Effects of Fire on Texas Wintergrass Communities

S.G. WHISENANT, D.N. UECKERT, AND C.J. SCIFRES

Abstract

The effect of season of burning on standing crop, point frequency, density, and reproductive vigor of Texas wintergrass *(Stipa leucotricha* Trin. & Rupr.) communities was measured in this study. Additional information on the effects of fire on Texas wintergrass will aid resource managers plan the use of fire in these communities. Burning or clipping Texas wintergrass did not significantly affect the number of reproductive culms per plant in the northern Edwards Plateau region of Texas. Burning, regardless of season, reduced standing crops for 1 year and burning in January or March reduced Texas wintergrass point frequency for 1 year. Burning where annual cool-season grasses were abundant in the southern Rolling Plains tended to increase Texas wintergrass density, point frequency, and standing crop, apparently a result of reduced competition from annual plants. Increases in Texas wintergrass point frequency and standing crop were greater following burning in the fall than following burning in the spring. Prescribed burning in Texas wintergrass communities generally killed annual grasses and forbs if burning occurred subsequent to seedling emergence. However, soil reserves of seed and/or subsequent seed immigration into burned areas appeared to be sufficient to reestablish populations of annual plants during the second year following burning. Annual grass populations consistently tended to be higher in the second year after burning than on unburned rangeland.

Texas wintergrass (*Stipa leucotricha* Trin. & Rupr.) is an erect, tufted, cool-season perennial that commonly occurs on fine-textured, calcareous soils in the Edwards Plateau, Rolling Plains, Cross Timbers and Prairies, and other land resource areas of Texas (Correll and Johnston 1970). On the western Edwards Plateau, Texas wintergrass is representative of sites with relatively deep soils (Smeins et al. 1976).

Texas wintergrass is one of the most important grasses in the diets of domestic livestock and wildlife in Texas (Drawe and Box 1968, Ramsey and Anderegg 1972, Sanders 1975, Bryant et al. 1979, Taylor et al. 1980). Texas wintergrass may contain green foliage at any time of the year, but usually provides an adequate forage supply from October through June in years with at least average rainfall and relatively warm winters. Texas wintergrass has some characteristics objectionable to sheep and hair-goat producers because the sharp-pointed, densely hairy callus of the floret, and the stout, twisted awn of the lemma enable the floret to easily penetrate the fleece and skin of sheep and hair-goats. This can result in decreased value of wool (Bell 1973) and mohair, loss of weight, decreased carcass quality, and occasional death losses.

Attitudes among resource managers are mixed relative to the values of Texas wintergrass. There is an abundance of cool-season forages in many areas and a corresponding shortage of warm-season forages so that producers are interested in shifting the forage balance toward the warm-season species. When cool-season forage is limiting and warm-season forage is plentiful, a shift in vegetative composition toward the cool-season species may be desirable. Several species of warm-season grasses occur in many Texas wintergrass communities while cool-season, annual grasses are codominants in others.

Fire can change the species composition of plant stands. Burning in the fall minimizes potential damage to cool-season perennial plants (Wright 1974). Results of 17 years of burning research in the Kansas Flint Hills showed that cool-season species were reduced and warm-season species favored by spring burning (Anderson et al. 1970). Burns early in the growing season were lethal to more plants than burns late in the season. Similar results were obtained in Alberta with western porcupinegrass (*Stipa spartea* var. *curtiseta* Trin.) (Bailey and Anderson 1978). Texas wintergrass is reported to be severely harmed by intense fires (Dahl and Goen 1973) but it increased following spring fires of low intensity (Bean et al. 1975). Production of Texas wintergrass increased for 2 growing seasons after burning in late-winter in the southern Rolling Plains (Ueckert and Whisenant 1980). Box et al. (1967) reported that standing crop of Texas wintergrass was not affected by burning in the fall on the Coastal Prairie region of Texas.

Burning after seedling emergence is usually detrimental to annual plants (Daubenmire 1968, Wright 1974). Seeds of annual grasses are seldom damaged by the flames of grassland fires unless they are in the upper parts of the inflorescence. Seeds in or on the soil surface are seldom damaged by grassland fires (Daubenmire 1968, Vogl 1974).

Two distinctly different responses of annual grasses to litter removal have been reported. Most annual grasses are pioneers requiring bare ground and sunlight, conditions common on post-burn sites (Curtis and Partch 1950, Ehrenreich and Aikman 1957, Daubenmire 1968, Wright 1974). However, other annual grasses require a certain amount of mulch on the soil surface for their seeds to germinate. This requirement for mulched seedbeds has been demonstrated for prairie threeawn *(Aristida oligantha* Michx.) (Owensby and Launchbaugh 1977); soft brome (*Bromus mollis* L.); and downy brome (*Bromus tectorum* L.) (Heady 1956, Smith 1970).

The purpose of this study was to determine the effect that season of burning has on standing crop, point frequency, density, and reproductive vigor of Texas wintergrass and associated species in central and northcentral Texas. An appropriate burning prescription could potentially enable resource managers to manipulate the quantity of Texas wintergrass with fire as needed to achieve a more desirable balance in the yearlong forage base.

Study Areas and Methods

Research was conducted on 6.5 ha in McCulloch County and on 7.5 ha in Coleman County, Texas. These areas typically have dry winters and hot summers with precipitation peaks in April, May, September, and October. Mean annual precipitation is 59 and 69 cm for McCulloch and Coleman Counties, respectively (Bynum and Coker 1974, Botts et al. 1974). Study areas at both locations were fenced to exclude livestock.

The McCulloch County study area has Tobosa clay (fine, montmorillonitic, thermic, Typic Chromustert) on lower areas and

---

The authors are at present assistant professor, Department of Botany and Range Science, Brigham Young University, Provo, Utah 84602; professor, Texas Agricultural Experiment Station, Rt. 2, Box 950, San Angelo 76901; and Thomas M. O'Connor professor, Department of Range Science, Texas A&M University, College Station 77843. Published with the approval of the Director, Agricultural Experiment Station, as TA-18668.

The authors wish to thank J.D. Brotherson, J.F. Vallentine, and H.A. Wright for their helpful suggestions concerning this manuscript.

Manuscript accepted March 21, 1984.

Valera clay (fine, montomorillonitic, thermic, Petro Calciustoll) on higher areas. The Coleman County study area contains both Rowena clay loam (fine, mixed, thermic Vertic Calciustoll) and Kavett silty clay (clayey, montmorillonitic, thermic, shallow Petrocalcic Calciustoll).

The McCulloch County study area is located in the northcentral Edwards Plateau and is in the Oak Savannah floristic association of McCulloch County (Whisenant 1981). The Coleman County study area is located in the mesquite *(Prosopis glandulosa* Torr. var. *glandulosa)* grassland floristic association of the Rolling Plains.

Fine fuel loads and fuel-water contents were determined before each burn by clipping fifteen, 0.25-m^2 sampling areas to a 2.5-cm stubble height, drying at 60° C for 48 hr, and weighing. Air temperature, relative humidity, and instantaneous wind speed were measured with a mercury thermometer, sling psychrometer, and a hand-held wind meter immediately before, during, and after each burn.

One experiment at the McCulloch County location was designed as completely random and arranged as a split-plot (hereafter called small plots), with season of treatment as the main-plot effect and treatment as the sub-plot effect. Treatments and seasons were each replicated 4 times and applied to 3- by 3-m subplots. Treatments used were (1) burn, (2) clip and remove all vegetation and mulch, and (3) no treatment. Treatments were conducted during fall (September 28, 1979); winter (January 24, 1980); and spring (March 19, 1980). Each subplot was separated from the others by a 1-m buffer.

Plant density and numbers of reproductive culms per plant were determined on June 3, 1980, and June 4, 1981, in two, 13- by 192-cm (0.25-m^2) quadrats placed on a permanently marked diagonal across each plot. Point frequency (hereafter referred to as frequency) was determined (based on foliar hits) on June 3, 1980, and June 2, 1981, using 10 placements of an inclined 10-point frame on each plot. Statistical comparisons of numbers of reproductive culms were conducted on a per plant basis.

The second experiment at the McCulloch County study site contained ten, 0.3-ha plots arranged as a randomized complete block design (hereafter called large plots). Soil type was used as the criterion for the 2 blocks. Two of these were not burned and 2 each were burned on September 27, 1979; January 24, 1980; March 19, 1980; and November 21, 1980.

Standing crops were determined using fifteen to twenty-five, 0.25-m^2 quadrats in each plot. Standing crops were determined on June 3, 1980; June 2, 1981; and October 23, 1981. Green herbaceous vegetation was clipped, by species, to a 2.5-cm stubble height and oven-dried at 60° C for 48 hr before weighing. Frequency was determined on each 0.3-ha plot along 2 permanently marked 61-m lines with 200 points spaced 30.5-cm apart per line. Evaluation dates were June 3, 1980; October 10, 1980; June 2, 1981; and October 23, 1981.

The Coleman County experiment contained eight 0.8-ha plots arranged in a randomized complete block design. Soil type was used as criterion for the 2 blocks. Two of these were not burned, and two each were burned on October 9, 1979; January 25, 1980; and March 21, 1980.

Frequency was determined on each 0.8-ha plot along 2 permanently marked 91-m lines with 200 points spaced 45.7-cm apart per line. Evaluation dates were June 12, 1980; October 10, 1980; May 22, 1981; and November 6, 1981. Plant density was measured in four 13- by 192-cm (0.25-m^2) quadrats at each of four, permanently marked sampling areas in each 0.8-ha plot. Standing crops were determined on June 12, 1980; May 22, 1981; and November 6, 1981, by harvesting to a 2.5-cm stubble height in 15 to 25, 0.25-m^2 quadrats in each plot.

Treatment effects on frequency, plant density, and the numbers of reproductive culms per plant were determined for the split-plot experiment using analyses of variance of plot means. Differences in frequency among treatments on the randomized complete block experiments were determined with analyses of variance using data from each transect as a subsample. Differences in standing crop among treatments with the randomized complete block experiments were determined with analysis of variance using quadrat data as subsamples. Treatment means from the large plot experiments were separated with Duncan's multiple range test ($P \leq 0.05$) when appropriate. Orthogonal comparisons were made of untreated vs. treated plots (clipped and burned) and clipped vs. burned plots on the small plot experiment.

Results and Discussion

Weather at Time of Burns

Environmental and fuel variables during fires installed in Texas wintergrass stands during 1979-1980, at both study sites, are listed in Table 1.

Texas Wintergrass

At the McCulloch County site in June 1980, Texas wintergrass densities on treated plots were significantly higher after September treatments and lower following January treatments compared to untreated plots (Table 2). In June 1981, Texas wintergrass densities were higher on plots treated in September, 1979, January 1980, or March 1980 when compared to untreated plots. No significant

Table 1. Environmental and fuel variables during fires installed in Texas wintergrass stands during 1979-1980, McCulloch County and Coleman County, Texas.

Date burned	Experiment[1]	Ambient temperature (°C)	Wind speed (km/hr)	Relative humidity (%)	Fuel water (%)	Fine fuel (kg/ha)
				McCulloch County		
Sep. 1979	LP	32	1-5	19	14	2,700
	SP	35	10-13	18	16	2,680
Jan. 1980	LP	18	10-16	42	14	3,700
	SP	16	10-13	44	13	3,650
Mar. 1980	LP	20	18-24	30	18	3,000
	SP	22	13-23	33	18	3,000
Nov. 1980	LP	12	0-5	54	22	3,300
				Coleman County		
Oct. 1979		23	8-16	24	13	3,000
Jan. 1980		18	10-14	35	12	3,100
Mar. 1980		21	14-18	23	9	2,500

[1]LP = Large plots.
SP = Small plots.

Table 2. Live plant densities (no./m²) in June 1980 and 1981 after burning or clipping at several dates in 1979-1980, for small plots, McCulloch County, Texas.[1]

Treatment	September 1979		January 1980		March 1980		Treatment means	
Texas Wintergrass, June 1980								
No treatment vs Treated[2]	170 224	*	133 78	*	122 111	NS	141 138	NS
Clipped vs. Burned	202 247	NS	87 69	NS	118 104	NS	135 140	NS
Texas Wintergrass, June 1981								
No treatment vs Treated	85 114	**	75 112	**	78 141	**	79 122	**
Clipped vs. Burned	114 113	NS	117 106	NS	142 140	NS	124 120	NS
Ozarkgrass, June 1980								
No treatment vs Treated	34 27	NS	10 7	NS	24 8	*	22 35	NS
Clipped vs. Burned	24 30	NS	12 3	*	16 1	*	17 11	NS

[1]NS means the contrast is not significantly different, * means significant at the 5% error level, and ** means significant at the 1% error level using an F-test for comparison.
[2]Treated category includes both clipped and burned treatments.

differences in Texas wintergrass densities were found between burned and clipped plots regardless of treatment date or evaluation date. Comparison of densities on the untreated plots indicated decreases from June 1980 to June 1981. There were no obvious reasons for this apparent natural mortality on untreated plots; it may have been related to excessive litter accumulation on those plots. Untreated plots had not been grazed for almost 2 years before the June 1981 evaluation.

Texas wintergrass densities on the Coleman County site were not significantly affected ($P \leq 0.05$) during the first spring after burning, regardless of season of burning (Whisenant 1982). However, there was a strong (yet not significant) trend toward increased Texas wintergrass densities following burning, especially following burns installed in October or January. Plant densities on plots burned in October, January, or March increased by 66, 75, and 53%, respectively, by the first spring subsequent to burning compared to densities on adjacent unburned rangeland.

Average numbers of reproductive culms per Texas wintergrass plant were not affected by burning or clipping, regardless of season of treatment or location (Whisenant 1982). Frequencies of Texas wintergrass on the treated small plots in June 1980 were reduced (Table 3), but did not differ at the end of the second growing season. No significant differences in Texas wintergrass frequency were found between burned or clipped plots, regardless of treatment date or evaluation date.

Reduction in Texas wintergrass frequency attributable to clipping or burning appeared to be related to the amount of green tissue removed. Treatments in September 1979 were applied when the Texas wintergrass plants were dormant. Extremely small amounts of green tissue were removed, and treatments did not reduce Texas wintergrass frequencies. Large amounts of green tissue were removed by burning or clipping during January or March.

The length of time between treatment and evaluation is another important consideration in assessing reduction of Texas wintergrass frequency. The September treatments had the longest post-treatment growth period and reflected the least treatment effect. The January and March treatments had shorter post-treatment growth periods prior to evaluation and relatively large reductions in Texas wintergrass frequencies.

Texas wintergrass frequencies on the large plots burned in October or January, had increased by June 1980 compared to

Table 3. Texas wintergrass frequencies (%) after burning or clipping at several dates in 1979-1980, for small plots, McCulloch County, Texas.[1]

Treatment	September 1979		January 1980		March 1980		Treatment means	
June 1980								
No treatment vs. Treated[2]	56 46	NS	74 52	*	68 44	**	66 47	**
Clipped vs. Burned	45 47	NS	48 55	NS	48 41	NS	47 48	NS
June 1981								
No treatment vs. Treated	83 79	NS	81 79	NS	81 78	NS	82 79	NS
Clipped Burned	78 81	NS	82 75	NS	72 85	NS	77 80	NS

[1]NS means the contrast is not significantly different, * means significant at the 5% error level, and ** means significant at the 1% error level using an F test for comparison.
[2]Treated category includes both clipped and burned treatments.

Table 4. Frequencies (%) and standing crops (kg/ha) after burning in 1979-1980, Coleman County, Texas.[1]

Date burned	June 1980	October 1980	May 1981	November 1981
	Texas Wintergrass Frequency (%)			
Unburned	24 c	22 a	30 a	38 a
Oct. 1979	48 a	26 a	44 a	42 a
Jan. 1980	44 ab	26 a	43 a	44 a
Mar. 1980	29 bc	19 a	37 a	40 a
	Texas Wintergrass Standing Crop (kg/ha)			
Unburned	339 a	—	523 a	538 b
Oct. 1979	500 a	—	943 a	689 a
Jan. 1980	400 a	—	743 a	539 b
Mar. 1980	402 a	—	1264 a	545 b
	Japanese Brome Standing Crop (kg/ha)			
Unburned	212 a	—	726 a	—
Oct. 1979	130 a	—	660 a	—
Jan. 1980	357 a	—	447 a	—
Mar. 1980	31 b	—	375 a	—

[1]Means within a column within an evaluation date, followed by the same letter, are not significantly different ($P\leq0.05$) according to Duncan's multiple range test.

the unburned plots at the Coleman County study site (Table 4). Texas wintergrass frequencies on plots burned in March 1980 were not different ($P\leq0.05$) from frequencies on unburned plots when evaluated in June 1980. Although no differences in Texas wintergrass frequencies occurred in October 1980, May 1981, or November 1981, frequencies on untreated and on plots burned in March 1980 tended to be less than on plots burned in October or January. This trend is consistent with observations of Daubenmire (1968), Wright (1974), and Wright and Bailey (1982) that fall burns benefit cool-season plants.

Texas wintergrass standing crops on the McCulloch County study site were reduced during the first spring subsequent to burning in September 1979, January 1980, or March 1980 (Table 5). However, burning in November 1980 reduced standing crops during the first growing season. Texas wintergrass standing crops on burned rangeland were equal to those on unburned rangeland during the second growing season when rainfall was slightly below average (1980 evaluation) and during the first growing season when it was above average (see 1981 evaluations of November 1980 burn in Table 5).

Texas wintergrass standing crops demonstrated variable responses to fall burning in different years. Burns in September 1979 were conducted under relatively hot, dry conditions (Table 1); most of the ground mulch was consumed. Plots burned in November 1980 were burned under relatively cool and humid conditions (Table 1); little ground mulch was consumed and 3 to 6 cm of green leaf material was left relatively undamaged. Standing crop data indicated that "cool" fall burns followed by excellent growing conditions did not hurt Texas wintergrass during the first growing season.

Table 5. Standing crops (kg/ha) after burning in 1979-1980, for large plots, McCulloch County, Texas.[1]

Date burned	June 1980	June 1981	October 1981
	Evaluation date		
	Texas Wintergrass		
Unburned	893 a	2028 a	1964 a
Sep. 1979	334 b	1206 a	1753 a
Jan. 1980	396 b	2268 a	1715 a
Mar. 1980	320 b	1492 a	1247 a
Nov. 1980	—	1736 a	1883 a
	Ozarkgrass		
Unburned	36 b	251 a	—
Sep. 1979	138 a	433 a	—
Jan. 1980	6 b	257 a	—
Mar. 1980	2 b	51 b	—
Nov. 1980	—	122 a	—

[1]Means within a column within an evaluation date, followed by the same letter, are not significantly different ($P\leq0.05$) according to Duncan's multiple range test.

Texas wintergrass standing crops on the Coleman County study site during June 1980 and May 1981 did not differ significantly between burned and unburned plots (Table 4). However, there were trends toward greater standing crops on burned plots during both years. Standing crops of Texas wintergrass in May 1981 on plots burned in October, January, or March tended to be greater than on unburned plots. Standing crops of Texas wintergrass in November 1981 were significantly greater ($P\leq0.05$) on plots burned in October 1979 than on unburned plots or on plots burned on other dates (Table 4).

Cool-season Annual Grasses

Ozarkgrass [*Limnodea arkansana* (Nutt.) Engelm.] plant density was significantly reduced during the first growing season at the McCulloch County study area by treatments conducted in March after seedling estabishment (Table 2). However, ozarkgrass density on clipped plots was significantly greater than on plots burned in January or March, indicating that mortality resulted from heat damage and not simply from removal of above-ground vegetative material (Table 2).

Standing crops of ozarkgrass at the McCulloch County study area increased during the first growing season following burning in September (Table 5). At the Coleman County study area there were nonsignificant trends toward reductions in frequency of Japanese brome (*Bromus japonicus* Thun.) following March burns, and increases following burning in October or January (Whisenant 1982). Standing crops of Japanese brome were reduced ($P\leq0.05$) for the first growing season following burning in March (Table 4). Plots burned in March 1980 supported only 52% of the unburned Japanese brome standing crop during the second growing season

Table 6. Reproductive culms per red threeawn plant in June 1980 after burning or clipping at several dates in 1979-1980, for small plots, McCulloch County, Texas.[1]

Treatment	September 1979	January 1980	March 1980	Treatment means
	Treatment date			
No treatment vs. treated[2]	10 16 NS	2 13 NS	7 19 *	6 16 NS
Clipped vs. burned	17 15 NS	7 18 NS	20 18 NS	15 17 NS

[1]NS means the contrast is not significantly different, * means significant at the 5% error level, and ** means significant at the 1% error level using an F test for comparison.
[2]Treated category includes both clipped and burned treatments.

after burning. However, this difference was not statistically significant.

Warm-season Perennial Grasses

Red threeawn (*Aristida longiseta* Steud.) density, frequencies and standing crop at the McCulloch County study area were not affected by burning or clipping, regardless of season (Whisenant 1982). However, the March treated plots had significantly more reproductive culms per plant than the untreated plots in June 1980 (Table 6). No significant differences in the number of reproductive culms were found between clipped and burned plots.

Conclusions

Response of Texas wintergrass to burning is largely a function of environmental conditions during the fire, growing conditions following burning, and interspecific competitive interactions. Grazing by domestic livestock may also be a critical regulatory influence, but was eliminated as a factor in this study. Responses of Texas wintergrass to burning or clipping were similar for all attributes measured in this study, indicating that most of the responses brought about by burning or clipping result from mulch removal and associated indirect influences rather than direct heat effects.

Burning Texas wintergrass in dense homogeneous stands during January or March reduced Texas wintergrass standing crops and frequencies. Low intensity fall burns that did not consume the surface mulch and were followed by several months of average or above-average rainfall allowed plants to recover from any potentially detrimental effects during the first growing season. Fire-induced changes in Texas wintergrass were relatively short-lived (<1 year).

The pattern of Texas wintergrass response to burning was different in plant communities in which cool-season, annual grasses were major components of the vegetation. Consistent trends indicated that Texas wintergrass density, frequency, and standing crop may increase following burning in these communities. Increases in Texas wintergrass were more pronounced following burning in the fall and less pronounced following burning in the spring. These increases in Texas wintergrass appear to be a result of reduced interspecific competition following removal of annual plants by fire.

Plant density is probably a better long-term indicator of community response to burning than frequency or standing crop. Using this assumption, Texas wintergrass was benefited by burning, particularly when burning reduced interspecific competition. Texas wintergrass may increase its density to partially fill the resulting void when competition is reduced. Some evidence suggested that excessive litter accumulation may reduce Texas wintergrass density on unburned rangeland. Grazing or periodic burning will probably prevent excess litter accumulation.

Cool-season, annual grasses and forbs were generally killed when burning occurred after emergence. However, seed reserves in the soil and/or subsequent seed immigration into burned areas allowed annual plant populations to reestablish in the second year. Seed immigration into large areas would probably be less than in the small plots treated in this experiment. Clipping did not reduce ozarkgrass frequency as much as burning, indicating that mortality resulted from heat damage and not simply from removal of aboveground vegetative material. Annual grass frequencies and standing crops on plots burned in September-October were greater than on unburned plots whereas burning in March decreased annual grass density, frequency, and standing crop. Burning in January was less detrimental to annual grasses, than burning in March. Annual grasses and forbs tended to be more abundant in the second year after burning than on unburned rangeland.

A fire designed to benefit Texas wintergrass at the expense of warm-season, perennial grasses should be applied in the fall before growth of Texas wintergrass begins and while warm-season perennial grasses are still actively growing. If management objectives demand favoring warm-season, perennial grasses, and reducing Texas wintergrass, the Texas wintergrass should be burned when it is actively growing and before initiation of warm-season perennial grass growth. However, the detrimental effect of fire on Texas wintergrass may last only 1 year.

Literature Cited

Anderson, K.L., E.F. Smith, and C.E. Owensby. 1970. Burning bluestem range. J. Range Manage. 23:81-92.

Bailey, A.W., and M.L. Anderson. 1978. Prescribed burning of a *Festuca-Stipa* grassland. J. Range Manage. 31:446-449.

Bean, W.E., J.P. Goen, and B.E. Dahl. 1975. Livestock response to mechanical brush control and seeding on tobosa ranges. *In:* Noxious Brush and Weed Control Research Highlights. H.A. Wright and R.E. Sosebee (Eds.) Texas Tech. Univ., Vol. 6.

Bell, H.M. 1973. Rangeland management for livestock production. Univ. Oklahoma Press, Norman.

Botts, O.L., B. Hailey, and W.D. Mitchell. 1974. Soil survey of Coleman County, Texas. USDA, Soil Conserv. Serv.

Box, T.W., J. Powell, and D.L. Drawe. 1967. Influence of fire on south Texas chaparral communities. Ecology 48:955-961.

Bryant, F.C., M.M. Kothmann, and L.B. Merrill. 1979. Diets of sheep, angora goats, Spanish goats and white-tailed deer under excellent range condition. J. Range Manage. 32:412-417.

Bynum, O.W., and J.L. Coker. 1974. Soil Survey of McCulloch County, Texas. USDA, Soil Conserv. Serv.

Correll, D.S., and M.C. Johnston. 1970. Manual of the vascular plants of Texas. Tex. Res. Found., Renner, Tex.

Curtis, J.T., and M.L. Partch. 1950. Some factors affecting flower production in *Andropogon gerardi.* Ecology 31:488-489.

Dahl, B.E., and J.P. Goen. 1973. 2,4,5-T plus fire for management of tobosa grasslands. *In:* Noxious Brush and Weed Control Research Highlights. H.A. Wright and R.E. Sosebee (Eds.) Texas Tech Univ., Vol. 4.

Daubenmire, R. 1968. Ecology of fire in grasslands. Advan. Ecol. Res. 5:209-266.

Drawe, D.L., and T.W. Box. 1968. Forage ratings for deer and cattle on the Welder Wildlife Refuge. J. Range Manage. 21:225-228.

Ehrenreich, J.H., and J.M. Aikman. 1957. Effect of burning on seedstalk production of native prairie grasses. Iowa Acad. Sci. Proc. 64:205-212.

Heady, H.F. 1956. Changes in a California annual plant community induced by manipulation of natural mulch. Ecology 37:798-812.

Owensby, C.E., and J.L. Launchbaugh. 1977. Controlling prairie threeawn (*Aristida oligantha* Michx.) in central and eastern Kansas with fall burning. J. Range Manage. 30:337-339.

Ramsey, C.W., and M.J. Anderegg. 1972. Food habits of an aoudad sheep, *Ammotragus lervia* (Bovidae) in the Edwards Plateau of Texas. Southw. Natur. 16:267-280.

Sanders, K.D. 1975. Continuous vs. short duration grazing on northcentral Texas rangeland. Ph.D. Diss. Texas Tech. Univ., Lubbock.

Smeins, F.E., T.W. Taylor, and L.B. Merrill. 1976. Vegetation of a 25-year exclosure on the Edwards Plateau, Texas. J. Range Manage. 29:24-29.

Smith, T.A. 1970. Effects of disturbance on seed germination in some annual plants. Ecology 51:1106-1108.

Taylor, C.A., M.M. Kothmann, L.B. Merrill, and D. Elledge. 1980. Diet selection by cattle under high-intensity low-frequency, short duration, and Merrill grazing systems. J. Range Manage. 33:428-434.

Ueckert, D.N., and S.G. Whisenant. 1980. Chaining/prescribed burning systems for improvement of rangeland infested with mesquite and other undesirable plants. p. 25. *In:* Rangeland Resources Research. Texas Agr. Exp. Sta. Consol. Prog. Rep.

Vogl, R.J. 1974. Effects of fire on grasslands. p. 139-194. *In:* Fire and Ecosystems. T.T. Kozlowski (Ed.). Academic Press, New York.

Whisenant, S.G. 1981. The vascular flora of McCulloch County, Texas. Tex. J. Science 33:197-220.

Whisenant, S.G. 1982. Ecological effects of fire on Texas wintergrass *(Stipa leucotricha)* communities. Ph.D. Diss. Texas A&M Univ., College Station.

Wright, H.A., and A.W. Bailey. 1982. Fire Ecology. John Wiley and Sons, New York.