species diversity and an increase in disturbance species (Boettcher and Bragg 1989) although it also provides better control of woody invaders than does either a single mowing or a single prescribed fire (Evans 1983). Similarly, frequent burning results in both a decline in productivity (Conard 1954) and a change in community composition (McMurphy and Anderson 1965). For example Kucera and Koelling (1964) and Solecki and Toney (1986) found that, in contrast to an unburned area, annual burning resulted in a uniform grass cover with a reduction in forbs, whereas, burning every other year resulted in a greater number of forbs. Burning too infrequently, however, had nearly the same results as not burning. Communities burned at 5-year intervals, for example, differed little from those that were unburned (Kucera and Koelling 1964).

Season of treatment.- Seasonal effects of mowing or burning tallgrass prairie are generally divided into spring, summer, and fall. Spring is the season when C_3 (cool-season) species are actively growing but before growth of the C_4 (warm-season) species that dominate the region. Summer is the time of rapid growth of C_4 species but also the time of most lightning-caused fires (Bragg 1982) whereas fall is the season during which C_4 species are dormant but C_3 species may be active.

The season of treatment greatly affects individual and community-level responses to mowing. Spring (April) mowing tends to favor C_4 species (Hulbert 1969, Launchbaugh and Owensby 1978, Hover and Bragg 1981, Gillen and McNew 1987) and thus may be used to affect some control of introduced C_3 species such as Kentucky bluegrass (Curtis and Partch 1948, Ehrenreich and Aikman 1963), smooth brome (Solecki and Toney 1986) and to a lesser extent non-prairie woody plants (Lovell *et al.* 1983). The greatest diversity of prairie grasses and forbs, however, appears to occur on tallgrass prairies disturbed with summer (May-August) mowing (Launchbaugh and Owensby 1978, Solecki *et al.* 1986, Solecki and Toney 1986) although, annual summer mowing, over the long-term, decreases net productivity (Ehrenreich and Aikman 1963). Dormant-season mowing (October-February), whether periodic or annual, will retain at least some of native tallgrass species (Hayden and Aikman 1949) but generally reduces native plant diversity and leads to invasion by C_3 species such as Kentucky bluegrass and smooth brome (Weaver and Fitzpatrick 1934, Hayden and Aikman 1949, Launchbaugh and Owensby 1978, Boettcher and Bragg 1989, Gibson *et al.* 1993).

As with mowing, the season of occurrence of burning greatly affects individual and community-level responses. In tallgrass prairies dominated by C_4 species, spring burns more consistently decrease C_3 species, whether non-native species, such as Kentucky bluegrass, or native species, such as porcupine-grass (*Stipa spartea* Trin.), Canada wild rye (*Elymus canadensis* L.), and Scribner dichanthelium [*Dichanthelium oligosanthes* (Schult.) Gould var. *scribnerianum* (Nash) Gould] (Hensel 1923, Robocker and Miller 1955, Ehrenreich 1959, Hadley and Kieckhefer 1963, Anderson 1965, Old 1969). Spring burning also affects the forb community, although, late spring burning reduces canopy cover of all forbs to a greater extent than does earlier burning (McMurphy and Anderson 1965, Towne and Owensby 1984, Hulbert 1988). In contrast to spring burning, summer burns have been shown to be most successful in effecting some degree of woody plant control (Hulbert 1986). Fire in this season, however, may open sites to potential erosion and to invasion by exotic species (Solecki and Toney 1986) but it has also been shown to favor some prairie species such as prairie clover (*Dalea* spp.) and false sunflower (*Heliopsis helianthoides* var. *scabra*) (Bragg 1991). Fall burning, in general, has been found to increase rigid sunflower (*Solidago rigida* L.) (Schwegman and McClain 1985), leadplant (*Amorpha canescens* Pursh) (Towne and Owensby 1984) and white sweet clover (*Melolitus alba* Medic.) (Schwegman and McClain 1985). Annual fall burning may also increase forb diversity (Kline 1986) although it tends to lower C_4 grass production (Hulbert 1986).

Effects of no treatment.- In the absence of some form of management, (e.g. burning or mowing), litter accumulates, net annual primary production decreases, and aggressive plants, including non-native species, may increasingly replace prairie species (Hayden and Aikman 1949, Ehrenreich and Aikman 1963, Hulbert 1986, Knapp and Seastedt 1986, Leach and Givnish 1996). Studies on seasonal fire effects by Bragg (1991), for example, found that in both eastern Nebraska tallgrass prairies and northwestern Iowa loess hills prairies, forb cover declined most in areas that were not burned. Of particular concern, however, is the replacement of native prairie species by non-native exotics such as smooth brome and sweet-clover (Ross and Vanderpoel 1991). Once established, removal of these species, particularly smooth brome, can be difficult at best. For example, neither burning nor mowing was able to control smooth brome that had become established in a reseeded tallgrass prairie (Willson and Stubbendieck 1996). Further, where management may be suitable to control invasive species, it often may not be optimal for maintaining a desired prairie composition (Lovell *et al.* 1983). Over longer periods of time, woody plant encroachment of untreated areas is likely to degrade tallgrass prairie species composition (Tomanek 1948, Gehring and Bragg 1992) or replace tallgrass prairie with forest (Bragg and Hulbert 1976).

Only small stands of historic tallgrass prairie remain, especially in western Iowa, and maintaining the native diversity of these remnants is of particular ecological importance. Thus, there is a need to further identify and understand extant prairie remnants and draw from that knowledge that which will allow us to apply available management options intelligently in the future. Since historic cemeteries are one of the principal locations of western Iowa tallgrass prairie remnants, this study was initiated to identify the cemetery prairie management regime most likely to be successful in maintaining the greatest amount of native tallgrass prairie diversity.

METHODS

Study Area.- The study was conducted in western Shelby and Crawford counties of western Iowa. In 1994, eight cemetery sites, each containing native, tallgrass prairie, were selected for study based on relatively similar (1) previous management, (2) soil type, (3) topographic location, (4) presence of native tallgrass prairie species, and (5) no known history of inter-seeding or use of herbicides (Fig. 1). Sites selected included (1) three sites that, for many years, had been mulch-mowed three times annually and that were burned once in the spring of 1995 (mowed-burned), (2) three sites that had not been historically mulch-mowed but that were burned in 1995 (unmowed-burned), and (3) two sites that had a history of mowing but that were not burned (mowed-unburned) (Fig. 1). Permission to conduct research was obtained from the local cemetery boards with site management organized through the local county conservation boards.

Soils of the sites were generally well drained, silty, loess soils of the Mollisol or Entisol soil orders (Table 1). Climate of the region is continental, with normal daily highs averaging 30 C (86 F) in July and -12 C (10.9 F) in January. Annual precipitation (based on 1951 to 1980 data) averages 76 cm, with 74% occurring during the growing season (April through September) (National Oceanic and Atmospheric Association 1989).

Data Collection.- At each site, vegetation was evaluated in ten 30 by

Fig. 1. Location of tallgrass prairie remnants of western Iowa cemeteries.

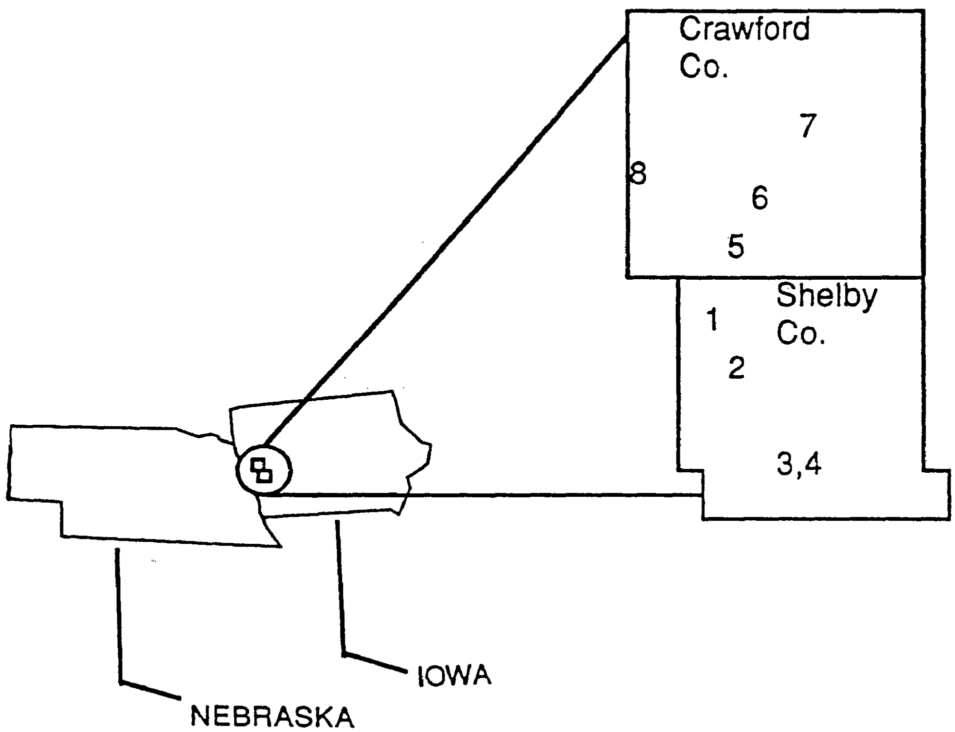

Fig. 1. 1-Manteno Cemetery
2-Holcomb Cemetery
3-Washington Township Cemetery, West
4-Washington Township Cemetery, East
5-Buckgrove Cemetery
6-Catholic Cemetery
7-King Cemetery
8-Willow Cemetery

Table 1. Characteristics of cemetery sites in Shelby and Crawford Counties, Iowa.

Site No.	Name	Treatment	Size (ha)	Location	Soil Type	Soil Order
1	Buckgrove	Unmowed-Burned	0.8	NE 1/4 of NE1/4 of Sect. 21	Monona-Ida Silt Loam	Mollisol-Entisol
2	Vail	Unmowed-Burned	4.0	NE1/4 of NE 1/4 of Sect. 25	Monona Silt Loam	Mollisol
3	Willow	Unmowed-Burned	2.0	SW 1/4 of NW 1/4 ofSect. 22	Colo-Napier-Nodaway Silt Loam	Mollisol-Mollisol-Entisol
4	Manteno	Mowed-Burned	0.4	SW 1/4 of SW 1/4 of Sect. 8	Judson Silty Clay Loam	Mollisol
5	Washington Township-East	Mowed-Burned	1.0	NW 1/4 of NE 1/4 of Sect. 22	Monona-Ida Silt Loam	Mollisol-Entisol
6	Catholic	Mowed-Burned	0.8	NW 1/4 of SE 1/4 of Sect. 18	Marshall Silty Clay Loam	Mollisol
7	Holcomb	Mowed-Unburned	0.8	NW 1/4 of NW 1/4 of Sect. 14	Monona Silt Loam	Mollisol
8	Washington Township-West	Mowed-Unburned	0.6	NW 1/4 of NE 1/4 of Sect. 22	Monona-Ida Silt Loam	Mollisol-Entisol

50 cm quadrats that were randomly located within hilltop locations. Sampling was conducted during both late spring (June) and late summer (September) in both 1995 and 1996 in order to ensure that the greatest number of resident species were detected, particularly those evident in the spring but not so in the fall. Sampling consisted of estimating canopy cover for each species in nine categories: absent, 0-1%, >1-5%, >5-25%, >25-50%, >50-75%, >75-95%, >95-99%, >99% cover (modified from Daubenmire 1959). Midpoint values were used for analysis. Voucher specimens were collected and are located in the University of Nebraska at Omaha Herbarium (OMA). Nomenclature follows the Great Plains Flora Association (1986).

Significant differences among and between treatment, by species, were based on a non-parametric, ranked ANOVA and the Student-Newman-Keuls (SNK) multicomparison tests, (SAS Institute Inc. 1985). Statistical comparisons between sites of Shannon-Weiner Diversity Indices used procedures described in Zar (1984).

RESULTS

Community Response.- Forty plant species were identified during this study of which sixteen were non-native (Table 2). The greatest number of native plants (S = 297) was found in one of the mowed-burned treatments and the greatest diversity of native species was found in unmowed-burned treatments (H' = 1.1716) (Table 3). In contrast, the lowest number of native plants (S = 45) was found in a mowed-unburned site, although, diversity was lowest (H' = 0.5827) in a mowed-burned treatment. When compared by treatment, no significant differences were found between grasses, forbs and woody plant cover.

Table 2. Mean canopy cover and Standard Error of all species in cemetery sites. Alphabetic superscripts that differ between treatments indicate a significant difference($p<0.05$) between mean values for the species, season and year indicated. tr = <1% cover; S = spring sampling, F=fall sampling. *= Non-native species. n=30 for mowed-burned and unmowed-burned treatments and n=20 for mowed-unburned treatment.

Common Name (*Scientific name*)	Season-Year of Evaluation	Treatment: Mowed Burned	Unmowed Burned	Mowed Unburned
Shannon-Weiner Diversity Index (H')	F95	0.6676	0.4981	0.8113
	F96	0.8351	0.9257	0.8032
Forbs	F96	32 ± 2.5^{a}	44 ± 3.4^{a}	39 ± 3.7^{a}
Grasses	F96	70 ± 2.9^{a}	65 ± 3.4^{a}	70 ± 3.9^{a}
Woody Plant	F96	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
Lead Plant	F95	4 ± 2.2^{ab}	8 ± 2.9^{a}	tr^{a}
(*Amorpha canescens*)	F96	2 ± 0.8^{a}	6 ± 1.9^{a}	6 ± 2.2^{a}
Big Bluestem	F95	61 ± 6.0^{a}	62 ± 4.7^{a}	27 ± 7.0^{b}
(*Andropogon gerardii*)	F96	29 ± 3.8^{a}	22 ± 2.9^{a}	28 ± 4.9^{a}
Little bluestem	F95	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Andropogon scoparius*)	F96	1 ± 1.3^{b}	5 ± 1.9^{a}	tr^{ab}
Meadow Anemone	F95	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Anemone cylindrica*)	F96	tr^{a}	0 ± 0.0^{a}	tr^{a}
Common Milkweed	F95	1 ± 0.5^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Asclepias syriaca*)	F96	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
Whorled Milkweed	F95	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Asclepias verticillata*)	F96	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
Sideoats Grama	F95	20 ± 4.9^{a}	1 ± 0.5^{b}	12 ± 4.3^{ab}
(*Bouteloua curtipendula*)	F96	8 ± 2.1^{a}	5 ± 1.5^{a}	4 ± 1.9^{a}
Smooth Brome*	F95	6 ± 2.1^{a}	2 ± 0.8^{b}	23 ± 4.9^{a}
(*Bromus inermis*)	F96	6 ± 1.6^{a}	2 ± 1.0^{b}	8 ± 2.2^{a}
Field Bindweed*	F95	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Convolvulus arvensis*)	F96	1 ± 0.5^{a}	1 ± 0.5^{a}	0 ± 0.0^{a}
Finger Coreopsis	F95	0 ± 0.0^{a}	tr^{a}	0 ± 0.0^{a}
(*Coreopsis palmata*)	F96	tr^{a}	1 ± 1.3^{a}	tr^{a}
Crown Vetch*	F95	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Coronilla varia*)	F96	0 ± 0.0^{b}	0 ± 0.0^{b}	3 ± 1.4^{a}

Table 2. Mean canopy cover ±S.E. of all species (continued).

Common Name (*Scientific name*)	Season-Year of Evaluation	Mowed Burned	Unmowed Burned	Mowed Unburned
Orchard Grass*	F95	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
(*Dactylis glomerata*)	F96	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
White Prairie Clover	F95	0±0.0^{a}	0 ±0.0^{a}	2±1.0^{a}
(*Dalea candida*)	F96	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
Prairie Larkspur	F95	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
(*Delphinium virescens*)	F96	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
Scribner Dichanthelium	F95	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
(*Dicanthelium oligosanthes*)	F96	0±0.0^{b}	2±0.8^{a}	0±0.0^{b}
Scouring Rush	F95	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
(*Equisetum hyemale*)	F96	tr^{a}	0 ±0.0^{a}	0±0.0^{a}
Daisy Fleabane	F95	2±1.0^{a}	0 ±0.0^{a}	1±0.8^{a}
(*Erigeron strigosus*)	F96	0±0.0^{a}	0 ±0.0^{a}	tr^{a}
Flowering Spurge	F95	0±0.0^{b}	7 ±2.7^{a}	tr^{b}
(*Euphorbia corollata*)	F96	0±0.0^{c}	8 ±1.9^{a}	1±0.2^{b}
White Avens	F95	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
(*Geum canadense*)	F96	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
False Sunflower	F95	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
(*Heliopsis helianthoides*)	F96	tr^{a}	0 ±0.0^{a}	1±0.8^{a}
Wild Lettuce*	F95	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
(*Lactuca canadensis*)	F96	tr^{a}	0 ±0.0^{a}	0±0.0^{a}
Black Medic*	F95	0±0.0^{a}	4 ±2.2^{a}	2±1.2^{a}
(*Medicago lupulina*)	F96	7±1.6^{a}	5±1.6^{ab}	1±0.3^{b}
White Sweet Clover*	F95	0±0.0^{a}	0±0.0^{a}	0±0.0^{a}
(*Melolitus alba*)	F96	0±0.0^{a}	0±0.0^{a}	0±0.0^{a}
Yellow Sweet Clover*	F95	3±1.7^{a}	0±0.0^{a}	0±0.0^{a}
(*Melolitus officinalis*)	F96	1±0.5^{a}	0 ±0.0^{a}	0±0.0^{a}
Yellow Wood Sorrel*	F95	0±0.0^{a}	tr^{a}	0±0.0^{a}
(*Oxalis stricta*)	F96	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
Prairie Phlox	F95	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}
(*Phlox pilosa*)	F96	0±0.0^{a}	0 ±0.0^{a}	0±0.0^{a}

Table 2. Mean canopy cover ±S.E. of all species (continued).

Common Name (*Scientific name*)	Season-Year of Evaluation	Mowed Burned	Unmowed Burned	Mowed Unburned
Timothy*	F95	1 ± 0.5^{a}	0 ± 0.0^{a}	4 ± 2.9^{a}
(*Phleum pratense*)	F96	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
Blackseed Plantain*	F95	6 ± 2.4^{a}	0 ± 0.0^{b}	0 ± 0.0^{b}
(*Plantago rugelii*)	F96	1 ± 0.7^{a}	0 ± 0.0^{b}	0 ± 0.0^{b}
Kentucky Bluegrass*	F95	0 ± 0.0^{b}	0 ± 0.0^{b}	21 ± 6.4^{a}
(*Poa pratensis*)	F96	0 ± 0.0^{a}	0 ± 0.0^{a}	tr^{a}
Bur Oak	F95	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Quercus macrocarpa*)	F96	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
Grayhead Prairie Coneflower	F95	2 ± 1.3^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Ratibida pinnata*)	F96	0 ± 0.0^{a}	1 ± 0.7^{a}	tr^{a}
Prairie Wild Rose	F95	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Rosa arkansana*)	F96	0 ± 0.0^{a}	1 ± 0.7^{a}	0 ± 0.0^{a}
Black Eyed Susan	F95	1 ± 0.7^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Rudbeckia hirta*)	F96	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
Yellow Foxtail*	F95	tr^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Setaria glauca*)	F96	4 ± 1.1^{a}	0 ± 0.0^{b}	4 ± 1.4^{a}
Prairie Goldenrod	F95	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
(*Solidago missouriensis*)	F96	tr^{a}	2 ± 0.8^{a}	0 ± 0.0^{a}
Indian Grass	F95	1 ± 0.7^{a}	1 ± 0.5^{a}	0 ± 0.0^{a}
(*Sorgastrum nutans*)	F96	25 ± 3.6^{a}	26 ± 4.5^{a}	5 ± 1.5^{b}
Porcupine Grass	F95	0 ± 0.0^{a}	1 ± 0.5^{a}	0 ± 0.0^{a}
(*Stipa spartea*)	F96	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
Goats beard*	F95	0 ± 0.0^{a}	0 ± 0.0^{a}	2.0 ± 1.9^{a}
(*Tragopogon dubius*)	F96	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}
Red Clover*	F95	1 ± 0.7^{b}	1 ± 0.5^{b}	8 ± 2.7^{a}
(*Trifolium pratense*)	F96	8 ± 1.6^{a}	2 ± 0.8^{b}	2 ± 1.2^{b}
Blue Vervain	F95	0 ± 0.0^{a}	1 ± 0.5^{a}	0 ± 0.0^{a}
(*Verbena stricta*)	F96	0 ± 0.0^{a}	0 ± 0.0^{a}	0 ± 0.0^{a}

Table 3. Shannon-Weiner Diversity values (H') based on all species collected in spring and fall of both 1995 and 1996, at eight Iowa cemetery sites. $S^2_{H'}$=variance of sites, s=species richness. Cemetery treatments for sites are as follows: 1-3 =unmowed-burned (UM-B), 4-6 = mowed-burned (M-B), 7-8 = mowed-unburned (M-UB).

Treatment	Site	Native Species			All Species		
		s	$S^2_{H'}$	H'	s	$S^2_{H'}$	H'
UM-B	1	183	.0014	0.9638	183	.0016	0.9829
UM-B	2	195	.0019	0.7124	195	.0011	0.9077
UM-B	3	237	.0008	1.1716	237	.0009	1.1716
M-B	4	166	.0046	0.5827	166	.0013	0.8286
M-B	5	293	.0007	1.1267	293	.0007	1.1267
M-B	6	181	.0014	0.6995	181	.0014	0.6995
M-UB	7	45	.0026	0.8866	45	.0026	0.8866
M-UB	8	175	.0014	0.9514	175	.0014	0.9514

Individual Species Response.-

Burning.- Maximum annual canopy cover of three native and one non-native species was significantly higher with burning, irrespective of whether or not the treatment had been mowed (Table 2). Native species were big bluestem (*Andropogon gerardii*) (1995; 62% cover), Indiangrass (*Sorghastrum nutans*) (1996; 25% cover), and leadplant (*Amorpha canescens*) (1995; 6% cover) (Fig. 2); the non-native species was red clover (*Trifolium pratense*) (1996; 5%). In contrast, four species were found which, for at least one year of the study, were significantly higher in areas from which burning had been excluded. These species were crown vetch (*Coronilla varia*) (1996; 3%), Scribner dichanthelium (1996; 6%), Kentucky bluegrass (1995; 21%), and red clover (1995; 13%). All but Scribner dichanthelium are non-native species.

Mowing.- No species were found that were significantly higher in mowed treatments. Overall, mowing alone resulted in significantly higher cover of smooth brome (*Bromus inermis* L.), an invasive, undesirable non-native grass (Fig. 3) irrespective of whether or not they had been burned. However, flowering spurge (*Euphorbia corollata*) (1996; 8%) and porcupine grass (1996; 2%) were two species in which maximum cover was significantly higher in the absence of mowing, although this treatment had also included burning. Canopy cover of finger coreopsis (*Coreopsis palmata*) (1995; 7%) and yellow sweet clover (*Melolitus officinalis*) (1996; 3%) were also significantly higher without mowing, but only in spring sampling periods.

Combined Burning and Mowing.- Blackseed plantain (*Plantago rugelli*) (1995; 6% cover and 1996; 1% cover) was the only species for which

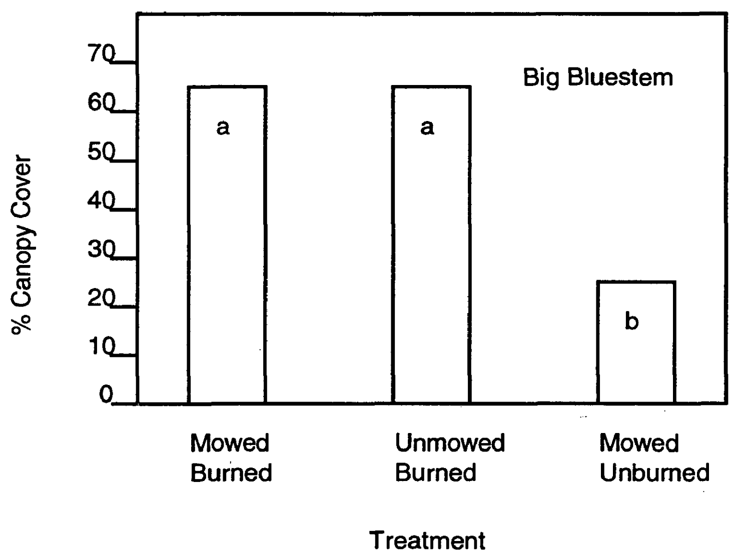

Fig. 2. Mean canopy cover of big bluestem by treatment. Different letters at the top of each bar indicate significant differences ($P \leq 0.05$) between treatments based on Student-Newman-Keuls multicomparison test.

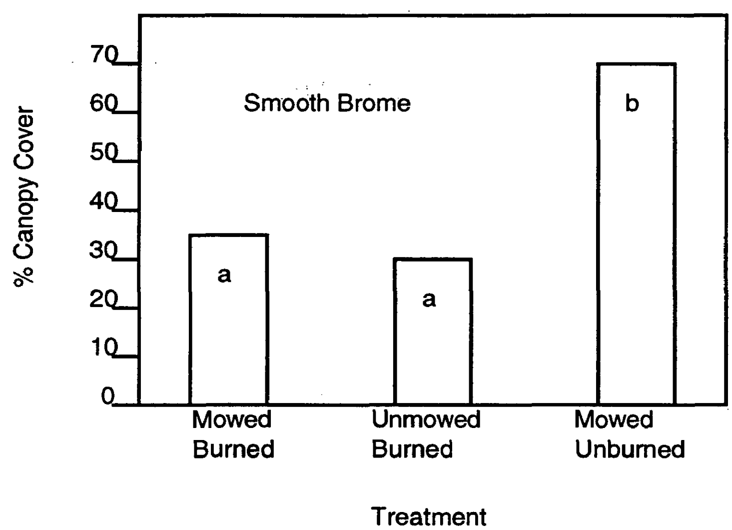

Fig. 2. Mean canopy cover of smooth brome by treatment. Different letters at the top of each bar indicate significant differences ($P \leq 0.05$) between treatments based on Student-Newman-Keuls multicomparison test.

maximum cover occurred with combined mowing and burning. However, in 1996, the year following burning, red clover also was significantly higher (8%) in the combined mowed-burned treatment areas. Both of these are non-native species.

DISCUSSION

In general, this study shows (1) that mowing and burning have the potential to affect substantially the floral composition of the tallgrass prairie, and (2) that burning is more suitable than mowing as a management practice for both maintaining native prairie species and for at least slowing the influx of aggressive, non-native species.

Many differences were noted in individual species and community-level responses to mowing and burning. Small sample size, experimental design that necessarily lacked close control of a substantial number of variables, and the unavoidable variability between individual treatments, such as specific timing and frequency, are but a few of the factors that complicate a reasonable interpretation of the results. Despite these factors, significant differences were noted that support the idea that different mowing and haying treatment of tallgrass prairie can affect species composition, results consistent with the literature (e.g. Dix 1960, McMurphy and Anderson 1965, Lovell *et al.* 1983).

One effect of treatment is the response to burning. Specifically, significant increases were noted for some of the dominant grasses and forbs, such as big bluestem, indiangrass, and leadplant (Table 2, Fig. 2) irrespective of mowing history. The effects on these grasses both support and contradict previous studies (Glenn-Lewin *et al.* 1990). In contrast, other native, but less common, grass species, in particular Scribner panicum, decreased in response to burning. This opposite effect on native species indicated the difficulty in providing a single management for any site. It also supports the current trend towards varying management from year to year in order to facilitate ecosystem diversity (Solecki and Toney 1986, Fitzgerald and Tanner 1992).

The response of non-native species to burning is equally as important as is the response of native species (Ross and Vanderpoel 1991). Canopy cover of red clover, a non-native species, for example, decreased significantly immediately following burning but increased significantly the following year. Other species with lower cover in response to burning included Kentucky bluegrass, smooth brome, and crown vetch, the latter two both being particularly aggressive and undesirable, non-native species (Lovell *et al.* 1983). The recovery of red clover the year following burning, and the high proportion of smooth brome with mowing and in the absence of fire (Fig. 3), suggest that some form of regular, prescribed burning is necessary, if only to reduce the rate of invasion of these species, results consistent with studies by Evans (1983) and Fitzgerald and Tanner (1992).

Mowing, another management likely to be used in tallgrass prairie remnants, is viewed by some as a suitable alternative to fire (Ehrenreich 1959, Dale 1983, Mooberry 1984). This study suggests otherwise. In particular, none of the native species were found to be significantly higher in mowed areas, irrespective of burning history, whereas cover of smooth brome and blackseed plantain, both non-native species, was significantly higher with mowing. The response of blackseed plantain, however, occurred only when accompanied by burning. Not only did mowing not favor native species as a group, but it appears to have adversely affected them. For example, flowering spurge and porcupine grass, both native species, were found to be significantly lower in mowed areas even when this treatment had also included burning. Canopy cover of finger coreopsis and yellow sweet clover, the latter a non-native ruderal species, was also significantly lower with mowing, but only in spring sampling periods.

Overall, my study suggests the importance of selecting management in maintaining the native tallgrass prairie plant diversity. Further, it supports the appropriate use of fire instead of mowing, both to favor native species and to limit the advance of non-native species. While many of the implications of my results are not new to the literature, they do provide yet more reinforcement to the argument favoring fire over mowing as a management tool where such application can be accommodated.

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Appendix

Appendix Table 1. Shannon Weiner Diversity Index (Matrix) Values ofall species, at eight Iowa cemetery sites. SD=significant difference between sites, NSD=no significant difference between sites. Sites have the following treatments: 1,2,3 are burned, 4,5,6 are mowed and burned, 7,8 are mowed.

	1	2	3	4	5	6	7	8
1		NSD t=1.460 $t_{0.05(2)371}$ =1.967	SD t=3.853 $t_{0.05(2)713}$ =1.963	SD t=2.864 $t_{0.05(2)349}$ =1.967	SD t=3.022 $t_{0.05(2)342}$ =1.967	SD t=5.241 $t_{0.05(2)362}$ =1.967	NSD t=1.482 $t_{0.05(2)104}$ =1.983	NSD t=.5828 $t_{0.05(2)357}$ =1.967
2			SD t=6.004 $t_{0.05(2)12}$ =2.179	NSD t=1.603 $t_{0.05(2)352}$ =1.967	SD t=5.166 $t_{0.05(2)413}$ =1.966	SD t=4.201 $t_{0.05(2)368}$ =1.966	NSD t=.3444 $t_{0.05(2)86}$ =1.988	NSD t=.8822 $t_{0.05(2)360}$ =1.967
3				SD t=7.351 $t_{0.05(2)344}$ =1.967	NSD t=1.144 $t_{0.05(2)511}$ =1.965	SD t=10.069 $t_{0.05(2)366}$ =1.967	SD t=4.821 $t_{0.05(2)76}$ =1.992	SD t=4.699 $t_{0.05(2)357}$ =1.967
4					SD t=6.595 $t_{0.05(2)334}$ =1.967	SD t=2.484 $t_{0.05(2)347}$ =1.967	NSD t=.9172 $t_{0.05(2)95}$ =1.985	SD t=2.364 $t_{0.05(2)341}$ =1.967
5						SD t=9.403 $t_{0.05(2)265}$ =1.969	SD t=4.141 $t_{0.05(2)71}$ =1.993	SD t=3.861 $t_{0.05(2)347}$ =1.967
6							SD t=3.587 $t_{0.05(2)97}$ =1.984	SD t=4.830 $t_{0.05(2)364}$ =1.967
7								NSD t=1.022 $t_{0.05(2)96}$ =1.985