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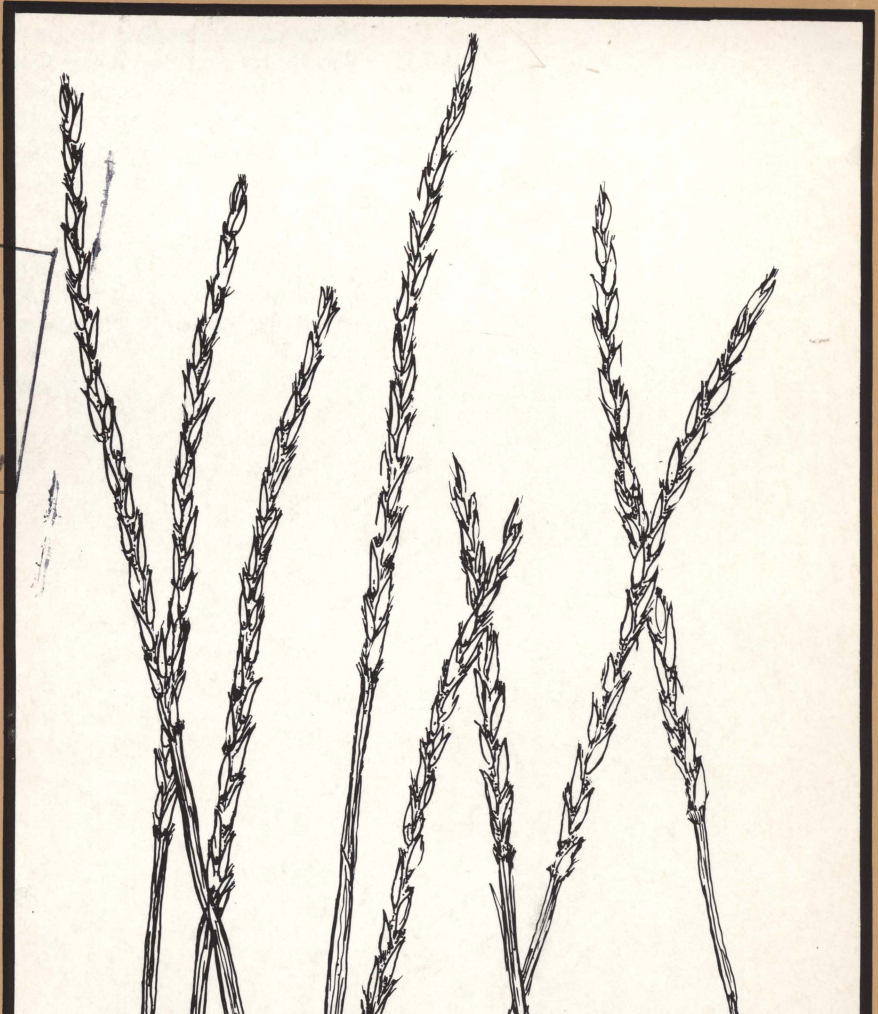
Response of Pan American Balsamscale, Soil, and Livestock to Prescribed Burning



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J. L. MUTZ, assistant research scientist
Texas Agricultural Experiment Station
(La Copita Research Area, Alice)

T. G. GREENE, graduate research assistant
Texas Agricultural Experiment Station
(Department of Range Science)

C. J. SCIFRES, Thomas M. O'Connor Professor
Texas Agricultural Experiment Station
(Department of Range Science)

B. H. KOERTH, research associate
Texas Agricultural Experiment Station
(La Copita Research Area, Alice)

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Summary

Prescribed burning in late winter (February) was evaluated from 1980 through 1983 near Cuero, Texas for removing rank vegetation, improving forage quality, and increasing use of Pan American balsamscale *(Elyonurus tripsacoides)* range by cattle. Burning increased Pan American balsamscale standing crops, compared to unburned rangeland, by fall of the first growing season. Average grass standing crop the growing season following burning in 2 successive years or in every other year was no different than following a single burn. However, burning for 2 or 3 consecutive years increased little bluestem and decreased Pan American balsamscale. Burning, whether a single burn or applied in 2 successive years, did not significantly influence soil water contents to 30 cm deep.

Generally, crude protein and digestible organic matter contents of Pan American balsamscale were increased for 5 to 8 weeks after burning, but did not differ thereafter from that of plants from unburned areas. Prescribed burning of Pan American balsamscale-dominated range had no effect on soil water insoluble nitrogen (WIN) contents for the first growing season, and there was an apparent increase in WIN contents during the second growing season after burning. Water insoluble nitrogen contents of the soils from burned and unburned areas did not differ by 3 years after burning. Water-soluble nitrogen content of the soil, representing primarily nitrates, increased in the spring after burning in winter but the differences were not detectable in subsequent growing seasons.

Calves, weaned from cows grazing burned pastures during the year of burning, weighed an average of 7 kg per head more than those from unburned areas. There was no difference in calf weights between treatments 1 year following burning. This response was attributed to increased quality of forage consumed by cows during lactation. Based on results of this research, burning for removal of rank growth and improved quality of Pan America balsamscale range at approximately 3-year intervals is suggested. Closer burning intervals may be warranted during a series of years with greater than average annual rainfall. A rotation burning program may be considered wherein a portion of the range is burned each year.

Response of Pan American Balsamscale, Soil, and Livestock to Prescribed Burning

J. L. Mutz, T. G. Greene, C. J. Scifres, and B. H. Koerth

Introduction

The Hochheim Prairie occupies approximately 120,000 to 160,000 hectares (ha) in parts of DeWitt, Lavaca, Gonzales, Goliad, and Victoria Counties.[1] Vegetation prior to settlement of the area was described as mid- to tallgrass prairie (Olmstead 1978). Much of the original vegetation has been altered either by excessive continuous livestock grazing or by cultivation. Most of the native grazing land is in relatively small tracts, and much of the cultivated acreage has been either abandoned or revegetated with introduced grasses such as coastal bermudagrass.[2] Little bluestem, Pan American balsamscale, knotroot bristlegrass, several species of *Panicum* and *Paspalum,* and a variety of forbs are common on well-managed prairies. However, little bluestem and other desirable grasses have been largely replaced by the less preferable Pan American balsamscale on areas subjected to heavy continuous grazing.

Pan American balsamscale is a native, warm season perennial bunchgrass which develops short rhizomes (Gould and Box 1965). It occurs only occasionally on well-managed rangeland of the Coastal Prairie, except on sandy and sandy loam sites where it may be locally abundant. Utilization of Pan American balsamscale by cattle is usually limited to a short period immediately following spring "greenup." As Pan American balsamscale matures, livestock preference shifts to other grasses and forbs.

Prescribed burning is an effective tool for improving forage quality, production, and utilization by livestock especially with grasses which are not preferred for grazing. For example, cattle graze regrowth of tobosagrass and gulf cordgrass following burning with greater relish than on adjacent unburned areas (Sharrow and Wright 1977b, Oefinger and Scifres 1977). The new growth contains more crude protein, phosphorus, and digestible energy than does unburned mature growth (McAtee et al. 1979).

The potential of prescribed burning for improving production and forage quality of Pan American balsamscale range had not been studied before. The extent to which increased forage quality and production following burning of rangeland may be translated into increased animal production has received relatively little attention (Anderson 1960, Hilmon and Hughes 1965, Kirk and Hodges 1970, McGinty et al. 1983), and no such estimates are available for Pan American balsamscale.

Little bluestem may increase in abundance following burning (Wright and Bailey 1982) and may dominate certain sites following burning of Coastal Prairie (Gordon and Scifres 1977). Since Pan American balsamscale occupies many sites previously dominated by little bluestem, prescribed burning may reestablish a little bluestem range.

As prescribed burning affects subsequent plant growth and development on a range site, it also may affect the demand for water and nutrients placed on the soil by postburn vegetative growth. Luxuriant regrowth in a warm environment will use nitrate as quickly as it is produced (Wright and Bailey 1982). Since the nitrogen content of rangeland soils may be low, the question arises as to potential effects of burning on soil nitrogen levels. Further, the probability of reducing soil nitrogen should increase as frequency of burning is increased, especially of a highly productive species such as Pan American balsamscale and in the long growing season of the Texas Coastal Prairie. Increased vegetal cover following burning may increase water availability requirements on burned, compared to unburned sites. Thus, burned sites tend to stress more quickly and completely during periods when soil water is limited.

We initiated research in 1980 to determine responses of vegetation, soils, and livestock to burning of Pan American balsamscale-dominated prairies. Specific objectives were to evaluate the effect of single and repeated burns in winter on:

1. Pan American balsamscale standing crops;
2. Relative proportion of Pan American balsamscale in the grass stands based on foliar cover;
3. Crude protein and digestible organic matter contents of Pan American balsamscale herbage at various times after burning;
4. Variation in soil water contents during the growing season;

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[1] Conversions from metric to English units are given in Appendix A.

[2] Scientific names of plants are given in Appendix B.

5. Soil nitrogen contents at various time intervals after burning; and
6. Influence on calf weaning weights.

Materials and Methods

Description of Study Site

Experiments were located on the Duderstadt Ranch approximately 9 kilometers (km) west of Cuero in DeWitt County, Texas. Soils of the study area are primarily Leming loamy fine sand and Sarnosa fine sandy loam on 0 to 5% slopes (USDA 1978). Soils are moderately well drained with slow-to-moderate runoff. According to Greene's (1983) analyses, soils of the study site are slightly acid (pH 6), contain 0.7 to 1.1% organic matter in the surface 8 centimeters (cm); and contain 83 to 97% sand to 30 cm deep.

Potential vegetation is true prairie dominated by seacoast bluestem in association with yellow Indiangrass, various *Paspalum* spp. and forbs. Pretreatment vegetation was dominated by Pan American balsamscale, generally having foliar cover of no less than 75% and usually 90% or greater (Greene 1983) with scattered seacoast bluestem, knotroot bristlegrass, Comb's paspalum, yellow Indiangrass, and common sandbur. Common forbs include Texas bullnettle, *Euphorbia* spp., sensitivebrier, Texas geranium, annual ragweed, and perennial ragweed.

Burn Installation and Experimental Design

Half of a 140-ha pasture was burned with a headfire on February 21, 1980 and the remaining half was burned on February 26, 1981. The half of the pasture burned in 1980 was burned again on February 23, 1982. An adjoining 140-ha pasture served as an unburned comparison. The pastures were part of a cow-calf operation stocked yearlong with one animal unit per 4 ha (AU/ha). Standing fine fuel and mulch loads were harvested from 50, 0.25 square meter (m^2) quadrats located randomly within each area on the day prior to burning. Immediately prior to ignition, fuel and mulch were collected from 10 to 25 randomly-located samples for determination of water content. At the same time, 10 soil cores (0 to 8- and 8 to 30-cm deep) were extracted for determination of water content.

A second experiment was superimposed on the half of the pasture which was burned on February 26, 1981. During late summer 1981, eight, 0.015-ha plots were established in a 35 × 50 m block on the burned area and on a similar but unburned site immediately adjacent to the burned area. Study sites were chosen based on similar soil, slope, and exposure and were fenced to exclude grazing by livestock. Four plots in each block were randomly selected and burned with headfires on February 23, 1982 which resulted in four treatments (unburned; burned in 1981; burned in 1982; and burned in 1981 and 1982) each with four replications. Immediately prior to burning, standing fuel was harvested to ground line and mulch was collected from five, 0.25m^2 sampling areas equidistantly spaced on a diagonal across each plot. At the same time, three soil samples at 0 to 8- and 8 to 15-cm deep and five standing fine fuel samples per plot were sealed in tins and their wet weights were recorded.

Two of the plots subjected to each of the burning treatments in 1982 were randomly selected for burning again in 1983. Thus, subplots not previously burned, burned in 1981, burned in 1982, or burned in 1981 and again in 1982 were burned on February 24, 1983. Fuel and soil samples were collected for determination of water content as described for the burns in 1982.

Fuel and soil samples for water content determinations were dried at 105°C in a forced-air oven for 72 hours (hr) and reweighed. Fuel load samples were weighed wet and then dried for 48 hr at 60°C before reweighing.

Weather variables recorded immediately prior to ignition and at burnout included wind direction, wind speed with a hand-held anemometer, air temperature, and relative humidity with a sling psychrometer. Asbestos cards supporting temperature-sensitive pellets (melting points ranging from 37°C to 650°C in 37°C increments) were placed at three to five randomly located points at 10 cm from ground line in each plot immediately prior to burning in 1980, 1981, and 1982. Fire temperatures during burns in 1983 were recorded at three locations each at ground line, and at 8 to 10 cm and 15 cm above ground line with a multipoint recorder. Variables describing fire behavior including rate of flame front movement, flame height, and smoke dispersal were recorded during the burns.

Data collected from the single burns in 1980 and 1981 were compared with those from similar, adjacent unburned portions of the pasture using least significant mean differences ($\alpha = 0.05$). Data from subsequent years' evaluations were subjected to two-way analysis of variance with year(s) of burning constituting treatment effects. When dates of data collection were included as variables, burning treatment was treated as subplot effects and date as mainplot effects in hierarchical analyses of variance. Mean differences were isolated by Student-Newman-Kuel's test ($\alpha = 0.05$) (Steel and Torrie 1980). Deviations from this general approach to data handling will be mentioned as applicable to specific variables.

Vegetation Measurements

Portable grazing exclosures were established after burning on each pasture-sized treatment (unburned, burned 1980, burned 1981, burned in 1980 and again in 1981) to facilitate evaluation of range forage production and disappearance. The terms "forage utilization" and "forage disappearance" are used interchangeably herein to indicate cumulative forage loss—the net effect of factors such as weathering, trampling, and consumption by wild animals and insects, in addition to forage consumed by livestock. Exclosures were constructed from 10-gauge welded wire with 15 × 15 cm openings. Each exclosure was approximately 1.5 m tall and 1 m in diameter. Five exclosures were placed along each of four, randomly selected lines in each treatment.

Herbaceous vegetation in 0.25 m^2 areas within each exclosure and a 2 m from each exclosure was harvested to a 2.5-cm stubble height on

April 30 and July 16, 1980; on April 30 and June 29, 1981; and on April 12 and May 26, 1982. Green herbage was separated into grasses and forbs then dried at 60°C for 48 hr and weighed. Differences in standing crops of green herbage from protected and grazed areas were considered estimates of disappearance for that sampling period. Exclosures were relocated 3 m from the original points along the permanent line after each sampling. On September 15, 1982 foliar cover of herbaceous vegetation was recorded from five, inclined 10-point frames within 1 m of each exclosure. Standing herbaceous crops were estimated to minimize disturbance in 10, 0.25m^2 quadrats placed randomly in each plot on April 2, and in 15 quadrats on May 14 and June 11, 1982 in the second experiment. Visual estimates of standing crops were corrected using a double-sampling technique wherein standing crop was estimated inside the plots; and, at every fifth sample, a similar area outside the plots was selected and standing crop harvested to ground line. Corrected visual estimates were calculated from $Y=mX+b$ where $X=$ uncorrected (visual estimate), $m=$slope of the regression line, and $b=Y$ intercept. Clipped forage was weighed in the field after separation into forbs and grasses. Forage samples for water-content measurements collected each hour were weighed fresh and reweighed after drying at 60°C for 48 hr. Standing crops on August 10 and November 4, 1982 and on May 7 and October 21, 1983 were measured by clipping vegetation to ground line in 10 randomly placed 0.25 m^2 quadrats per subplot. Herbage was separated into grasses and forbs before ovendrying and weighing. Mulch was collected from 20 quadrats on October 21, 1983 and dried as described for standing herbage. At the time of herbage harvests in October 1983, foliar contacts with 25 inclined, 10-point frames were recorded along a diagonal across each plot.

Five individual Pan American balsamscale plants were located on a diagonal across each plot in April 1982. Each plant was marked with a numbered, metal tag staked at the base of the plant. All tillers on each plant were counted on each sampling date. A tiller was defined as a living stem or whorl of leaves of any size originating from the base of the plant. Reproductive culms on tagged plants were counted on June 15 and November 3, 1982. Only culms bearing infloresences were counted, and branched culms were counted as one. The ratio of reproductive culm numbers to tiller numbers was calculated for each plant on each date.

Monitoring Soil Water and Nitrogen Contents

Samples of Pan American balsamscale were collected when forage standing crops were harvested during 1980 and 1981 for analysis of crude protein and digestible energy contents. Crude protein was determined using the Kjeldahl procedure for nitrogen determination (AOAC 1960), and digestible energy contents were determined as outlined by Tilley and Terry (1963).

Two samples of approximately 5 grams (g) dry weight of live Pan American balsamscale leaf blades were collected from each plot on each sampling date (April 2, May 14, June 11, August 10, and November 4) in 1982 for determination of crude protein content. Samples were dried at 105°C for 1 hr, and then at 60°C for 24 hr, after which they were ground in a Wiley mill to pass 1-millimeter (mm) mesh. Total nitrogen was determined using standard semimicro Kjeldahl techniques (AOAC 1960).

Three, 2 × 30 cm soil cores were collected on the April, May, August, and November sampling dates in 1982 from each plot for nitrogen determination. One core per plot was taken on June 11, 1982. Approximately 1 cm of soil was removed from the cores at depths of 1, 15, and 30 cm. These samples were immediately sealed in plastic bags, taken to the laboratory, and frozen. The samples were air-dried at room temperature to constant weight before analysis. Water soluble and water insoluble nitrogen fractions were separated by two distilled water washings and centrifugation. Each fraction was analyzed by modified Kjeldahl digestion (AOAC 1980) followed by colorimetric determination of ammonium ($NH_4{}^+$) concentration. Soil water contents at 0- to 8-, 8- to 15-, and 15- to 30-cm deep were determined gravimetrically from two sample cores for each plot on each sampling date. Rainfall was monitored with a rain gauge on the immediate study area. Data collected within dates were subjected to analysis of variance and means separated using Student-Newman-Kuel's test ($\alpha=0.05$) (Steel and Torrie 1980).

Cattle Responses

Cows on the study pastures were bred to calve in January. Calves were weighed when weaned at approximately 6 months of age (late July 1980). Twenty-five calves (approximately half of which were heifers) were weighed from each treatment, and the weights averaged without adjustment for sex. There was no difference in weaning percentage between pastures.

Results and Discussion

Burning Conditions and Fire Behavior

Pan American balsamscale stands produce relatively large amounts of fine fuel. For example, total fine fuel load (standing herbaceous crop plus mulch) was 8,852 kg/ha of which 52% (4,640 kg/ha) was standing material and the remainder was mulch when burns were installed in 1980 (Table 1). Water content of standing fine fuel was 22% and mulch water content was 32%. Soil water contents were 17 to 18% regardless of sampling depth to 30 cm.

Winds during the 1980 burn were steady at 6 to 10 km/hr from the south/southeast (Table 1). Relative humidity during the burn was 55%. The flame front moved across the area at approximately 70 m/min. Flame heights of 2 to 2.5 m were observed during the burn, and smoke dispersion was complete within 15 min after burnout.

Total fine fuel load on the area burned in 1981 was 9,720 kg/ha, of which 5,831 kg/ha was standing with an average water content of 18% (Table 1). Mulch accounted for 40% (3,889 kg/ha) of the fuel load and contained 60% water. Soil water contents during the 1981 burn were 14% in the 0- to 8-cm layer and 15% at 8- to 30-cm deep.

TABLE 1. FUEL AND ENVIRONMENTAL VARIABLES AT THE TIMES OF INSTALLING PRESCRIBED BURNING IN FEBRUARY 1980, 1981, 1982, AND 1983 TO PAN AMERICAN BALSAMSCALE PASTURES NEAR CUERO, TEXAS

	Year(s) of burning							
Variable	1980	1981	1982	1982 (Burned 1981)	1983	1983 (Burned 1981)	1983 (Burned 1982)	1983 (Burned 1981, 1982)
Standing fine fuel								
Load (kg/ha)	4,640	5,831	3,632	3,142	3,983	4,207	3,100	2,460
Water Content (%)	22	18	10	12	14	13	13	13
Mulch								
Load (kg/ha)	4,212	3,889	2,950	1,236	1,937	1,541	1,200	305
Water content (%)	32	60	49	—	—	—	—	—
Soil water (%)								
0-8 cm	17	14	8	17	7	11	13	14
8-30 cm	18	15	7	19	6	13	15	16
Weather variables								
Air temperature (°C)	22	26	22	27	24	27	24	25
Relative humidity (%)	55	80	44	64	53	54	61	61
Wind speed (km/hr)	6-10	6-12	11	8-16	8-15	8-11	8-11	2-5
Origin	S./SE.	S./SE.	S./SE.	SE.	SW.	SW.	SW.	SW.
Maximum fire temperature (°C)								
Ground line	—	—	—	—	413	437	—	132
8-10 cm	600	430	560	540	599	504	—	427
15 cm	—	—	—	—	624	527	—	488

Wind speeds ranged from 6 to 12 km/hr during the 1981 burn (Table 1). Relative humidity at time of ignition was 80%. Rate of fire front movement was estimated at 50 m/min, and flame heights varied from 0.8 to 2.5 m.

Standing fine fuel loads in February 1982 were fairly uniform ranging from 3,142 kg/ha on areas which had been burned in 1981 to 3,632 kg/ha on plots burned in 1982 only (Table 1). Difference in standing fine fuel load between the area not previously burned and plots burned in 1982 after burning in 1981 were not significant ($\alpha = 0.05$). However, reduction in mulch load by burning the previous year accounted for the difference in total fine fuel, 4,378 kg/ha compared to 6,582 kg/ha on areas burned only in 1982. Standing fine fuel water content at the time of burning varied from 10 to 12% (ovendry weight basis) with slightly greater water content where the area had been burned the previous year.

Relative humidity ranged from 44 to 64% during burns in 1982, and wind was from the southeast at 8 to 16 km/hr (Table 1). Soil water contents varied from 14 to 17% in the surface 8 cm and from 15 to 19% at 8 to 30 cm deep. Air temperatures during the 1982 burns varied from 22 to 27°C, and flame temperatures at 10 cm above ground line ranged from 430 to 540°C. The fires moved at an average of 105 m/min and blackened 95% or more of the burned areas.

Standing fine fuel loads during burns in the winter 1983 varied with frequency of previous burnings. Standing fine fuel loads on plots burned for the first time in 1983 and those which had been burned two seasons previously (1981) were not different, with averages varying from 3,983 to 4,207 kg/ha (Table 1). Total fuel loads (standing crop + mulch) were similar between the two treatments, averaging from 5,750 to 5,900 kg/ha. In contrast, plots which had been burned the previous year (1982) supported 4,300 kg/ha of fine fuel of which 3,100 kg/ha was standing. The least amount of fine fuel was available for burning in 1983 on plots which had been burned previously for 2 consecutive years. Only 305 kg/ha of mulch occurred on plots burned in 1981 and in 1982, and standing fine fuel averaged about 2,500 kg/ha.

Lowest average maximum fire temperatures (132°C) occurred near ground line on plots burned for the third consecutive year. Although relative humidity was somewhat higher and wind speeds were lower when the third burns were installed, compared to installation of other treatments, reduced fire temperatures at the ground surface were attributed primarily to the reduced fine fuel load on plots burned repeatedly.

Suggested Fire Plan

The "Tallgrass Fire Plan" (Wright and Bailey 1982) was employed in this research and was effective for prescribed burning of Pan American balsamscale. However, we observed that Pan American balsamscale, although a relatively large and coarse bunchgrass, burned in an extremely flashy manner. Often the stout culms burned through at the base, detached and the firebrands were moved with the wind as far as 50 m. For this reason, it is our opinion that fire-

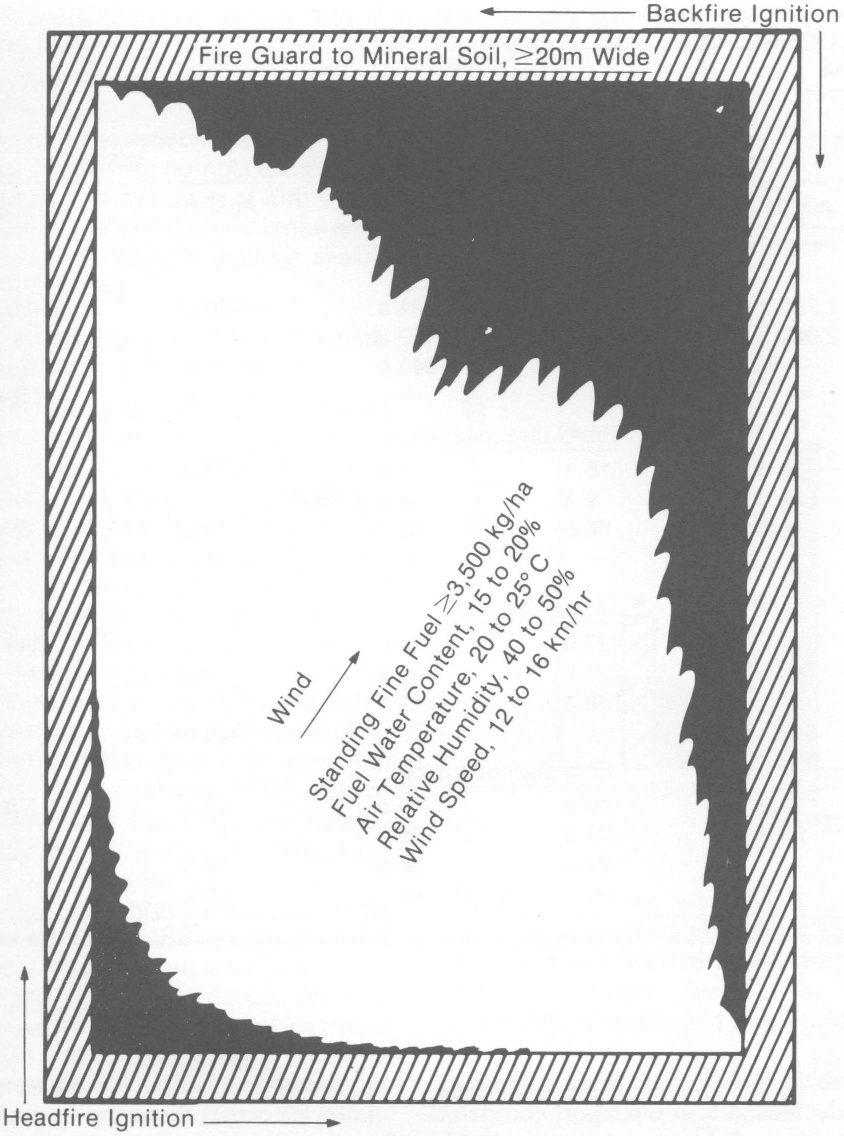


Figure 1. Example of firing plan used successfully for prescribed burning of Pan American balsamscale range near Cuero, Texas.

breaks (fireguards to mineral soil plus backfired area) should be at least 150 m wide before the headfire is ignited. This is especially important when fine fuel water contents are low (less than 12% in our study), standing fine fuel exceeds 4,000 kg/ha, and wind speed is greater than 16 km/hr. Burning Pan American balsamscale to uniformly remove rank, mature growth was effectively accomplished when the standing fine fuel load averaged 3,500 kg/ha, fine fuel water content was 18%, air temperature was 20 to 25°C, relative humidity was 40 to 50%, and wind speed was 12 to 16 km/hr (Fig. 1). Strip headfiring may be used to increase the rate of installation of the backfired areas. However, the strips usually should be fired at intervals no wider than 2 to 3 m and only after the backfire has blackened at least 30 m from plowed or disced fireguards.

Herbaceous Standing Crops and Utilization: Pasture-scale Burns

Grasses. On April 30, 1980 standing grass crop on the half of the pasture burned in February 1980 averaged 1,126 kg/ha, of which 66% was utilized (Table 2). There was little difference in amount of standing crop between burned and unburned halves of the pasture. However, standing crop on the burned half of the pasture was composed entirely of new growth whereas herbage on the unburned portion included culms and leaves from the previous year. Consequently, only 29% of the standing crop was utilized on the unburned half of the pasture (data not shown). Standing crop averaged 1,750 kg/ha on the adjacent unburned pasture, of which 51% was utilized.

Standing crop of grasses on July 16, 1980 was greater on the treated half of the burned pasture than on the unburned pasture (Table 2). Disappearance of grasses in midsummer from the unburned pasture averaged only 20%. This reduction, compared to the level of herbage removal in spring, was attributed to the increased proportion of Pan American balsamscale topgrowth as culms which reduced its preference to the cattle. In contrast, nearly 60% of the grass herbage produced on burned areas had been removed by mid-July.

The half of the pasture not burned in 1980 was the burned half in 1981. Grass standing crop on the pasture burned in February 1981 averaged 1,135 kg/ha on April 30, 1981 compared to 884 kg/ha on the unburned pasture (Table 2). Cattle concentrated on the burned portion of the pasture, removing 66% of the standing crop compared to only 9% removed from the half of the pasture burned in 1980 and 15% disappearance from the unburned pasture. There was no detectable disappearance of grasses from the unburned pasture during April 30 to June 29, 1981. However, herbage removal from the half of the pasture burned the previous February averaged 63%, about the same as after burning in 1980. Also, 36% of the herbage produced from April 30 to June 29, 1981 was grazed from the half of the pasture burned in February 1980.

Disappearance into the second growing season after burning was also increased in the 1982 growing season following burning in 1981 (Table 2). There were no differences in standing crops among areas never burned, burned in 1981, or burned in 1980 and again in 1982 based on sampling in mid-April or late May. As

TABLE 2. STANDING CROPS (KG/HA) AND DISAPPEARANCE (%) OF GRASSES AND FORBS AT VARIOUS TIMES AFTER BURNING PAN AMERICAN BALSAMSCALE-DOMINATED RANGELAND IN FEBRUARY OF 1980, 1981 OR 1980, AND AGAIN IN 1982 NEAR CUERO, TEXAS

	Year of evaluation[1]					
	1980		1981		1982	
Year(s) burned	April 30	July 16	April 30	June 29	April 12	May 26
			Grass standing crop			
None	1,750 a	1,786 a	884 a	2,404 a	800 a	2,480 a
1980	1,126 a	2,900 b	1,029 a	2,529 ab	—	—
1981	—	—	1,135 a	3,240 b	1,080 a	2,324 a
1980 & 1982	—	—	—	—	1,160 a	2,280 a
			Grass disappearance			
None	51 a	20 a	15 a	0 a	33 a	0 a
1980	66 a	58 b	9 a	36 b	—	—
1981	—	—	66 b	63 c	48 ab	38 b
1980 & 1982	—	—	—	—	54 b	54 c
			Forb standing crop			
None	216 b	360 b	427 c	246 a	907 b	543 b
1980	111 a	152 a	300 b	333 a	—	—
1981	—	—	132 a	444 b	317 a	445 b
1980 & 1982	—	—	—	—	339 a	194 a
			Forb disappearance			
None	68 a	79 a	46 a	0 a	56 c	70 c
1980	38 a	34 a	24 a	63 b	—	—
1981	—	—	24 a	36 b	19 b	35 b
1980 & 1982	—	—	—	—	0 a	5 a

[1] Means within a herbage variable and data followed by the same letter are not significantly different ($\alpha = 0.05$) according to least significant difference (two means compared) or Student-Newman-Keul's test (when three means compared).

with evaluations in previous years, grass disappearance from the unburned pasture was greatest in early spring and decreased sharply as summer approached. During the grazing period April 12 to May 26, 1982, the greatest amount of herbage was removed from the area burned the previous winter (the half of the pasture originally burned during winter 1980). Grass disappearance averaged 38% from the portion of the pasture burned during winter 1981. Cattle grazing during 1981 and 1982 had equal access to freshly burned areas and those burned the year previously.

Forbs. Forb standing crops in April and July 1980 following burning the previous February were less than on unburned areas (Table 2). This was attributed to fire damage to cool season forbs. Although forb standing crops were highly variable, our data indicate that the reduction in availability on burned areas apparently decreased forb utilization compared to the unburned pasture.

Forb standing crops in April 1981 and 1982 were also reduced on burned compared to unburned areas (Table 2). The reduction in forb standing crops during spring 1981 was most apparent on areas burned the previous winter, but there was no difference in standing crops in April 1982 whether the areas had been burned during the previous winter or during the preceding year. In 2 of 3 years of study (1980 and 1982) forb crops were depressed into late spring-summer following winter burning. Forb standing crops on burned areas exceeded those on the unburned pasture in 1981.

Utilization of forbs was greater from burned than from unburned pastures with the exception of evaluations in late June 1981 (Table 2). The exception occurred during the period when forb standing crops on burned areas exceeded those on unburned areas. Reduced disappearance of forbs from burned areas was attributed partially to their reduced availability. The apparent utilization difference was also attributed to greater grazing use of grasses (i.e., less demand for forbs) from burned compared to unburned areas.

Primary forbs (including members of the Liliaceae) on the study area were annual ragweed, Texas geranium, winecup, plantain, crow poison, Karne's sensitivebrier, blue-eyegrass, scarlet globemallow, camphorweed, spotted beebalm, prairie flax, yellow woodsorrel, cutleaf eveningprimrose, sawtooth fogfruit, smallflower vetch, Texas ironweed, Texas bluebonnet, upright prairie coneflower, prairie peppergrass, Texas paintbrush, frostweed, Englemann daisy, roughstem resinweed, Texas bullnettle, horsetail conyza, and snow-on-the-prairie. It appeared that relatively unpalatable forbs, especially ragweeds, horsetail conyza, spotted beebalm and Texas ironweed were most abundant during the growing season following burning. There were no noticeable differences in composition of forb stands between burned and unburned areas during the second growing season after burning.

Vegetation and Soil Water Content Responses to Multiple Burns

Standing grass crop on burned plots in the second experiment (the 0.15 ha subplots subjected to multiple burns) equaled or exceeded ($\alpha = 0.05$) mean standing crops on unburned plots during the 1982 growing season (Fig. 2). Standing crop increases attributable to burning during 1982 were most pronounced in May and August. Standing crop on plots burned only in 1982 exceeded that of unburned areas at all sampling dates except in April. Plots burned in 1981 and again in 1982 yielded greater grass standing crops than did unburned areas at all sampling dates except November.

Standing grass crops on plots burned only in 1981 were somewhat more variable than with other treatments, and did not exceed those of unburned plots in June or November 1982 (Fig. 2). This variation could not be attributed to site differences since treatment areas were in close proximity, were selected for uniformity of slope exposure, and did not differ greatly in soil texture (90 to 97% sand in the surface 8 cm), organic matter (0.7 to 1.1%) or pH (6.0).

Although soil water is usually reduced on burned grassland because of increased water-use demand of postburn plant growth (Wright and Bailey 1982), soil water contents during the 1982 growing season did not differ ($\alpha = 0.05$) from that of unburned plots following the single burn of Pan American balsamscale range in winter 1982 (Fig. 3). Moreover, at some sampling dates during the 1982 growing season (primarily in spring and fall), water contents of soils from plots burned in 1981 or in 1981 and again in 1982 exceeded those of unburned plots.

Rainfall from time of burning in February 1982 until mid-May totaled 17.8 cm of which 10.8 cm occurred during April 2 to May 14. This probably accounted for relatively high soil water contents in May (Fig. 3). Rainfall totaled 7.5 cm from May 14 to August 10, 1982. The low amount of summer rainfall coupled with progressive topgrowth development of Pan American balsamscale (Fig. 2) would account for the general reductions in soil water contents during midsummer (Fig. 3). Soil-water content increased again in November, reflecting the influence of 14 cm of precipitation which occurred during August 11 to November 3.

Although total rainfall (49.3 cm) for the 1982 growing season (March-November) was only 72% of the long-term average, grass standing crops and soil-water contents on burned areas were not negatively influenced. We speculate that the increased water-use demand placed on the soil system by postburn vegetative growth was compensated by reduction of mulch cover on burned plots. Although mulch cover generally favors water infiltration and percolation (Wright and Bailey 1982), such positive effects were apparently offset by water interception and retention by heavy mulch accumulation (2,950 kg/ha in late winter 1982) on unburned plots.

By late October 1983, average ovendry mulch load on plots burned in February 1981 (2,222 kg/ha) was not different ($\alpha = 0.05$) from that of unburned plots (2,300 kg/ha) (Table 3). Mulch loads on plots burned in February 1982 (1,352 kg/ha) and on those burned in 1981 and again in 1982 (1,253 kg/ha) were significantly less than on unburned plots. Mulch loads on plots burned in February

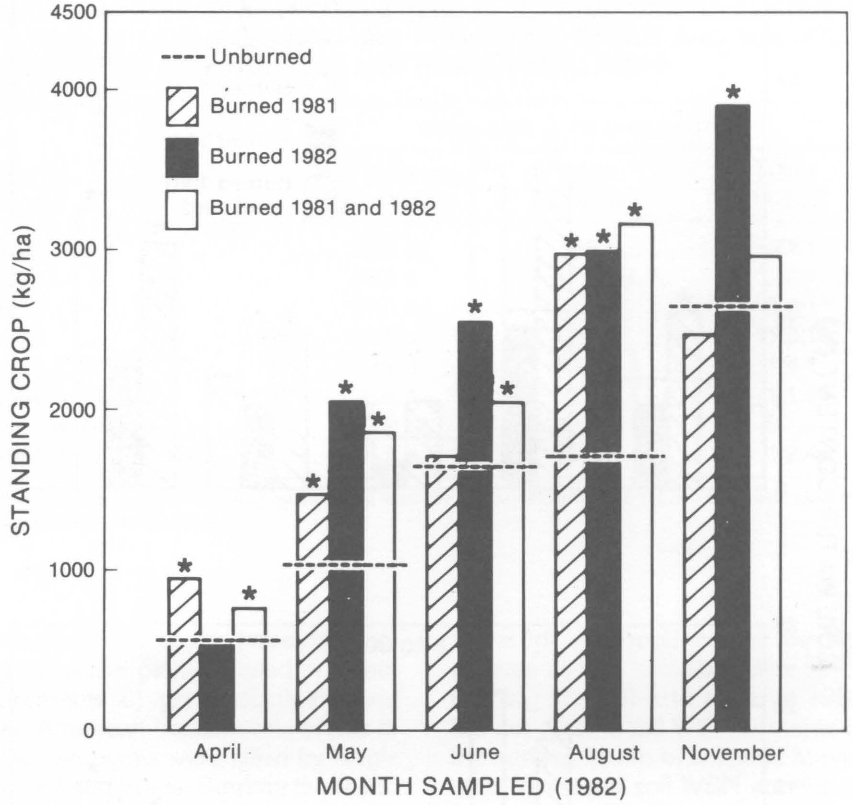


Figure 2. Grass standing crop at selected times during the 1982 growing season on unburned Pan American balsamscale communities and on areas burned in February 1981, 1982, and 1981 and again in 1982 near Cuero, Texas. Asterisks indicate means different ($\alpha = 0.05$) from that of unburned plots within a sampling date.

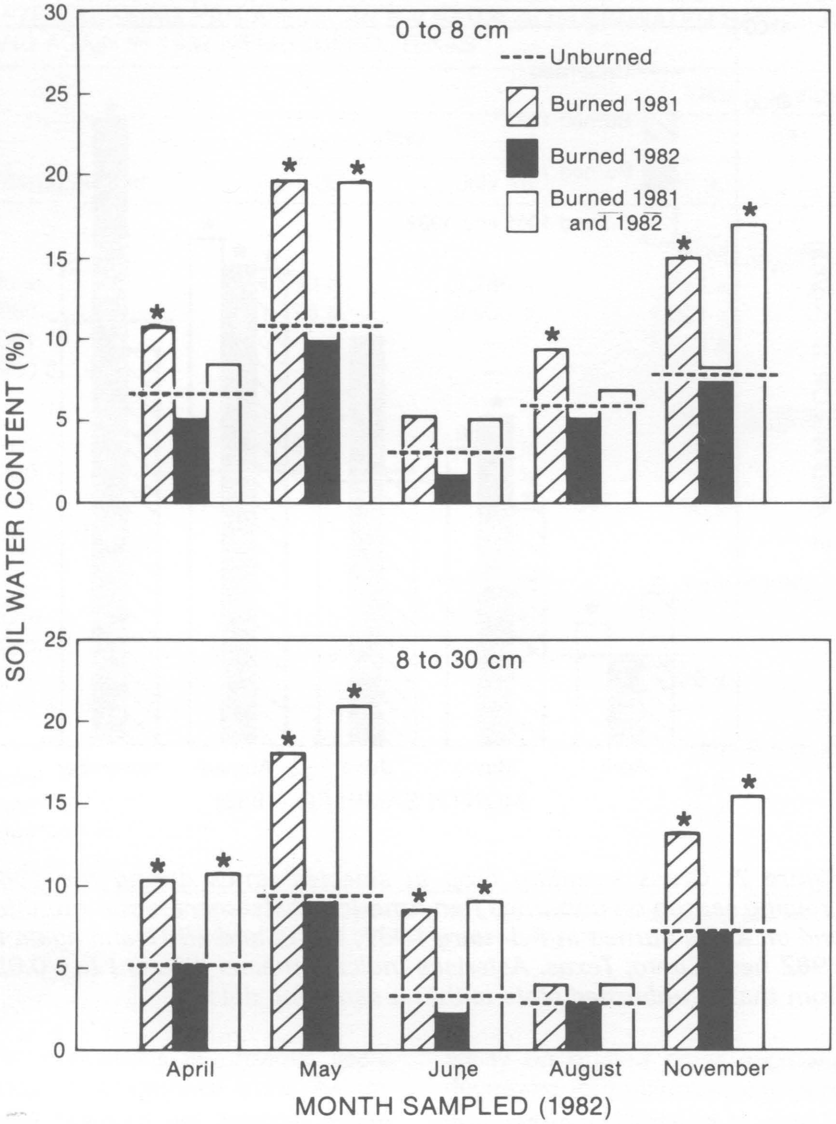


Figure 3. Soil-water contents at 0-8 and 8-30 cm deep at selected times during the 1982 growing season on unburned Pan American balsamscale communities and on areas burned in February 1981, 1982, and 1981 and again in 1982 near Cuero, Texas. Asterisks indicate means different ($\alpha = 0.05$) from that of unburned plots within a sampling date.

1983, whether or not they were burned in previous years, ranged from 20 to 100 kg/ha. However, these data indicate that mulch replacement rates are adequate to allow prescribed burning of the Pan American balsamscale community at 2- to 3-year intervals. For example, the mulch load on unburned plots averaged 2,300 kg/ha in October 1983. Mulch loads on plots burned in February 1982 averaged 1,352 kg/ha, roughly 60% of that on unburned plots. These data indicate that mulch replacement rates approximate 25 to 33% per year.

Grass standing crops in spring 1983 were reduced on plots burned the previous winter, regardless of burning frequency (Table 3). However, grass standing crops were equivalent to, or greater than, those on unburned areas by October 1983 regardless of year or frequency of burning. Forb standing crops in May 1983 were reduced on all burned plots, except those burned only in February 1982. Reduction of forb standing crops on plots burned in 1981 was attributed to random chance in sampling since forb standing crops were reduced in fall 1983 only on those plots burned the previous winter.

Grass Stand Composition as Influenced by Burning

Data recovered during late October 1983 from small plots were used to evaluate the potential role of burning in shifting botanical composition of Pan American balsamscale stands. That this experiment had been protected from grazing since midsummer 1981 is relevant to interpreting the data.

TABLE 3. GRASS AND FORB STANDING CROPS (KG/HA) IN SPRING AND FALL AND MULCH WEIGHTS (KG/HA) IN FALL 1983 AFTER BURNING IN THE WINTER AT VARIOUS FREQUENCIES, 1981-1983

	Standing crops[1]				
	Grasses		Forbs		Mulch
Year(s) burned	May 7	Oct. 21	May 7	Oct. 21	Oct. 21
Unburned	393 b	3937 a	200 b	827 b	2300 c
1981	688 c	4394 a	44 a	866 b	2222 c
1982	325 ab	3466 a	262 c	820 b	1352 b
1983	201 a	5438 b	85 a	248 a	41 a
1981-1982	1000 d	3690 a	76 a	955 b	1253 b
1981-1983	169 a	4784 ab	23 a	112 a	20 a
1982-1983	225 a	4756 ab	21 a	249 a	20 a
1981-1982-1983	181 a	4146 ab	20 a	60 a	99 a

[1] Means within a column followed by the same letter are not significantly different ($\alpha = 0.05$) according to Student-Newman-Keul's test.

TABLE 4. PROPORTION OF FOLIAR COVER (%) CONTRIBUTED BY PAN AMERICAN BALSAMSCALE AND LITTLE BLUESTEM, AND THEIR COVER RATIOS, IN LATE OCTOBER 1983 FOLLOWING SINGLE AND MULTIPLE BURNS FROM 1981 THROUGH 1983 NEAR CUERO, TEXAS

	Proportion of foliar cover (%)[1]		
Year(s) burned	Pan American balsamscale	Little bluestem	Ratio PAB:LB
None	73.0 cd	2.5 a	29.2:1
1981	45.3 b	14.2 ab	3.2:1
1982	60.5 bc	2.0 a	30.3:1
1983	86.8 a	2.1 a	41.3:1
1981 & 1982	12.8 a	53.0 c	1:4.1
1981 & 1983	26.8 a	51.4 c	1:1.9
1982 & 1983	62.9 bc	20.3 b	3.1:1
1981 & 1982 & 1983	26.6 a	58.2 c	1:2.4

[1] Means within a column followed by the same letter are not significantly different ($\alpha = 0.05$) according to Student-Newman-Keul's test.

Botanical composition of grass stands on unburned plots were represenatative of the entire study pasture at the onset of the research. Grass stands were dominated by Pan American balsamscale (relative foliar cover averaged 73% with only 2.5% of the grass cover attributed to little bluestem (Table 4). With the exception of plots burned in 1981, a single burning did not alter the ratio of Pan American balsamscale to little bluestem. This ratio ranged from 30 to 40 times more cover provided by Pan American balsamscale than by little bluestem.

Burning twice, in 1981 and again in 1982 or in 1981 and 1983, greatly increased the proportion of little bluestem to Pan American balsamscale cover (Table 4). However, two consecutive burns (1982 and 1983) did not change the relative foliar cover of Pan American balsamscale or its ratio to the cover of little bluestem.

Burning in 3 consecutive years (1981-1982-1983) had no more effect on the ratio of Pan American balsamscale to little bluestem than did two consecutive burns. These data provide evidence that prescribed burning may reduce the proportion of Pan American balsamscale in the grass stands since absolute foliar cover varied little (33 to 43%) among plots. Other grasses which appeared to increase in foliar cover on burned plots included thin paspalum, brownseed paspalum, knotroot bristlegrass, Texas wintergrass, ozarkgrass, and hooded windmillgrass. In the second spring after burning and with no grazing, species such as Texas bromegrass, rescuegrass, canarygrass, and 6-weeks fescue were more apparent than on unburned plots.

Based on evaluations of the large-scale burns on September 15, 1982, ratios of Pan American balsamscale to little bluestem foliar cover were: unburned, 11.3:1; burned the winters of 1980 and 1982, 2.3:1; and burned in 1981 only, 1.3:1. These data, collected from pastures which were grazed, also indicate that prescribed burning increased the proportion of little bluestem in Pan American balsamscale stands.

It is not clear from these data whether burning increases Pan American balsamscale mortality rate or simply reduces size (area covered) by individual plants. Based on measurements of permanently-marked Pan American balsamscale plants in 1982 no plants were killed by single or repeated burns. Burning tended to increase tiller production early in the growing season and then decrease it, compared to unburned plants, late in the growing season. These data also suggest that burning shifted the proportion of vegetative to reproductive tillers in June 1982 varied from two to four per Pan American balsamscale plant if plots were not burned the previous winter (i.e., burned in 1980 or 1981) or had never been burned. In comparison, plants from plots burned in 1982, whether or not they were also burned in 1980 or 1981, contained 11 to 22 reproductive tillers. In general, however, there were no differences in average number of reproductive tillers (usually 13 to 20 per plant) by late November.

Soil Nitrogen Responses to Burning

Prescribed burning of Pan American balsamscale stands, regardless of year, had negligible effects on water-soluble nitrogen (WSN) content of the soils based on sampling during the 1982 growing season (Fig. 4). Soil WSN content (representing primarily nitrates) was significantly decreased ($\alpha = 0.05$) in the surface cm and at 15 cm deep only during November, and only where burns were applied in 1982. There was no apparent explanation for the decreases at this sampling date since burning in 1981 and again in 1982 did not reduce soil WSN contents in the surface 15 cm of soil, and apparently increased soil WSN content at 30 cm deep. Further, WSN contents generally were higher in soils of burned plots during April and August. Thus, these data give no basis for concluding that increased Pan American balsamscale vegetative growth following burning will result in a concommitant decrease in soil WSN content.

Soil water-insoluble nitrogen (WIN) contents, monitored during the 1982 growing season, apparently varied with plot location rather than with burning treatment. For example, excepting the first sampling date, soil from plots burned in 1981 (whether or not they were burned again in 1982) invariably contained greater amounts of WIN than did unburned soils or those burned in 1982 only (Fig. 5). Moreover, soils from unburned plots and from those burned in 1982 contained the same amounts of WIN. These generalizations occurred regardless of soil depth. Sharrow and Wright (1977a) emphasized that variation in site may mask influence of burning treatment on soil nitrogen concentrations. Our data also indicate, based on comparison of soil WIN contents of plots burned in 1982 with those from unburned areas (Fig. 5), as well as comparison

Figure 4. Crude protein content of Pan American balsamscale leaves sampled at various times in 1982 from plants in unburned plots and those in plots burned in February 1981, 1982, and 1981 and again in 1982 near Cuero, Texas. Asterisks indicate means different (α = 0.05) from that of unburned plots within a sampling date.

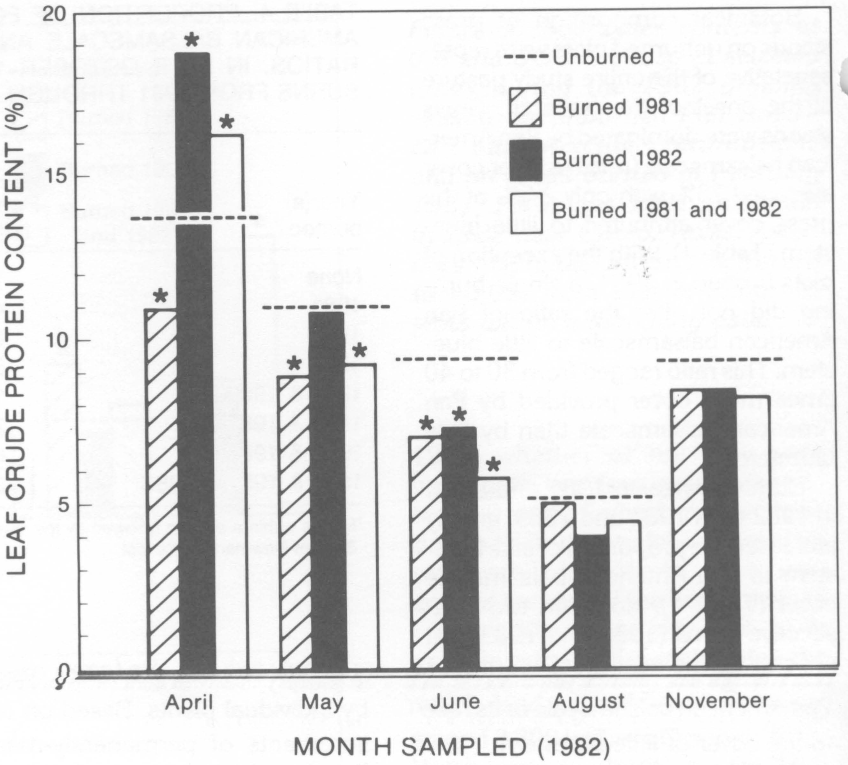
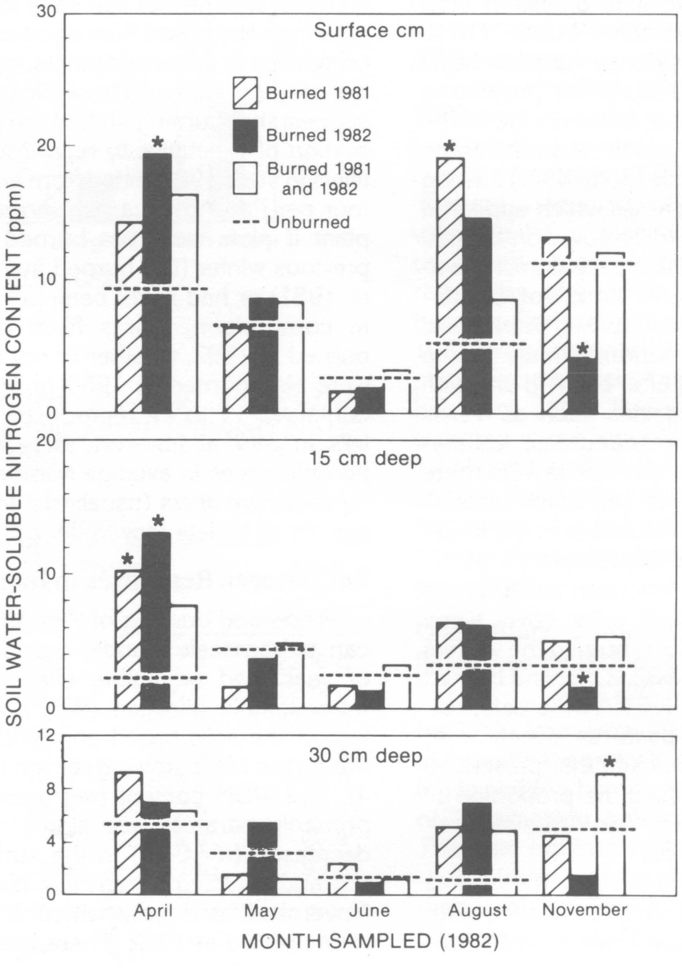


Figure 5. Soil water-soluble nitrogen contents at three depths during selected dates of the 1982 growing season from unburned Pan American balsamscale stands and from areas burned in 1981, 1982, and 1981 and again in 1982 near Cuero, Texas. Asterisks indicate means different (α = 0.05) from that of unburned plots within a sampling date.



of soil WSN contents (Fig. 4), that the single burn did not negatively influence soil nitrogen contents during the subsequent growing season.

Herbage Crude Protein and Digestible Organic Matter Contents

Crude protein contents of Pan American balsamscale leaves at 8 to 9 weeks following burning in 1980 averaged 14.6% compared to 9.6% on the unburned portion of the pasture. There was no difference in crude protein content of Pan American balsamscale leaves at 21 weeks after pasture-scale burns in 1980.

Patterns in leaf crude protein contents based on intensive sampling in 1982 yielded results similar to those reported for 1980. Leaf crude protein content of Pan American balsamscale from burned plots was greater than that of plants from unburned plots only in April 1982 and only where burns had been installed the previous February (Fig. 6). Leaf crude protein contents of plants from plots burned in 1981 were significantly less ($\alpha = 0.05$) than those of plants from unburned areas through June 1982. In this single case, there was an early summer (May-June) depression in leaf crude protein contents of plants from burned areas, compared to those from unburned plots. However, leaf crude protein contents did not differ among treatments in August (Fig. 6) during the time of uniformly low soil-water contents (Fig. 3).

Digestible organic matter content of leaves from burns in 1980 averaged 2,450 kilocalories (kcal)/kg at 8 to 9 weeks following burning, while leaves from unburned plots contained 2,050 kcal/kg of digestible organic matter. There were no differences in digestible organic matter contents of Pan American balsamscale leaves from burned and unburned pastures after 21 weeks.

Calf Weaning Weights

The effects of prescribed burning Pan American balsamscale during winter 1980 appeared to be relatively short term. Based on this research, the most important influence appears to be providing cows with a higher level of nutrition during lactation. Average weaning weight of

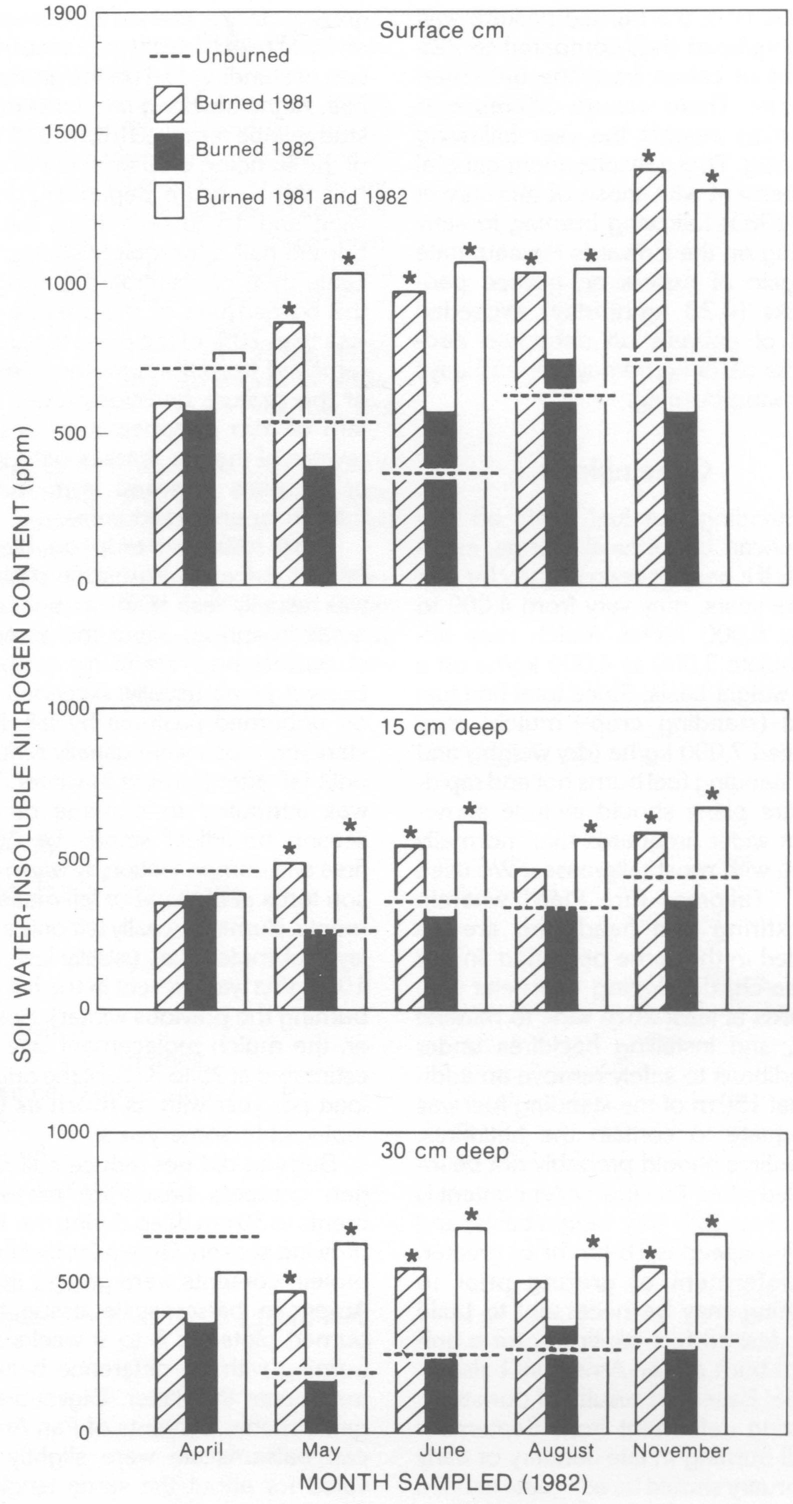


Figure 6. Soil water-insoluble nitrogen contents at three depths during selected dates of the 1982 growing season from unburned Pan American balsamscale stands and from areas burned in 1981, 1982, and 1981 and again in 1982 near Cuero, Texas. Asterisks indicate means different ($\alpha = 0.05$) from that of unburned plots within a sampling date.

calves from the burned pasture was 232 kg/head (hd) compared to 225 kg/hd of calves from the unburned pasture. There was no difference in weaning weights the year following burning. These results are in general agreement with those of McGinty et al. (1983) following burning in early spring on the Edwards Plateau. Rate of gain of heifers on burned paddocks (0.28 kg/hd/day) exceeded that of animals on unburned paddocks (0.05 kg/hd/day) for 155 days following burning.

Conclusions

Standing fine fuel loads on Pan American balsamscale range, especially if it has not been burned for 3 or more years, may vary from 4,000 to near 6,000 kg/ha. Mulch may accumulate 3,000 to 4,000 kg/ha on a dry-weight basis. Since total fine fuel load (standing crop + mulch) may exceed 7,000 kg/ha (dry weight) and the standing fuel burns hot and rapidly, fire plans should include somewhat wider fireguards than normally used with most tallgrasses. We used the "Tallgrass Fire Plan" wherein backfiring and headfiring are installed in the same operation. In our research, developing perimeter fireguards at least 20 m wide to mineral soil, and installing backfires under conditions to safely remove an additional 150 m of the standing fuel was adequate to contain the headfires. Headfires should probably not be installed when fine fuel water content is less than 15% (dry weight basis) and if wind speed is 16 km/hr or greater.

Deferment of grazing prior to burning may be necessary to build the desired fuel continuity for a uniform burn of Pan American balsamscale. Based on results of our study, grazing deferment from September until burning in late January or early February should be adequate to build the necessary fuel load and continuity. Such deferment allows Pan American balsamscale herbage to accumulate in response to fall rains.

Standing fine fuel loads on our experimental area were such that deferment of grazing prior to burning was not necessary. We burned one-half of the pasture in alternating years. Cattle largely concentrated grazing on the burned half in spring and into fall which allowed accumulation of standing fuel on the unburned half. At the stocking rate used in this study, cattle removed from 50 to 70% of the standing crop from the burned half of the pasture, depending on the year; and 15 to 60% from the unburned half during early spring. The cattle then concentrated grazing on the burned half of the pasture with less than 20% of the grass topgrowth removed from the unburned portion of the pasture by midsummer. Pattern of forb disappearance was the reverse of that for grasses with greater amounts removed from burned than from unburned areas.

Grass standing crop on burned Pan American balsamscale pastures was usually less than on unburned areas in spring, about the same by summer, and standing crop on burned areas usually exceeded that on unburned pastures by fall. Forb standing crops were usually reduced until fall after burning in winter. This was attributed to damage of cool season broadleaf stands by winter fires and compensation by warm season forbs at the time of fall measurements. Burning usually left only a thin layer of mulch (i.e., usually less than 100 kg/ha was present in the fall after burning the previous winter). However, the mulch replacement rate was estimated at 25 to 33% of the original load per year with as much as 60% replaced in some years.

Burning did not reduce soil nitrogen contents based on measurements to 30 cm deep during the 1982 growing season. Generally, leaf crude protein contents were greater in Pan American balsamscale tissue from burned plots for 8 to 9 weeks after burning with no difference between treatments thereafter. Digestible organic matter contents of Pan American balsamscale were slightly elevated for about the same length of time following winter burns. However, short-term increases in forage quality following burning were translated into an average increased weaning weight of calves of 7 kg/hd.

Our data indicate that burning in 2 or 3 consecutive years decreases the proportion of Pan American balsamscale and increases the amount of little bluestem in the grass stands. Although most of these data were collected from areas protected from grazing, our results suggest that prescribed burning may be applied to intentionally increase the amounts of little bluestem and other grasses in the stands otherwise dominated by Pan American balsamscale. However, this objective can probably be met only by repeated burns in consecutive years.

Burning in 2 successive years did not prove harmful to grass standing crops but such frequent burning should be considered only in a series of "wet" years. Our results also suggest an average burning interval of 3 years as feasible for removing mulch and unpalatable topgrowth from Pan American balsamscale range.

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APPENDIX A

Conversion of Metric to English Units

Metric unit	English unit(s)
Centimeter (cm)	0.3937 inch
Cubic centimeter (cm^3)	0.0002642 gallon
Degree Centigrade (°C)	$(°C \times 1.8) + 32 = °$Fahrenheit
Gram (g)	0.03527 ounce, 0.0022 pound
Hectare (ha)	2.471 acres
Kilogram (kg)	0.4535 pound
Kilogram/hectare (kg/ha)	1.12 pounds per acre
Kilometers (km)	0.621 mile
Kilometers/hour (km/hr)	1.61 miles/hour
Meter (m)	39.4 inches, 3.28 feet
Square meter (m^2)	1552.36 square inches, 10.76 square feet

APPENDIX B

Scientific Names of Plants Mentioned in Text

Common name	**Scientific name**
Annual ragweed	*Artemisia artemisifolia*
Blue-eyegrass	*Sisyrinchium* spp.
Brownseed paspalum	*Paspalum plicatulum*
Camphorweed	*Heterotheca subaxillaris*
Canarygrass	*Phalaris caroliniana*
Coastal bermudagrass	*Cynodon dactylon*
Comb's paspalum	*Paspalum almum*
Common sandbur	*Cenchrus incertus*
Crow poison	*Nothoscordum bivalve*
Cutleaf evening primrose	*Oenthera laciniata*
Englemann daisy	*Engelmannia pinnatifida*
Frostweed	*Verbesina microptera*
Gulf cordgrass	*Spartina spartinae*
Hooded windmillgrass	*Chloris verticillata*
Horsetail conyza	*Conyza canadensis*
Karnes sensitivebrier	*Schrankia latidens*
Knotroot bristlegrass	*Setaria geniculata*
Little bluestem	*Schizachryium scoparium*
Ozarkgrass	*Limnodia arkansana*
Pan American balsamscale	*Elyonurus tripsacoides*
Perennial ragweed	*Ambrosia psilostachya*
Plantain	*Plantago spp.*
Prairie flax	*Linum lewisii*
Prairie peppergrass	*Lepidium densiflorum*
Rescuegrass	*Bromus unioloides*
Roughstem resinweed	*Silphium asperriumum*
Sawtooth fogfruit	*Phyla incisa*
Scarlet globemallow	*Sphaeralcea coccinea*
Seacoast bluestem	*Schizachyrium scoparium* var. *littoralis*
Six-weeks fescue	*Festuca octoflora*
Smallflower vetch	*Vicia minutiflora*
Snow-on-the-prairie	*Euphorbia marginata*
Spotted beebalm	*Monarda punctata*
Texas bluebonnet	*Lupinus texensis*
Texas bromegrass	*Bromus texensis*
Texas bullnettle	*Cnidoscolus texanus*
Texas geranium	*Geranium texanum*
Texas ironweed	*Vernonia texana*
Texas paintbrush	*Castilleja indivisa*
Texas wintergrass	*Stipa leucotricha*
Thin paspalum	*Paspalum setaceum*
Tobosagrass	*Hilaria mutica*
Upright prairie coneflower	*Ratibida columnaris*
Yellow Indiangrass	*Sorghastrum nutans*
Yellow woodsorrel	*Oxalis dillenii*
Winecup	*Callirhoe involucrata*

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