Response of Buffalograss (*Buchloe dactyloides*) and Blue Grama (*Bouteloua gracilis*) to Fire

Paulette Ford
Rocky Mountain Research Station

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Paulette L. Ford

Rocky Mountain Research Station
2205 Columbia SE
Albuquerque, NM 87106

and

University of Arizona
School of Renewable Natural Resources
Tucson, AZ 85721
pford@ag.arizona.edu

ABSTRACT— I analyzed primary literature, spanning 42 years (1948-1990) that addressed buffalograss and blue grama's response to fire; no relevant literature has been published since 1990. The results suggest that fire in shortgrass steppe need not be negative. Plant response to fire depends mainly on levels of precipitation, though some studies indicated that the season during which fire occurs may also affect recovery of buffalograss and blue grama.

This paper re-examines the primary literature on the effects of fire on two major plant species of shortgrass steppe, buffalograss [*Buchloë dactyloides* (Nutt.) Engelm] and blue grama [*Bouteloua gracilis* (H. B. K.) Lag.]. These shortgrasses are considered drought resistant and fully adapted to the driest sections of the central Great Plains, where they constitute the principal native vegetation in terms of basal area coverage (Savage and Jacobson 1935). The two species are co-dominants over much of the shortgrass region in North America. The central and southern Great Plains is referred to as a *Bouteloua gracilis-Buchloë dactyloides* association (Shantz 1923; Küchler 1964; Coffin et al. 1996).

Buffalograss is a perennial, sod-forming shortgrass of central North America (Hitchcock 1951) (Fig. 1). The species is largely dioecious, with plants bearing either male, pollen-producing flowers or female, seed-producing flowers (Quinn and Engel 1986). Buffalograss seeds are enclosed in hard burs (usually 1-5 seeds per bur) that serve as the dispersal unit (Quinn 1987). Burs greatly reduce fire or heat damage to seeds (Ahring and Todd 1977). Fire was a regular feature of the original buffalograss environment

Figure 1. Buffalograss, *Buchloë dactyloides*.

Figure 2. Blue grama, *Bouteloua gracilis*.

(Haley 1929; Vogl 1974; Wright and Bailey 1982; Quinn 1987), so such protection from heat damage may have been important.

Blue grama, a bunchgrass, is also a perennial (Fig. 2). It is widely recognized as the key species in shortgrass ecosystems (Hyder et al. 1975; Hook et al. 1991; Burke et al. 1995; Coffin et al. 1996), and it is thought to be the most drought- and grazing-tolerant plant species in shortgrass communities (Hyder et al. 1975; Coffin et al. 1996).

Both buffalograss and blue grama are warm-season plants with C_4 photosynthesis. Plants with C_4 photosynthesis use the dicarboxylic acid pathway for carbon dioxide assimilation. They are adapted to warmer climates and generally are distributed toward the south, where average temperatures during the growing season are higher (Fort Hays State University 1989). Cool-season plants with C_3 photosynthesis (e.g., *Stipa*), tend to have early spring, winter, or fall growing seasons when temperatures are cooler (Fort Hays State University 1989; Raven and Johnson 1996; Lincoln et al. 1998). Growing-season fires are thought to be differentially detrimental to plants based on their season of active growth, because defoliation by fire reduces total available carbohydrates required for regrowth (Vallentine 1990). Plant growing season and fire season, along with other biotic and abiotic environmental variables, including grazing and rainfall, are important factors in determining the response of plants to disturbance by fire.

Methods

I compiled 15 studies from the literature (5 wildfire, 10 experimental), from 1948 to 1990. The studies were located through a comprehensive search of databases and references. Only 15 studies (out of over 100 references) directly measured the response of either buffalograss or blue grama or both to fire. Keywords were used to search various Dialog databases including Dissertation Abstracts Online 1861-1999, Agricola 1970-1999, GeoRef 1785-1999, Agris 1974-1999, Water Resource Abstracts 1967-1999, GEOBASE 1980-1999, Pascal 1973-1999, BIOSIS PREVIEWS 1969-1999, Life Sciences Collection 1982-1999, and CAB Abstracts 1972-1999. Recent studies were reviewed to generate keywords for the literature search. Keywords used included: shortgrass, blue grama, *Bouteloua gracilis*, buffalograss, *Buchloë dactyloides*, fire, recovery, disturbance, wildfire. In addition, references cited in the studies were reviewed to find any additional studies missed in the previous search steps. No relevant literature was located post-1990.

In the reviewed studies, plant response to fire was measured over various time periods (3 months to 16 years) and in a number of ways, including production (herbage yield), seedstalk counts, percent cover, percent species composition, and basal area (Table 1). Five studies assessed the effects of fire by comparing burned sites with nearby or adjacent unburned sites (Hopkins et al. 1948; Dix 1960; Launchbaugh 1964; Dwyer and Pieper 1967; Morrison et al. 1986). Ten studies used experimental fire treatments and controls (Box et al. 1967; Box and White 1969; Trlica and Schuster 1969; Anderson et al. 1970; Heirman and Wright 1973; Wright 1974; White and Currie 1983; Schacht and Stubbendieck 1985; Whisenant and Uresk 1989, 1990).

To assess the relationship between the time period covered by the studies and their results, I generated a bivariate plot of these factors (Fig. 3). Negative, neutral, or positive responses, as reported by each study, were placed on the figure along with time since fire. Negative responses are defined as reductions in response variables as compared to pre-burn, control, or adjacent unburned cover areas. Positive responses are increases in response variables, as compared to pre-burn, control, or adjacent unburned areas. Neutral responses are no, or statistically nonsignificant, changes in response variables as compared to pre-burn, control, or adjacent unburned areas. Many studies report all three responses over time and therefore are represented by more than one data point.

Results

Both wildfire and experimental studies reported some manner of negative, neutral or positive responses, i.e., reductions, increases, or no difference in response variables. Out of the 56 total recorded responses of buffalograss (22) and blue grama, (34), 12 (21%) were negative, 28 (50%) were neutral, and 16 (29%) were positive (Fig. 3). The vast majority (79%) of responses to fire were either positive or neutral. Both species had a higher number of neutral responses to fire than negative or positive responses. In the 9 studies that documented responses to fire by buffalograss, the response or averaged response of all parameters was: 18% negative, 64% neutral, and 18% positive. Similarly, in the 11 studies that documented responses to fire by blue grama, the net response was: 24% negative, 41% neutral, and 35% positive (Fig. 3). Responses of buffalograss and blue grama over time generally flowed from negative to positive, or neutral; positive to neutral; or neutral to positive. Only rarely did responses flow from positive or neutral to negative (i.e., Anderson et al. 1970; Morrison et al. 1986) (Table 1).

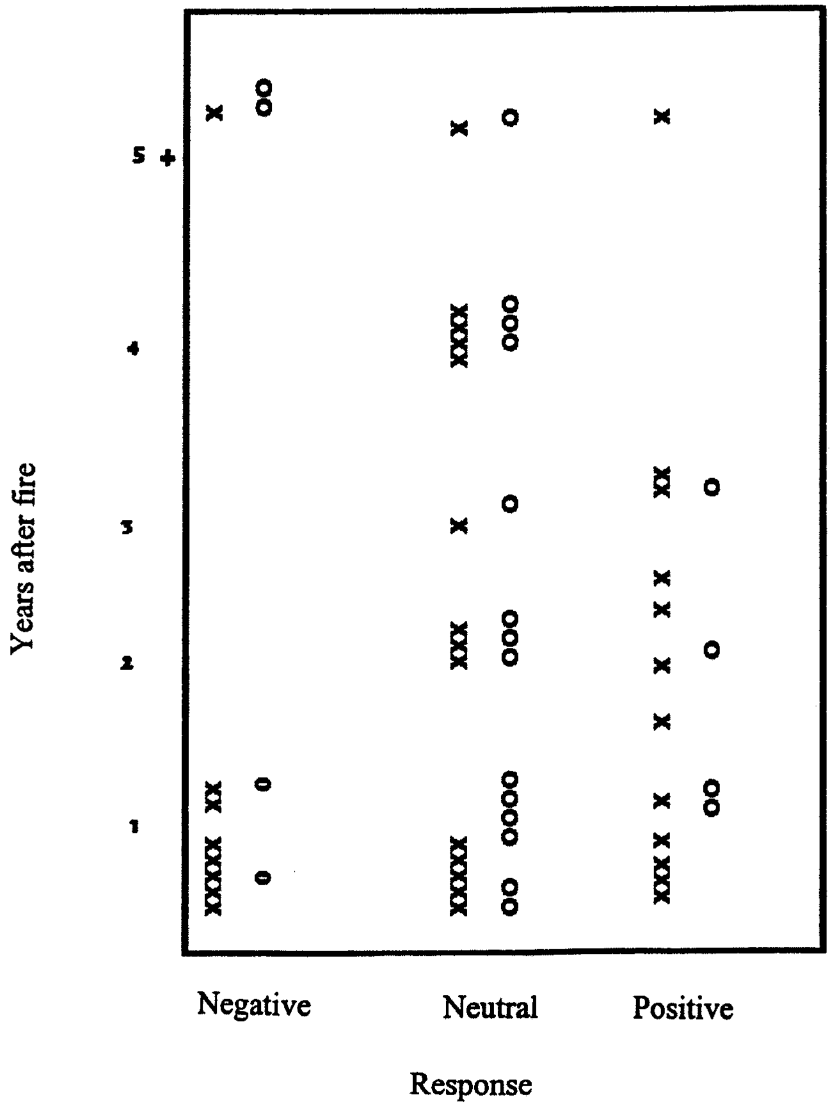

Figure 3. Buffalograss (O) and blue grama (X) response to fire through time. Negative, neutral, and positive responses indicate the direction of change of the response variables as compared to pre-treatment, control, or unburned areas.

TABLE 1
PRIMARY LITERATURE: BLUE GRAMA (*Bouteloua gracilis*) AND BUFFALOGRASS (*Buchloë dactyloides*) RESPONSE TO FIRE

Citation and study area	Method	Grazing	Fire date	Mean annual precipitation	Blue grama response	Buffalograss response
North Dakota, Badlands (Dix 1960)	Wildfires	Little or no domestic livestock	August 1954, September 1955, May 1958	41 cm/yr	Field work for the study was done in August 1958. Blue grama frequency was relatively similar in burned and unburned paired stands from 3 months to 4 years after fire.	No data
South Dakota, Badlands (Whisenant and Uresk 1990)	Experimental fire	No domestic livestock	Spring, April 1983 and/or April 1984	38 cm/yr	No data	Buffalograss standing crops were increased for 2 to 3 years after burning.
South Dakota, upland (Whisenant and Uresk 1989)	Experimental fire	No domestic livestock	April and October 1984, 1985	34 cm/yr	Burning in April reduced blue grama standing crop after both the 1984 and 1985 fires. Burning in October reduced blue grama standing crop relative to unburned plots when the next growing season was dry, but increased it when greater precipitation occurred during the next growing season. Blue grama standing crop was higher on burned plots in 1986 and 1987 compared to unburned plots.	No data
Texas, chaparral (Box et al., 1967)	Experimental fire	No data	Fall, September 1965	76 cm/yr	No data	Buffalograss increased significantly on burned plots across all treatments one year later.
Texas, chaparral (Box and White 1969)	Experimental fire	No data	Fall fire (September 1965), Winter fire (December 1966)	76 cm/yr	No data	In summer 1967, buffalograss was more abundant on combination fall/winter burn plots, and unburned plots than on fall burned or winter burned plots, but statistically significant differences were not shown.

TABLE 1 Continued

Citation and study area	Method	Grazing	Fire date	Mean annual precipi-tation	Blue grama response	Buffalograss response
Texas, High Plains (Trlica and Schuster 1969)	Experi-mental fire	No data	Fall 1965, spring and fall 1966, 1967, summer 1966	53 cm/yr	Seedstalk production of blue grama in 1967 was greater in plots burned two years in succession than on the unburned control. Blue grama produced more seedstalks in 1966 than in 1965 regardless of burning treatment. Plant height went down in the first year after fire, but recovered by the second season. Plant height was greater in plots burned in spring and summer of 1966 than in the unburned control.	No data
Texas, High Plains (Heirman and Wright 1973)	Experi-mental fire	Domestic livestock	March 23, 1970	48 cm/yr	No data	Spring burning had no effect on yields of buffalograss 3 to 6 months later.
Texas, High Rolling Plains (Wright 1974)	Experi-mental fire	Protected from domestic livestock	March 15 to April 7, 1968, 1970, 1972	48-71 cm/yr	For all three years, blue grama yields were higher on all three burned versus unburned sites, but not significantly so.	For all three years, buffalograss yields were higher on all three burned versus unburned sites, but not significantly so.
Kansas, mixed prairie (Hopkins et al., 1948)	Wildfires	Light domestic livestock	Novem-ber 1944, March 1945	43-58 cm/yr	Blue grama basal cover was reduced by 66% immediately after fire, and thereafter recovery of blue grama was difficult to determine based on the data presented.	Buffalograss basal cover was reduced by 48% immediately after fire. By fall 1946, buffalograss had almost completely recovered cover and production; both yield and cover increased where burning occurred, but declined in the unburned area.

TABLE 1 Continued

Citation and study area	Method	Grazing	Fire date	Mean annual precipitation	Blue grama response	Buffalograss response
Montana, mixed grass prairie (White and Currie 1983)	Experimental fire	No data	Fall 1978, Spring 1979	34 cm/yr	Burning stimulated blue grama yield. By mid-August 1979, fall burning had resulted in 60% more herbage than the control, and spring burning resulted in 40% more herbage than the control treatment. Blue grama cover was approximately the same for fall and spring burns and the control.	No data
Nebraska, Loess Hills (Schacht and Stubbendieck 1985)	Experimental fire	Rested from domestic livestock the year prior to the study	Late-spring burn, April 1980	55 cm/yr	Post-treatment measurements were made in 1980 and 1981. Blue grama had higher basal cover and herbage yields on burned as compared to unburned plots.	Buffalograss herbage yield did not significantly differ between burned and unburned plots.
Nebraska, Sandhills (Morrison et al., 1986)	Wildfire	No domestic livestock	Fall, October 1981	50 cm/yr	Post-fire measurements were taken from June-October 1982. Initially blue grama had greater phytomass in the burned area than in the unburned area, but from July - October had relatively less phytomass on the burned site as compared to the unburned site.	No data
New Mexico, blue grama-pinyon-juniper rangeland (Dwyer and Pieper 1967)	Wildfire	Ungrazed by domestic livestock	April 10, 1964	39 cm/yr	For 3 years following the fire, blue grama % cover was higher in burned than unburned areas. Production of grass was reduced by nearly 30% the first year, but recovered by the second year.	No data

TABLE 1 Continued

Citation and study area	Method	Grazing	Fire date	Mean annual precipi-tation	Blue grama response	Buffalograss response
Kansas, shortgrass (Launch-baugh 1964)	Wildfire	Lightly grazed native pasture. Burned and unburned vegeta-tion were protected from domestic livestock	March 18, 1959	43-58 cm/yr	Measurements were made in late summer each year from 1959-1961. A comparison of mean yields from burned and unburned plots shows that 1959 grass yields in buffalograss-blue grama mixture were reduced 65% by the fire the first season. By the third year, herbage production of the buffalograss-blue grama mixture was not significantly different from that on unburned sites.	Same as blue grama.
Kansas, Flint Hills (Anderson et al., 1970)	Experi-mental fire, annual burns for 17 years (1950-1966)	Season long	Early spring (March 20, mid spring (April 10), late spring (May 1)	81 cm/yr	Blue grama mixed with B. hirsuta (hairy grama) over 10 years remained at a low steady level in unburned pasture. Early- and mid-spring burn pastures had higher basal cover than late-spring burn pastures, and unburned pastures. From 1956 to 1965 basal cover of blue and hairy grama was steady under all treatments except late-spring burning, where it declined slightly.	Buffalograss over 10 years declined in unburned and late-spring burn pastures, but was stable in early- and mid-spring burn pastures. Over 16 years, early- and late-spring burning reduced basal cover.

The breakdown by type of study produced a similar pattern. Sixty-seven percent of responses came from experimental studies, and 51% of these responses were neutral, 32% were positive, and 17% were negative. Among the 33% of responses from wildfire studies responses, 47% were neutral, 33% were negative, and 20% were positive.

Study area average annual precipitation was not an indicator of the direction of plant response (Table 1). Rainfall ranged from a low of 34 cm/year in Montana and South Dakota (White and Currie 1983; Whisenant and Uresk 1989) to highs of 76-81 cm/year in Texas and Kansas (Anderson et al. 1970; Box and White 1969). Rainfall in shortgrass steppe in Kansas was mid-range with 43-58 cm/year (Launchbaugh 1964). Negative, neutral, and positive responses were present across all precipitation ranges. Sixty-seven percent of negative responses came from studies that specifically stated that conditions were dry, or reported below average precipitation during the study (Hopkins et al. 1948; Launchbaugh 1964; Dwyer and Pieper 1967; Trlica and Schuster 1969; Whisenant and Uresk 1989). The other studies with negative responses had years with both below and above average rainfall (Anderson et al. 1970), or reported a negative response with slightly above average precipitation for the area (Morrison et al. 1986).

The effect of fire season on buffalograss and blue grama responses to fire was not clear. Four studies, including Anderson et al. (1970), Heirman and Wright (1973), White and Currie (1983), and Schacht and Stubbendieck (1985), reported mixed results from spring fire ranging from negative, neutral, or positive responses, over a time frame of 3 months to 16 years (Table 1). Separation of spring burns into early- and late-spring categories revealed a pattern of early-spring burns producing neutral or positive responses, late-spring burning producing negative results (Anderson et al. 1970; Heirman and Wright 1973). And, fall burns produced more herbage than did spring burns (White and Currie 1983). However, a late-spring burn by Schacht and Stubbendieck (1985) showed a positive response by blue grama and a neutral response by buffalograss, compared to unburned plots.

Grazing on study areas ranged from areas protected from domestic livestock grazing to season-long grazing on the sites (Table 1). Four studies did not report grazing conditions, while eight studies reported study areas were rested from grazing or supported little or no domestic livestock grazing. Three study areas reported various degrees of domestic livestock grazing. Variation in the grazing histories of the 15 studies made it difficult to draw any general conclusions about grazing effects on buffalograss or blue grama response to fire. Negative, neutral and positive responses to fire were

evident in both season-long grazed areas (Anderson et al. 1970), and areas protected from domestic livestock grazing (Dwyer and Pieper 1967).

Discussion

The effect of fire on shortgrass steppe is generally considered negative. This is largely the result of the frequent citation of a handful of studies, i.e., Hopkins et al. 1948, Dix 1960, Launchbaugh 1964, Dwyer and Pieper 1967, Trlica and Schuster 1969, Heirman and Wright 1973, and Wright 1974. For example, Wright (1978) said:

> Few uses can be found for fire in shortgrass prairie. First of all, the grasses do not benefit from fire. They tolerate fire with no loss in forage production during wet years (Trlica and Schuster 1969; Heirman and Wright 1973; Wright 1974), but are moderately to severely harmed for 2 to 3 years when precipitation is below normal (Hopkins et al. 1948; Launchbaugh 1964; Dwyer and Pieper 1967).

Another example is Daubenmire (1968), who said:

> In western Kansas where the steppe is more arid and *Bouteloua gracilis* is dominant, fire brought about a great reduction of production in the first post-burn season (Hopkins et al., 1948; Launchbaugh, 1964). In this area, fall burning is far more detrimental to subsequent production than is spring burning (Hopkins et al., 1948). In somewhat similar *Bouteloua gracilis* steppe in South Dakota, fire reduced dry-matter production (Larson and Whitman, 1942), and in North Dakota production quantity was reduced by a single burn with recovery not completed 4 years later (Dix 1960). In the southern Rockies where steppes are dominated by several species of *Bouteloua* including *B. gracilis*, production was reduced the first post-burn season but normal thereafter (Reynolds and Bohning, 1956).

Other examples include comments by Wright and Bailey (1980, 1982), Wright (1986), and McDaniel et al. (1997).

A careful examination of the papers cited by Wright (1978) and Daubenmire (1968) suggest that their conclusions do not accurately summa-

rize the full range of the results they cited. First, Hopkins et al. (1948) reported that the recovery of cover and production by buffalograss was almost complete 1.5 - 2 years after fire. In addition, both yield and percent cover had increased where burning occurred, instead of decreasing as it had in the unburned area. Blue grama cover was reduced by 66% immediately after fire, but thereafter recovery of blue grama was difficult to determine based on the data presented. Second; Trlica and Schuster (1969) discovered that blue grama seedstalk production responded favorably to fire. Third, Heirman and Wright (1973) actually reported that spring burning had no effects on yields of buffalograss 3-6 months later. Fourth, Wright (1974) reported that buffalograss and blue grama yields for 3 years were higher on burned than unburned sites, but not significantly so. Fifth, although Launchbaugh (1964) found a 65% reduction in buffalograss-blue grama production in the first growing season after fire, production in the third year did not differ significantly from unburned sites. Sixth, Dwyer and Pieper (1967) reported that blue grama percent cover, was higher in burned areas than in unburned areas for 3 years following fire, and, although production was reduced by nearly 30% the first year, it had recovered by the second year. Seventh, Dix (1960) indicated that blue grama frequency was similar in burned and unburned paired stands from 3 months to 4 years after fire. And, eighth, the research area of Reynolds and Bohning (1956) in southern Arizona did not include blue grama among the perennial grass species studied. In addition, the study by Larson and Whitman (1942) makes no mention of the effects of fire on blue grama.

Because of the variety of fire types, seasons, weather conditions, and fuel conditions in which a burn can occur, one must be careful in interpreting the effects of fire. Results from my review suggest that the mix of fire and shortgrass steppe need not be perceived in a negative light. Regardless of fire type (i.e., experimental or wildfire), buffalograss and blue grama response to fire was predominantly neutral or positive, and it depended largely on precipitation and possibly season of fire.

Most of the literature I reviewed was primarily interested in the use of fire as a tool to increase the forage value of the grassland vegetation. Perceptions about the value of fire in shortgrass steppe may have been colored by a desire for rapid recovery or for increases in grassland productivity to benefit domestic livestock. However, fire is a natural component of shortgrass steppe, and all ecosystem benefits can not be measured in terms of forage/ha.

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References

Ahring, R.M. and G.W. Todd. 1977. The bur enclosure of the caryopses of buffalograss as a factor affecting germination. *Agronomy Journal* 69:15-17.

Anderson, K.L., E.F. Smith, and C.E. Owensby. 1970. Burning bluestem range. *Journal of Range Management* 23:81-92.

Box, T.W., J. Powell, D.L. Drawe, and D. Lynn. 1967. Influence of fire on south Texas chaparral communities. *Ecology* 48:955-61.

Box, T.W. and R.S. White. 1969. Fall and winter burning of south Texas brush ranges. *Journal of Range Management* 22:373-76.

Burke, I.C., W.K. Lauenroth, and D.P. Coffin. 1995. Soil organic matter recovery in semiarid grasslands: implications for the Conservation Reserve Program. *Ecological Applications* 5:793-801.

Coffin, D.P., W.K. Lauenroth, and I.C. Burke. 1996. Recovery of vegetation in a semiarid grassland 53 years after disturbance. *Ecological Applications* 6:538-55.

Daubenmire. R. 1968. Ecology of fire in grasslands. In *Advances in Ecological Research,* Vol. 5, ed. J.B. Cragg, 209-66. New York: Academic Press.

Dix, R.L. 1960. The effects of burning on the mulch structure and species composition of grasslands in western North Dakota. *Ecology* 41:49-56.

Dwyer, D.D. and R.D. Pieper. 1967. Fire effects on blue grama-pinyon-juniper rangeland in New Mexico. *Journal of Range Management* 20:359-62.

Fort Hays State University, Hays, Kansas. 1989. *Pasture and Range Plants.* Phillips Petroleum Company.

Haley, J.E. 1929. Grass fires of the southern Great Plains. *West Texas Historical Year Book* 5:23-42.

Heirman, A.L. and H.A. Wright. 1973. Fire in medium fuels of west Texas. *Journal of Range Management* 26:331-35.

Hitchcock, A.S. 1951. *Manual of the grasses of the United States*, 2d ed. (Revised by A. Chase). US Department of Agriculture Miscellaneous Publication 200.

Hook, P.B., I.C. Burke, W.K. Lauenroth. 1991. Heterogeneity of soil and plant N and C associated with individual plants and openings in North American shortgrass steppe. *Plant and Soil* 138:247-56.

Hopkins, H., F.W. Albertson, and A. Riegel. 1948. Some effects of burning upon a prairie in west-central Kansas. *Transactions Kansas Academy of Science* 51:131-41.

Hyder, D.N., R.E. Bement, E.E. Remmenga and D.F. Hervey. 1975. Ecological responses of native plants and guidelines for management of shortgrass range. US Department of Agriculture, *Agricultural Research Service Technical Bulletin* 1503.

Küchler, A.W. 1964. *The Potential Natural Vegetation of the Coterminous United States*. New York: American Geographical Society.

Larson, F. and W. Whitman. 1942. A comparison of used and unused grassland mesas in the badlands of South Dakota. *Ecology* 23:438-45.

Launchbaugh, J.L. 1964. Effects of early spring burning on yields of native vegetation. *Journal of Range Management* 17:5-6.

Lincoln, R., G. Boxshall, and P. Clark. 1998. *A Dictionary of Ecology, Evolution and Systematics*. 2d ed. New York: Cambridge University Press.

McDaniel, K.C., C.R. Hart, and D.B. Carroll. 1997. Broom snakeweed control with fire on New Mexico blue grama rangeland. *Journal of Range Management* 50:652-59.

Morrison, L.C., J.D. DuBois, and A. Lawrence. 1986. The vegetational response of a Nebraska sandhills grassland to a naturally occurring fall burn. *Prairie Naturalist* 18:179-84.

Quinn, J.A. 1987. Relationship between synaptospermy and dioecy in the life history strategies of *Buchloë dactyloides* (Graminae). *American Journal of Botany* 74:1167-72.

Quinn, J.A. and J.L. Engel. 1986. Life-history strategies and sex ratios for a cultivar and a wild population of *Buchloë dactyloides* (Gramineae). *American Journal of Botany* 73:974-81.

Raven, P.H. and G.B. Johnson. 1996. *Biology*. 4th ed. Dubuque, IA: Wm.C. Brown Publishers.

Reynolds, G.H. and J.W. Bohning. 1956. Effects of burning on a desert grass-shrub range in southern Arizona. *Ecology* 37:769-77.

Savage, D.A. and L.A. Jacobson. 1935. The killing effect of heat and drought on buffalograss and blue grama at Hays, Kansas. *Journal of the American Society of Agronomy* 27:566-82.

Schacht, W. and J. Stubbendieck. 1985. Prescribed burning in the Loess Hills mixed prairie of southern Nebraska. *Journal of Range Management* 38:47-51.

Shantz, H.L. 1923. The natural vegetation of the Great Plains region. *Annals of the Association of American Geographers* 13:81-107.

Trlica, M.J., Jr., and J.L. Schuster. 1969. Effects of fire on grasses of the Texas High Plains. *Journal of Range Management* 22:329-34.

Vallentine, J.F. 1990. *Grazing Management*. San Diego: Academic Press.

Vogl, R.J. 1974. Effects of fire on grasslands. In *Fire and Ecosystems*, ed. T. Kozlowski and C.E. Ahlgren, 139-94. New York: Academic Press.

Whisenant, S.G. and D.W. Uresk. 1989. Burning upland, mixed prairie in Badlands National Park. *Prairie Naturalist* 21:221-27.

Whisenant, S.G. and D.W. Uresk. 1990. Spring burning Japanese brome in a western wheatgrass community. *Journal of Range Management* 43: 205-8.

White, R.S. and P.O. Currie. 1983. Prescribed burning in the northern Great Plains: Yield and cover responses of 3 forage species in the mixed grass prairie. *Journal of Range Management* 36:179-83.

Wright, H.A. 1974. Effect of fire on southern mixed prairie grasses. *Journal of Range Management* 27:417-19.

Wright, H.A. 1978. Use of fire to manage grasslands of the Great Plains: Central and southern Great Plains. In *Proceedings, 1st International Rangelands Congress; 1978, August 14-18,* ed. D.N. Hyder, 694-96. Denver, CO: Society for Range Management.

Wright, H.A. 1986. Manipulating rangeland ecosystems with fire. In *Prescribed Fire and Smoke Management: Symposium Proceedings: 39th Annual Meeting of the Society for Range Management. February 13, 1986, Kissimmee, Florida,* ed. E.V. Komarek, S.S. Coleman, and G.W. Tanner, 3-6. Denver, CO: Society for Range Management.

Wright, H.A. and A.W. Bailey. 1980. Fire ecology and prescribed burning in the Great Plains: A research review. *USDA General Technical Report* INT-77. 61 pp. Ogden, UT: Intermountain Forest and Range Experiment Station.

Wright, H.A. and A.W. Bailey. 1982. *Fire Ecology, United States and Southern Canada.* New York: John Wiley and Sons.