Responses of Semidesert Grasses and Shrubs to Fall Burning

S. CLARK MARTIN

Abstract

Four 0.8-ha plots south of Tucson, Ariz., were burned November 12, 1975, in a pasture where cattle had not grazed for 12 months. The fire top-killed most small mesquites, killed almost all of the burroweed and much of the cactus, except in unburned patches. Within 5 years regrowth of mesquite and newly established stands of burroweed equalled or exceeded pre-burn levels. Lehmann lovegrass increased following the burn; most other perennial grasses were not greatly affected. Results suggest that periodic burning can maintain a grassland aspect if the intensity and frequency of grazing allow enough dry herbage for an effective fire to accumulate between burns.

A common question in southern Arizona is: can fire be used to control such plants as velvet mesquite *(Prosopis juliflora* var. *velutina),* cholla and prickly pear cactus (*Opuntia* spp.), and burroweed *(Applopappus tenuisectus)* that now occupy former grasslands (Humphrey 1949)?[1] This report describes the effects of fall (November) burning on velvet mesquite, other shrubs, and herbaceous vegetation in: (1) undisturbed invasion stands of mesquite, and (2) stands of young mesquites that have come in since the invasion stand was killed with sodium arsenite in 1940. The sites were relatively free of mesquite in 1903 when the "Range" was fenced out of the Public Domain.

Background

Glendening and Paulsen (1955) found that mortality and top kill of velvet mesquite were higher for June fires than for October, November or February fires. Similarly, Tschirley and Martin (1961) reported that mortality of burroweed in June fires was about twice as high as for fires in late fall or early spring. A disadvantage of June fires is that they often kill high percentages of several grasses as well as shrubs (Cable 1965, 1967, 1972). Pase (1971) found that Lehmann lovegrass was not severely damaged by a February fire. Consequently, June burning was considered too hazardous to include in the study. Fall burning was chosen over spring because the quantity of herbaceous fuel is greatest in the fall, because perennial grasses are mainly dormant at that time, and because fall fits best with the grazing-rest schedule of the Santa Rita Grazing System (Martin 1978). The Santa Rita grazing schedule is: (1) *rest November 1 through October,* (2) graze November 1 through February, (3) *rest March 1 through February,* then (4) graze March 1 through October to complete the 3-year cycle. Both 12-month rest periods provide an ungrazed summer forage crop, but burning in the fall or spring of the March-February rest period is not advisable because the burned area would be grazed during the following spring and summer. Spring burning following November-February grazing would not be effective because cattle consume most of the grass under and around each tree well before the end of February. Burning in fall immediately following the November-October year of rest provides a full herbage crop with cattle on the burned area November 1 through February. The most common herbaceous perennials are usually dormant and relatively insensitive to grazing or burning during this period. The area is then rested 12 months, March through February, before it is grazed again.

Study Area and Treatments

The study was conducted at elevation of 1100 m, average annual precipitation 350 mm, on the Santa Rita Experimental Range near Tucson, Ariz. The abundance of Lehmann lovegrass on this part of the Experimental Range has increased greatly in recent years (Cable 1971). The study area was rested for 1 year before the burn November 12, 1975. Grazing periods since the burn were: November 12, 1975, to February 28, 1976; March 1 to October 31, 1977; November 1, 1978, to February 28, 1979; and March 1 to October 31, 1980. Three 6.4-m² sub-plots on each burned plot were protected from grazing after the fire to help evaluate effects of grazing after burning. The study area is one where mesquite, burroweed, both, or neither was killed in 1940 (Parker and Martin 1952). The 16 0.4-ha plots form a latin square with treatments: (a) none, (b) mesquite control (1940), (c) burn November 12, 1975 (burroweed control 1940), and (d) burn November 12, 1975, mesquite (and burroweed) control 1940. Since burroweed density has fluctuated widely since 1940 the 1940 burroweed control treatment is considered to have had no influence on plant populations in this study.

Data Analysis

Pre-burn measurements were made in the fall of 1975 with follow-up observations in 1976, 1978 and 1979. Data for each year were analyzed as 4 × 4 latin square. Average differences among years and treatments were tested against the treatment × year interaction. Mean separation was by Duncan's (1955) new multiple range test. Results are presented in tables 2, 3, 5, and 6. For additional analysis the design was treated as a randomized block with four replications using rows of the original latin square as blocks. The four treatments were considered as main effects and the four re-measurements as subplots in a split-plot design. However, preliminary analyses revealed that, because of inconsistent among- year correlations, univariate analysis was appropriate for only about one third of the data sets and that the remainder were more properly analyzed by multivariate procedures.[2] Since the results of these split-plot analyses agreed closely with those in tables 2, 3, 5, and 6 they will not be discussed.

Vegetation Measurements

Vegetation measurements before and after treatment were made

Author is professor of range management, School of Renewable Natural Resources, College of Agriculture, University of Arizona, Tucson 85721.
This article submitted as Paper No. 3606 Arizona Agricultural Experiment Station, Tucson 85721. This research was supported in part by a grant from the Rocky Mountain Forest and Range Experiment Station, Forest Service USDA, Work Unit FS-RM-1710, Tempe, Ariz.
Manuscript received May 28, 1982.

[1]Botanical names are from Kearney, Thomas H. and Robert H. Peebles 1951. Arizona Flora. University of California Press.

[2]Statistical analysis and computer programs for these analyses were developed and executed by Brian Maurer, research assistant, Center for Quantitative Studies, College of Agriculture, University of Arizona.

on sample plots (10 × 40m) centered in each 61 × 61m treatment plot. Observations included: (1) density (plants/m²) of perennial grasses, perennial forbs and shrubs and estimates of percent bare soil, on 30 0.3 m² quadrats along each of 8 randomly located 9m transects in each sample plot, (2) height and crown diameter of mesquites, and (3) estimates of utilization.

Burning Conditions

Following a summer of near-average rainfall (192mm) and a rain-free period of about 40 days, burning was done November 12, 1975. The surface soil was dry. Yields of perennial grasses before burning averaged 340 kg/ha. Maximum daily temperatures for the 5 days before burning ranged from 26 to 28° C, with minimums of 7 to 10° C except for the night before burning when the minimum was 4° C. Relative humidity ranged from 40 to 50% at the predawn peak to lows of 12 to 20% in late afternoon. Fuel moisture samples taken at 10:00 a.m. showed moisture contents of 29% for burroweed, 83% for green mesquite twigs, and 16% for grass herbage. Immediately before the burn (1:30 p.m.) the moisture content of grasses and burroweed were 10% and 23% respectively. Burning was done between 1:45 and 2:45 in the afternoon with temperature 26° C, relative humdity 8%, and wind 13 km/hr, SSE. Maximum rate of spread was about 2 km/hr with rates of about 0.5 km/hr during lulls in the wind, where ground cover was more sparse. Relatively clean burns were obtained on all plots.

Precipitation

Rainfall during the 12 months before the burn and summer precipitation for the 6-year study period were near the long time averages but 12-month (June 1-May 31) average precipitation for the period (407 mm) was almost 16 percent above the 40-year mean (Table 1). Winter and spring moisture combined was markedly deficient in 1975-76 but well above average in 1977-78 and 1978-79.

Table 1. Precipitation (mm) at study area by 4-, and 12-month periods from June 1, 1974 to May 31, 1980.

	Period			
Year	June-September	October January	February-May	June May
1974-75	311[1]	102	61	474
1975-76	192	54[1,2]	75	321
1976-77	188	124	40[1]	352
1977-78	169[1]	187	113	469
1978-79	130	305[1]	41	476
1979-80	210	33	106[1]	349
6-yr mean	200	134	73	407
40-yr mean	206	94	52	352

[1]Periods when cattle had access to the study area.
[2]Burning was done in this period (November 12, 1975).

Results

Effects of Fire and Mesquite Control on Shrub Densities

Except for burroweed, changes in shrub densities were generally too small and erratic to be significant.

Burroweed

Carryover effects of the 1940 treatments were not significant. Fire reduced burroweed density on transects from 1975 to 1976 but density on unburned plots did not change (Table 2). High winter-

Table 2. Shrub densities (No./m²) by treatment before burning (1975) and in 1976, 1978, and 1979.

	Treatment		Density					
Species	1940[1]	1975	1975	1976	1978	Average	1979[2]	
Burroweed	None	None	1.74	1.71	4.33	2.96	2.68	—
	MK	None	1.45	1.46	8.38	2.27	3.39	—
	BK	Burn	1.92	0.61	2.82	2.52	1.97	1.61
	MK, BK	Burn	2.28	0.37	2.52	2.72	1.97	1.55
	Average		1.85a[3]	1.04a	4.51b	2.62ab		1.58
Pricklypear	None	None	0.04	0.04	0.01	0.08	0.04a	—
	MK	None	0.12	0.07	0.08	0.14	0.10b	—
	BK	Burn	0.01	0.01	0.01	0.01	0.01a	0.01
	MK, BK	Burn	0.09	0.06	0.14	0.10	0.10b	0.10
	Average		0.06	0.04	0.06	0.08		0.06
Cholla cactus	None	None	0.12	0.04	0.05	0.02	0.06b	—
	MK	None	0.17	0.06	0.04	0.05	0.08b	—
	BK	Burn	0.05	0.01	0.02	0.01	0.02a	0.00
	MK, BK	Burn	0.12	0.05	0.01	0.02	0.05ab	0.04
	Average		0.12b	0.04a	0.03a	0.02a		0.02
Desert zinnia	None	None	0.19	0.22	0.00	0.03	0.11	—
	MK	None	0.01	0.01	0.00	0.00	0.01	—
	BK	Burn	0.07	0.07	0.00	0.10	0.06	0.03
	MK, BK	Burn	0.01	0.00	0.00	0.00	0.00	0.00
	Average		0.07	0.08	0.00	0.03		0.02
Mesquite	None	None	0.19b	0.21	0.13	0.10	0.16b	—
	MK	None	0.04a	0.10	0.10	0.12	0.09a	—
	BK	Burn	0.05a	0.06	0.06	0.05	0.06a	0.13
	MK, BK	Burn	0.12ab	0.11	0.08	0.12	0.11ab	0.21
	Average		0.10	0.12	0.09	0.10		0.17
Total shrubs	None	None	2.28	2.22	4.52	3.19	3.05	—
	MK	None	1.79	1.72	8.60	2.58	3.67	—
	BK	Burn	2.10	0.76	2.91	2.69	2.12	1.78
	MK, BK	Burn	2.62	0.59	2.75	2.96	2.23	1.90
	Average		2.20a	1.32a	4.79b	2.86ab		1.84

[1]1940 Treatments: MK = mesquite killed, BK = burroweed killed.
[2]Ungrazed caged plots were sampled in 1979 only.
[3]Within species and year, and for averages, means are different ($p \leq .05$) if subscripts do not include a common letter.

spring precipitation in 1977-78 brought densities to higher levels than before the burn. Burroweed seedlings in 1978 were especially abundant on unburned plots where mesquite was killed in 1940. Greater densities on unburned plots in 1978 confirm findings of Humphrey (1937) who observed more burroweed seedlings in presence of litter than on bare soil and that seedlings were most abundant near parent plants. Burroweed density in 1979 was slightly lower on ungrazed plots within the burn than on burned or unburned areas that were grazed. Vigorous top growth of the ungrazed perennial grasses in these lots may have reduced seedling establishment. Densities (numbers per unit area) of burroweed in 1979 were about the same for all treatments and all but those for ungrazed plots were above pre-burn levels.

Other Shrubs

Control of mesquite in 1940 apparently resulted in higher densities of pricklypear *(Opuntia engelmannii)* than in undisturbed mesquite (though not significant), and the apparent effect of mesquite control was still evident in 1979 (Table 2). The effect of fire on cholla cactus (*Opuntia* spp.) was masked by a decrease from 1975 to 1976 for all treatments and very little change thereafter. Desert zinnia *(Zinnia pumila)*, before, burning, and in 1976, apparently was more abundant on plots that were not treated in 1940, but there were no detectable responses to burning. Mesquite densities in 1975 were highest on plots untreated in 1940 and lowest where either mesquite or burroweed were killed. Observations from 1976-1979 showed that burning did not measurably change mesquite numbers (Table 2). Minor species include catclaw acacia *(Acacia greggii)*, falsemesquite *(Calliandra eriophylla)*, snakeweed (*Gutierrezia* sp.), littleleaf baccharis *(Baccharis brachyphlla)*, mormon tea *(Ephedra trifurca)*, and carlowrightia *(Carlowrightia arizonica)*.

Other Effects of Fire on Mesquite

Average percent top-kill exceeded 80% for mesquites up to 5 cm basal diameter or upt to 1.5 m tall (Figure 1). Negative correlations were strong between percent top-kill and both measures of plant size. The percentages of trees that sprouted from the base also were related negatively to tree height and diameter. The number of stem-sprouting trees, however, was positively correlated with both stem diameter and height. These results generally confirm the findings of Cable (1961, 1965, and 1972), Glendening and Paulsen (1955) and others, that small mesquites are more easily top-killed by fire than are large ones.

Burning had little effect on net change from 1975 to 1979 in plant height or crown cover of mesquite. Mesquite crown cover was greater in 1979 than in 1975 on all plots. Crown cover in 1975, before burning, was more than twice as great on untreated plots (16%) as where mesquite was killed in 1940 (6%). Crown cover in 1979 was 31% on the 1940 check plots and 16% where mesquite was controlled. Reductions in mesquite cover by burning were quickly offset by regrowth. Average heights of mesquites in 1975 were about 25% greater on plots that were not cleared on 1940 (1.2 m) than on cleared plots (0.95 m) due to the presence of older, larger trees. By 1979 mesquite heights on the burned and unburned plots were 105% and 116% of their respective pre-burn levels. A few of the sprouts from top-killed plants flowered and set seed in 1981.

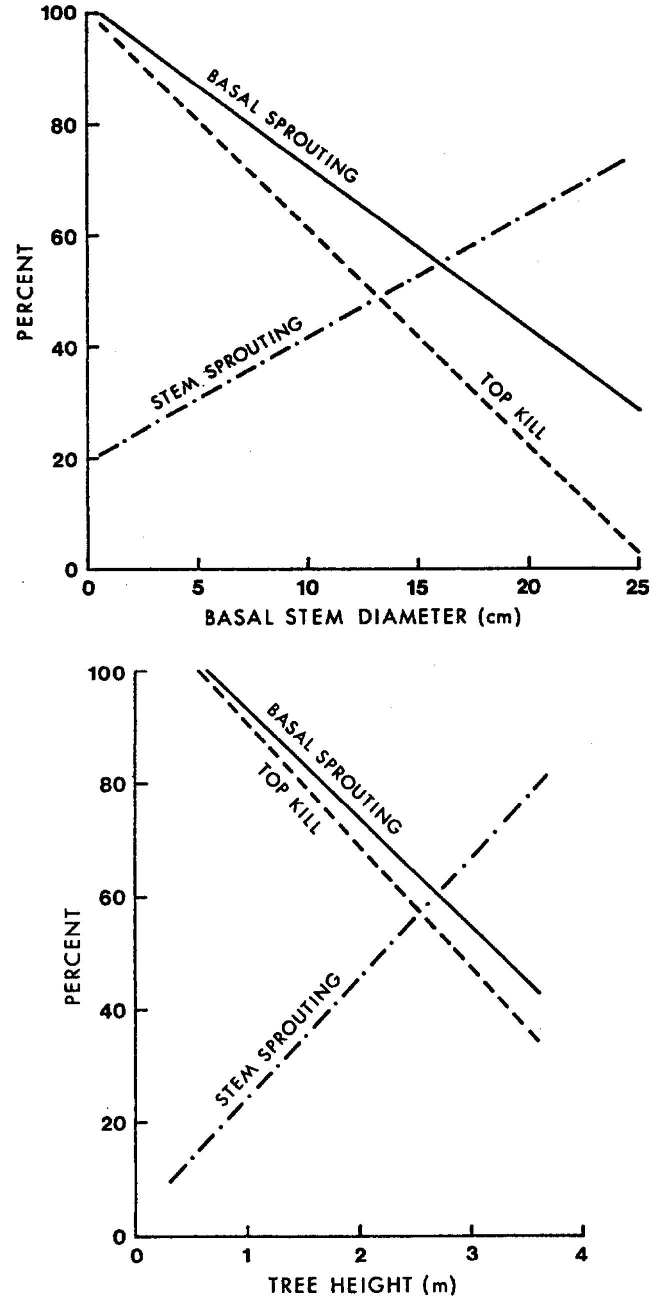

Fig. 1. *Relation between basal stem diameter (cm) and percentages of mesquite that: (a) sprouted from the base ($\hat{Y}$ = 1.01.5 - 2.92x, r = -0.974), (b) were top-killed ($\hat{Y}$ = 99.5 - 3.75x, r= -0.983), or (c) sprouted from well above ground on the trunk or major branches ($\hat{Y}$ 19.2 + 2.56x, r = 0.836). Similar relationships exist between tree height (m) and percentages of mesquite that: (a) sprouted from the base $\hat{Y}$ = 112 - 19.20x, r = -0.968), (b) were top-killed ($\hat{Y}$ = 112-21.66xr = -0.947), or (c) sprouted from well above ground on the trunk or major branches ($\hat{Y}$ = 3.91 × 22.03 x, r = 0.866).*

Effects on Perennial Grass Density

Within mesquite treatments total perennial grass density on burn and check plots was similar before burning but grass density on mesquite killed plots was almost twice as great as on untreated plots. Density declined sharply from 1975 to 1976 under all treatments but the relative decline was greater on burned plots (Table 3). Grass density continued to decline on check plots and reached its lowest point in 1979. On burned plots density increased essentially to pre-burn levels in 1978 then dropped to about 50% of the pre-burn level in 1979. If Lehmann lovegrass *(Eragrostis lehmanniana)* and Rothrock grama *(Bouteloua rothrockii)*, 2 pioneer perennials, are excepted, total perennial grass densities on burn and check plots were about the same in all years with declines under all treatments from 1975 to 1976 and from 1978 to 1979. These results suggest that fire may have decreased perennial grass density during the first year but fluctuations thereafter were probably induced by changes in rainfall.

Santa Rita Threeawn

Cable (1967) reported that Santa Rita threeawn *(Aristida glabrata)* increased following burning. In this study, density of this species changed little from 1975 to 1976 under all treatments (Table 3). On the burn, densities peaked in 1978 and were still above pre-burn levels in 1979, except in exclosures where the density was less than half as great. The combination of burning and heavy grazing seems clearly beneficial for this species.

Tall Threeawns

Densities of these threeawns (*A. hamulosa* and *A. ternipes*) were severely reduced by the burn but were back to about 2/3 of the original density in 1979.

Black grama

Black grama (*Bouteloua eriopoda*) density was markedly reduced on mesquite-killed plots in the grazed portion of the burn. Its greatest density in 1979 was in exclosures within the burn. This suggests that burning probably reduced the density of black grama initially and that heavy grazing kept it from recovery. Densities of black grama on unburned plots were greatest in 1978 then declined to about the same level as in 1976, almost 40% below the pre-burn level. For the 4-year period black grama density was several times higher on unburned plots than on burned plots. These results confirm Cable's (1965) statement that burning severely damages black grama and are consistent with Canfield's (1939) findings on its susceptiblity to clipping to 1-inch stubble height.

Rothrock Grama

Rothrock grama was consistently more abundant where mesquite was controlled. This grass behaves somewhat as an annual, increasing in favorable years and declining in drought regardless of the kind of grazing management (Martin 1973). Its density decreased rather steadily on unburned plots but exhibited highs in 1975 and 1978 and lows in 1976 and 1979 on the burn (Table 3). By

Table 3. Perennial grass densities (No./m²) by treatment before burning (1975) and in 1976, 1978 and 1979.

	Treatment		Density					
Species	1940[1]	1975	1975	1976	1978	1979	Average	1979[2]
Santa Rita threeawn	None	None	0.36	0.37	0.09	0.29	0.28a[3]	—
	MK	None	0.06	0.03	0.06	0.02	0.04a	—
	BK	Burn	0.72	0.70	1.99	1.26	1.17b	0.72
	MK, BK	Burn	0.34	0.27	0.84	0.59	0.51b	0.06
	Average		0.37	0.34	0.74	0.54		0.39
Tall threeawns	None	None	0.14	0.19	0.68	0.14	0.29	—
	MK	None	0.23	0.12	0.09	0.18	0.16	—
	BK	Burn	0.35	0.09	0.03	0.21	0.17	0.18
	MK, BK	Burn	0.32	0.04	0.09	0.22	0.17	0.24
	Average		0.26	0.11	0.22	0.14		0.21
Black grama	None	None	0.59	0.48	1.14	0.52	0.68a	—
	MK	None	1.09	0.57	1.29	0.46	0.85a	—
	BK	Burn	0.01	0.03	0.04	0.02	0.02b	2.09
	MK, BK	Burn	0.29	0.12	0.08	0.02	0.03b	0.57
	Average		0.50ab	0.30ab	0.64b	0.26a		1.33
Rothrock grama	None	None	10.43a	5.18a	4.88a	1.57	5.51a	—
	MK	None	47.57ab	17.90b	13.46a	2.85	20.44ab	—
	BK	Burn	17.52a	4.85a	14.44a	5.17	10.50a	3.33
	MK, BK	Burn	50.23ab	11.96ab	44.43b	11.39	29.50b	5.11
	Average		31.44b	9.97a	19.30ab	5.24a		4.22
Arizona cottontop	None	None	3.74	3.17	3.02	1.90	2.96c	—
	MK	None	2.28	2.07	2.00	1.10	1.86a	—
	BK	Burn	3.00	2.26	2.79	1.70	2.44b	1.46
	MK, BK	Burn	3.11	2.41	2.86	1.94	2.58b	1.54
	Average		3.03c	2.48b	2.67b	1.66a		1.50
Lehmann lovegrass	None	None	5.20	4.86	8.35	6.24	6.16a	—
	MK	None	10.74	7.91	10.45	9.24	9.58b	
	BK	Burn	1.48	1.60	9.82	8.20	5.28a	7.95
	MK, BK	Burn	1.15	0.80	6.06	5.70	3.43a	9.12
	Average		4.62a	3.79a	8.67b	7.34b		8.56
Plains bristlegrass	None	None	7.34	3.88	2.86	2.06	4.02b	—
	MK	None	0.29	0.18	0.16	0.14	0.19a	—
	BK	Burn	7.16	3.63	3.15	2.06	4.00b	0.19
	MK, BK	Burn	0.93	0.18	0.08	0.06	0.31a	0.01
	Average		3.93b	1.97a	1.56a	1.08a		0.10
Other perennial grasses	None	None	0.17	0.11	0.03	0.13	0.11	—
	MK	None	0.27	0.12	0.04	0.18	0.15	—
	BK	Burn	0.32	0.13	0.18	0.13	0.16	0.07
	MK, BK	Burn	0.13	0.08	0.19	0.14	0.14	0.00
	Average		0.22	0.11	0.11	0.12		0.04
Total perennial grasses	None	None	27.97	18.24	21.07	12.81	20.02	—
	MK	None	62.53	28.90	27.55	14.15	33.28	—
	BK	Burn	30.56	13.29	32.44	18.63	23.73	15.99
	MK, BK	Burn	56.50	15.85	54.63	20.06	36.76	16.65
	Average		44.39b	19.07a	33.92b	16.41a		16.32

[1]1940 Treatments: MK = mesquite killed, BK = burroweed killed.
[2]Ungrazed caged plots were sampled in 1979 only.
[3]See footnote 3, Table 2.

1979 it was 2 to 3 times as abundant on the burn as on the unburned plots, except in exclosures where density was about half as great as on grazed parts of the burn. Here too, the fire impact was temporary and changes after 1976 were probably related to rainfall fluctuations and the responses of competing vegetation to grazing. By 1979 Rothrock grama made up 50% of the perennial grass in the burn but only 16% of the perennial grass density on check plots (Table 4).

Plains Bristlegrass

Plains bristlegrass *(Setaria macrostachya)* showed no measurable response to burning but was always more abundant on plots with old mesquite trees. The low density in the exclosures, therefore, may be due to the fact that the portable cages were placed in openings between trees. Close grazing apparently was detrimental, however, because the final density on all treatments was much below the original.

Arizona Cottontop

Arizona cottontop *(Trichachne californica)* apparently was not reduced in density by burning but its density decreased from 1975 to 1979 under all treatments, presumably due to drought and grazing pressure.

Lehmann Lovegrass

The density of Lehmann lovegrass on unburned plots did not change much (Table 2). Likewise there was little change on burn plots from 1975 to 1976 but densities in 1978 and 1979 were about 5 times as great as in the first 2 years. These results show that Lehmann lovegrass was not reduced in density by the November burn and responded favorably to conditions on the heavily grazed burned plots after 1976. Readings in the exclosures were about the same as in surrounding grazed areas.

Other Grasses

Minor species observed included: tanglehead *(Heteropogon contortus)*, bush muhly *(Muhlenbergia porteri)*, silver beardgrass *(Andropogon barbinodis)*, dropseeds *(Sporobolus contractus* and *S. cryptandrus)*, fluffgrass *(Tridens pulchellus)*, and green sprangle top *(Leptochloa dubia)*. Populations of these species were too sparse and too irregularly distributed to evaluate trends. Together they accounted for less than 2% of the perennial grass stand.

Effects on Species Composition

Together, Rothrock grama and Lehmann lovegrass made up over 80% of the perennial grass density in 1975 and from 73 to 81% in 1979 (Table 4). On check plots the relative contribution of these species was almost reversed during the study period. Rothrock grama decreased from 64 to 16%. While Lehmann lovegrass increased from 18 to 56%. On burned plots, the relative contribution of Rothrock grama from 1975 to 1979, decreased from 77 to 50% while Lehmann lovegrass increased ten fold from 3% to 31%.

Effects on Perennial Forbs

Perennial forbs are a minor component of the summer vegetation except in local colonies. Forb densities before the burn were generally higher on areas where mesquite was controlled in 1940 and higher in 1975 than later (Table 5). The sharp drop from 1975 to 1976 can be attributed in part to low Oct-Jan rainfall. In 1979, the density of Arizona evolvulus *(Evolvulus arizonicus)*, within mesquite treatments, was higher on the burned plots though not significantly so. Other forbs apparently were benefited by protection from grazing but silver-leaf nightshade *(Solanum elaeagnifolium)* and sida *(Sida procumbens)* did better without protection.

Effects on Amount of Bare Soil

Increases in bare soil on the burn were pronounced only in the first year. Bare soil on the burned area increased from 32% before the fire to 67% in 1976 and was 50% in 1979. Within the small exclosures on the burn the percent bare soil in 1979 was 53 (Table 6). The increase in bare soil on unburned plots was (29-34%) from 1975 to 1976, rose to 55% in 1978 and was 48% in 1979. Changes from 1975 to 1976 on burned plots were almost directly attributable to fire. Changes, thereafter, were primarily grazing and climatic effects as cattle and wildlife concentrated on the study area and used the unburned plots almost as heavily as the adjacent burned tracts. Observed utilization on perennial grasses in 1977 and 1978 was 72% on burned plots and 67% on plots not burned. Low herbage yields in 1978 and 1979 resulted in more complete herbage removal than would have occurred otherwise

Discussion

Cattle, deer, and jackrabbits were attracted to the burns almost immediately. Essentially all prickly pear cactus from which spines were burned was consumed in a few weeks. Cattle were removed at the end of February 1976 but jackrabbits and deer continued to concentrate on the burns. Cattle were returned to the pasture 12 months later and remained from March 1 to October 31, 1977. They again sought out burned plots and by mid-June had consumed 70% of perennial grass herbage on the burned and 62% on adjacent unburned plots. Visual inspection of the study area after it was grazed March-October, 1980, showed that attractiveness of the burned areas for cattle was still strong 5 years after the fire. The burned areas were attractive initially because fire removed most of the accumulated low-value herbage and singed spines off cactus. After the first year, the attractiveness of the burned plots was maintained by heavy use that allowed no herbage older than 12 months to accumulate. Grazing pressure on the 4 0.8-ha burned plots in this study was probably greater than would occur on project burns of several hundred hectares.

Measurements made in 1979 to determine differences between burned and unburned areas indicated that the fire had reduced numbers of barrel cactus, pricklypear cactus, desert zinnia, tall threeawns, and black grama. Santa Rita threeawn, and Lehmann lovegrass increased following the fire. Attributes not affected, or only temporarily, included percent of bare soil, mesquite crown cover, mesquite height, and numbers of mesquite, burroweed,

Table 4. Species composition (%) by treatment of perennial grasses before treatment (1975) and in 1979 on check and burn plots which were grazed by cattle on schedule and on 6.4m² plots that were protected from grazing after the fire.

Species	Year 1975 Check	Year 1975 Burn	Year 1979 Check	Year 1979 Burn	Year 1979 Ungrazed Burn
Santa Rita threeawn	0.47	1.23	1.68	4.14	2.39
Tall threeawns	0.04	0.75	1.75	0.98	1.22
Black grama	1.86	0.34	3.65	0.09	8.15
Rothrock grama	64.40	77.38	16.20	50.22	25.86
Arizona cottontop	6.68	6.99	10.95	8.11	9.18
Lehmann lovegrass	17.61	3.01	56.42	30.93	52.33
Plains bristlegrass	8.39	9.25	7.88	4.72	0.61
Other perennial grasses	0.53	1.03	1.46	0.80	0.24
Total	99.98	99.98	99.99	99.99	99.98

Table 5. Perennial forb densities (No./m²) by treatment before burning (1975) and in 1976, 1978, 1979.

Species	Treatment 1940[1]	1975	Density 1975	1976	1978	1979	Average	1979[2]
Arizona evolvulus	None	None	0.82	0.46	0.57	0.04	0.77a	—
	MK	None	3.16	1.16	0.99	0.15	1.36b	—
	BK	Burn	0.80	0.44	0.40	0.15	0.45a	0.70
	MK, BK	Burn	1.42	0.45	0.83	0.66	0.84ab	0.37
	Average		1.55b[3]	0.50a	0.70ab	0.25a		0.84
Sida	None	None	0.26	0.10	0.21	0.02	0.15	—
	MK	None	0.30	0.20	0.03	0.02	0.14	—
	BK	Burn	0.20	0.11	0.02	0.04	0.09	0.03
	MK, BK	Burn	0.40	0.08	0.11	0.08	0.17	0.00
	Average		0.29b	0.12a	0.09a	0.04a		0.02
Silver nightshade	None	None	0.61	0.30a	0.23	0.51	0.41a	—
	MK	None	0.54	0.29a	0.42	0.60	0.46a	—
	BK	Burn	0.32	0.29a	0.31	0.28	0.30a	0.10
	MK, BK	Burn	0.88	1.12b	0.65	1.23	0.97b	0.00
	Average		0.59	0.50	0.40	0.66		0.05
Other forbs	None	None	0.05	0.01	0.19	0.02	0.07a	—
	MK	None	0.82	0.26	0.15	0.08	0.33ab	—
	BK	Burn	0.12	0.00	0.18	0.02	0.08a	0.84
	MK, BK	Burn	0.45	0.13	0.63	0.75	0.97b	2.17
	Average		0.36	0.10	0.29	0.22		1.50
Total forbs	None	None	1.74	0.87	1.20	0.59	1.10ab	—
	MK	None	4.82	1.91	1.59	0.85	2.29bc	—
	BK	Burn	1.44	0.84	0.91	0.49	0.92a	1.67
	MK, BK	Burn	3.15	1.78	2.22	2.72	2.47c	2.54
	Average		2.79b	1.35a	1.48a	1.16a		2.10

[1]1940 Treatments: MK = mesquite killed; BK = burroweed killed.
[2]Ungrazed caged plots were sampled only 1979.
[3]See footnote 3, Table 2.

cholla cactus, Arizona cottontop, plains bristlegrass, other perennial grasses, Arizona evolvulus, sida, and silverleaf nightshade.

These results suggest that effects of fall burning on perennial vegetation are generally short lived. Numbers of susceptible shrubs such as burroweed may be markedly reduced for a year or two and others may be topkilled but recovery, either from seed or by sprouting, can be expected to restore pre-burn populations in a few years. Perennial grasses that increased markedly after burning are species with strong potential for reseeding themselves. Two of the more palatable and longer lived species, Arizona cottontop and plains bristlegrass, were little affected by burning. Black grama is the grass most likely to be severely reduced. This susceptibility is due in part to poor reseeding potential as well as to its susceptibility to heavy grazing that commonly follows burning and reduces plant vigor, seed yield, and vegetative reproduction. Lehmann lovegrass was exceptional. Its density not only was not reduced by burning, but had increased sharply by 1978, 3 years after the burn.

Cactus is adversely affected by repeated burning. Burning makes all cactus species more attractive to cattle and the reproductive rate of most species is low.

Fall burning as applied in the study fit well with the grazing rest schedule of the Santa Rita Grazing System. There is no indication that grazing November-February immediately after the burn was severely detrimental to the common perennial grasses. This agrees with earlier results (Martin 1973) in which perennial grass densities were as great under year long grazing as on areas rested each year during the November-February dormant period.

This study does not fully answer the question posed in the introduction. It suggests that periodic burning could maintain a grassland aspect by repeatedly top-killing most of the small mesquites and killing some seedlings outright as Cable (1972) proposed but the rate of regrowth of mesquite in this study was so fast that burning every 5 to 6 years would be necessary to keep the mesquites from reaching reproductive maturity. Burning at such intervals would almost certainly prevent the development of dense stands of pricklypear, cholla, or barrel cactus. An unanswered question on burroweed is whether new plants on the burns were from seed that survived the fires or from seeds imported from adjacent unburned plots. If seeds survive burning, burroweed would not be permanently reduced by periodic fires even on large-scale burns, unless cool-season precipitation between burns was too low to produce new crops of seedlings. Concentrated grazing of the small plots by both cattle and wildlife undoubtedly affected the results in this study. Despite rest periods in the rotation, use was so heavy that at

Table 6. Bare soil (%) by treatment before burning (1975) and in 1976, 1978, and 1979.

Treatment 1940[1]	1975	Year 1975	1976	1978	1979	Average	1979[2]
None	None	38.5b[3]	40.7a	54.7	49.8	45.9ab	—
MK	None	20.5a	27.5a	56.2	45.9	37.5a	—
BK	Burn	35.4ab	60.1b	60.4	48.1	51.0ab	52.6
MK, BK	Burn	27.8a	73.3b	66.7	51.8	54.9b	52.6
Average		30.6a	50.4b	59.5b	48.9b		52.6

[1]1940 Treatments: MK = mesquite killed, BK = burroweed killed.
[2]Ungrazed caged plots were sampled only in 1979.
[3]See footnote 3, table 2.

no time since the 1975 fire has there been enough dry herbage to carry a fire. Heavy use of perennial grasses did not greatly reduce their density but it may have reduced their vigor and their ability to compete with shrubs thereby contributing to the rapid regrowth of mesquite and reestablishment of burroweed.

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