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Range Vegetation Response to Burning Thicketized Live Oak Savannah

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SUMMARY

Response of live oak-dominated vegetation on thicketized uplands to burning in the fall 1974, spring 1975, and fall 1975 was evaluated through 1977 on the Aransas National Wildlife Refuge. Standing crop, species diversity, and botanical composition of herbaceous vegetation and density of woody plants were the major variables evaluated at various times after the burns. The areas were not grazed by domestic livestock during the study.

Burning uplands in the fall generally increased grass standing crops, compared to burning in the spring, for at least one growing season. However, areas burned in the spring were more productive than unburned areas based on evaluations for two growing seasons after the fires. Herbaceous species diversity increased following all burns but was greatest on areas burned in the fall. Burning tended to decrease the proportion of the grass species of poor grazing value in the stand, and to increase the proportion of the grass species of good-to-excellent forage value by the second growing season after the fires. Gulfdune paspalum and Heller panicum increased the first growing season after burning but began to decline as the proportion of little bluestem increased during the second growing season on burned areas. Forb standing crop on uplands burned in the fall, averaged across sampling dates, was five times that of unburned areas and twice that of areas burned in the spring.

Mulch accumulated rapidly after the burns on the upland sites in the absence of grazing by livestock. Accumulated mulch on unburned areas apparently delayed emergence of forbs and grasses in the spring and severely reduced species diversity. Although live oak dominated the area, stem density declined somewhat as mulch accumulated after burning.

The fires initially top killed the live oak, but densities of new sprouts the growing season after burning exceeded preburn stem densities by as much as five times. Although live oak densities recovered rapidly following the burns, reductions in stem height and standing crop of live oak released herbaceous species. Following the initial burst of resprouting, live oak stem numbers usually returned to preburn densities by 2 years following the fires, apparently because of mulch accumulations and competition from the herbaceous species which were released by the fires.

The vegetation also began to show signs of deterioration (heavy accumulations of mulch and reduced vigor of herbaceous plants) by 2 years following burning. Thus, burning thicketized live oak savannahs every 2 or 3 years, depending on rainfall, may be necessary to maintain the vegetation at a successional stage most suitable for quality wildlife habitat and at optimum potential for livestock grazing use.

KEYWORDS: Range vegetation and burning/live oak/standing crop/species diversity/woody plant density/botanical composition.

METRIC UNITS-ENGLISH EQUIVALENTS

Metric Unit	*English Equivalent*
Centimeter	0.394 inch
Hectare	2.47 acres
Kilogram	2.205 pounds
Kilogram per hectare	0.893 pounds per acre
Kilometer	0.62 statute mile
Kilometer per hour	0.62 miles per hour
Liter	0.264 gallons
Meter	3.28 feet
Square meter	10.758 square feet
(Degrees centigrade × 1.8) + 32	Degrees fahrenheit

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SCIENTIFIC NAMES OF PLANTS MENTIONED IN TEXT

Common Name	**Scientific Name**
Grasses	
Big bluestem	*Andropogon gerardii*
Brownseed paspalum	*Paspalum plicatulum*
Bushy bluestem	*Andropogon glomeratus*
Carolina jointtail	*Manisuris cylindrica*
Florida paspalum	*Paspalum floridanum*
Gulf cordgrass	*Spartina spartinae*
Gulfdune paspalum	*Paspalum monostachyum*
Hairyawn muhly	*Muhlenbergia capillaris*
Heller panicum	*Panicum oligosanthes* var. *helleri*
Little bluestem	*Schizachyrium scoparium* var. *frequens*
Pan American balsamscale	*Elyonurus tripsacoides*
Sheep panicum	*Panicum ovinum*
Silver bluestem	*Bothriochloa saccharoides* var. *torreyana*
Thin paspalum	*Paspalum setaceum*
Yellow Indiangrass	*Sorghastrum nutans*
Forbs	
American snoutbean	*Rhynchosia americana*
Coulter conyza	*Conyza coulteri*
Hairy bonamia	*Stylisma villosa*
Hairypod pepperweed	*Lepidium lasiocarpum*
Plains wildindigo	*Baptisia leucophaea*
Prairie senna	*Cassia fasciculata*
Sawtooth frogfruit	*Phyla incisa*
Spadeleaf	*Centella asiatica*
Texas croton	*Croton texensis*
Western ragweed	*Ambrosia psilostachya*
Woody Plants	
American beautyberry	*Callicarpa americana*
Live oak	*Quercus virginiana*
Post oak	*Quercus stellata*
Redbay	*Persea borbonia*
Saw greenbriar	*Smilax bona-nox*
Yaupon	*Ilex vomitoria*

Range Vegetation Response to Burning Thicketized Live Oak Savannah

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Woody plants, previously suppressed by natural fires, have increased on the Coastal Prairie apparently because of continuous overgrazing, indiscriminant burning, and unsuccessful attempts at farming (Blakely, 1947). As the woody plants increased in stature and spread to previously open areas, the production of range forage species of high value for grazing by cattle decreased and/or were replaced by less desirable species. Much of the Coastal Prairie was originally savannah, a grassland with isolated live oak[1] trees or scattered mottes which were of considerable value as shade for livestock and cover for wildlife. The closing of savannahs by increasing cover of woody plants was referred to as "thicketization" by Dyksterhuis (1957). On much of the Coastal Prairie, live oak savannahs have become heavily thicketized, and the interspaces between the scattered large trees or mottes are now infested with dense stands of the shinnery form of live oak. The shinnery form, hereinafter referred to as "running" live oak, spreads rapidly by a vigorous lateral root system, but individual stems are usually less than 1 meter tall.

Thicketized savannahs may be improved for cattle grazing by use of herbicides (Scifres and Haas, 1974), but the chemicals damage or control the large trees as well as the underbrush. The optimum treatment, considering needs of livestock and wildlife, would remove most of the underbrush but spare the large trees. Therefore, prescribed fire may have more potential than conventional brush control methods for restoring savannahs.

Fire has influenced the development of most natural grassland communities (Vallentine, 1971) and is a natural method of keeping primitive forests open and in stable equilibrium (Biswell, Schultz and Launchbaugh, 1955). Prior to settlement by white man and intensification of agriculture, fires periodically suppressed woody vegetation on prairies and savannahs of the coastal region of Texas (Blakely, 1947). Since fire generally favors grasses at the expense of woody vegetation (Daubenmire, 1967), its absence allows gradual recolonization by woody species on almost all types of grasslands (Saur, 1950; Cook, 1908).

Burning can magnify drouth stress in arid areas but may be beneficial in temperate zones when moisture is not usually limiting. Wildlife habitat is usually improved by burning (Harne, 1938). Compared with mature browse, new growth following burning of woody species is more palatable and nutritious, characterized in part by higher crude protein content which may persist for several years (Dewitt and Derby, 1955). Prescribed burns on the Sabine and Laccassine Refuges in Louisiana were considered simultaneously beneficial to water fowl, furbearing animals, white-tailed deer (*Odecoilus virginiana*), and cattle (Lynch, 1941). Increased calcium and phosphorus contents (Green, 1935) are also benefits of burning herbaceous forage species. Fire increases surface soil temperatures in the spring which encourages early emergence of forage plants and may stimulate nitrification (Wright, 1974). Burning improves utilization of range forages by livestock (Gordon and Scifres, 1977), establishes mineral soil seedbeds, and may suppress various diseases (Wright, 1974).

The primary objective of this study was to determine the response of thicketized Coastal Prairie vegetation to controlled burning in the spring or fall.

STUDY AREA

The Aransas National Wildlife Refuge is located on Blackjack Peninsula and bounded by San Antonio and Saint Charles Bays to the east and west, and by the Aransas Bay to the South. The refuge is located on a strip of deep whitish sand, 4 to 12 kilometers

[1] Scientific names of plants mentioned in text are listed on the preceding page.

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wide, occurring along the coast from Baffin to San Antonio Bays and interrupted by Corpus Christi, Copano, and Saint Charles Bays. This sandy body, sometimes called Flour Bluff Ridge, is the remains of barrier islands that formed offshore in the Pleistocene and, driven inward by wave action, finally came to rest 100,000 or more years ago at the outer edge of the Beaumont Formation Delta (Jones, 1975).

The major upland soils, Mustang and Galveston fine sands, are acid to moderately alkaline and usually contain more than 90 percent sand, less than 10 percent clay, and less than 1 percent organic matter in the surface 30 centimeters. The soils are deep, moderately drained, rapidly permeable, and often saturated or inundated in late fall and early spring.

The climate of the region is classified as dry subhumid (Jones, 1975). Mean annual rainfall is 91.4 centimeters. Relative humidity may vary from 80 to 90 percent during the mornings to less than 60 percent in the afternoons. Average maximum temperature during midsummer is 33 degrees centigrade with frequent highs of 40 degrees centigrade. The average minimum temperature is 24 degrees centigrade. The average high in January is 21 degrees centigrade, and freezing weather is likely to occur only three or four times each year. The average date of the first killing frost is December 20, and the last killing frost usually occurs by January 30.

The study area, consisting of approximately 2,025 hectares and typified by live oak mottes and upland flats interspersed with sloughs and swales, is separated from the remainder of the Refuge by a deer-proof fence. The deep sandy loam uplands typically support mid- and tallgrasses including big bluestem, little bluestem, yellow indiangrass, gulfdune paspalum, and *Dichanthelium* species. Major forb species are western ragweed, plains wild-indigo, Texas croton, hairy bonamia, and *Cassia* species. The major woody species is live oak, which occurs as scattered large trees, in mottes, and in shinnery form. Redbay, yaupon, American beautyberry, and saw greenbriar are commonly associated with live oak.

MATERIALS AND METHODS

Areas of approximately 700 hectares were burned in October 1974, April 1975, or October 1975. The area burned in October 1974 was reburned in November 1976. Vegetation of an unburned area, located outside the fence, was monitored for comparison with vegetation of the burned areas. Two or three permanent 183-meter lines were established on each burned area and on the unburned area for vegetation sampling.

Relative humidity, air temperature, and wind direction and velocity were recorded during each burn except during the spring burn. Standing fine fuel (herbaceous vegetation) was clipped to a 2.5-centimeter stubble height from twenty-five 0.25-square-meter areas equidistantly spaced along each sampling line and separated into green and dead. After removal of standing fine fuel, mulch was collected from each sampling station. Standing fine fuel and mulch samples were oven-dried and weighed. Twenty-five samples of fine fuel and mulch were collected for water-content determinations. At the same time, triplicate soil samples were taken from 0 to 8, 8 to 15, and 15 and 30 centimeters deep for gravimetric determination of soil water content. Soil textures from the same depths were determined by the hydrometer method (Bouyoucos, 1962), and pH on a 1:4 slurry (Mortensen, 1965). Post burn standing crop of herbaceous vegetation was harvested at 4-month intervals from fifteen to fifty 0.25-square-meter sampling areas equidistantly located along each permanent line. Care was exercised not to harvest areas sampled previously. Total oven dry standing crop (green + dead), total green standing crop, and green standing crop by plant species were recorded.

Live oak preburn and postburn densities, heights, and standing crop to a 2.5-centimeter stubble height were recorded for plants less than 1 meter tall from fifty 0.25-square-meter sampling areas equidistantly located along each sampling line. Density, height, and standing crop of live oak regrowth were evaluated in the same manner at 4-month intervals following each burn. New sprouts, entire stems, and leaves of live oak which were judged of adequate palatability and succulence to be browsed to ground level were separated from mature growth. Live oak canopy cover replacement was estimated from the permanent lines using a large, inclined 10-point frame (Arny and Schmidt, 1942; Levy and Madden, 1933). This approach facilitated evaluation of effects of fires on running live oak in the interspaces among the mottes.

Statistical analysis was conducted among seasons of burning within sampling dates based on variation among sampling lines. Significant differences in variables between burned and unburned areas were accepted at the 0.05-level of probability based on paired comparisons (t-test).

RESULTS

Soil Characteristics

The relative proportions of sand, silt, and clay were essentially the same at all depths from the upland sites (Table 1). Sand content averaged 91 to 92 percent, and silt content was only 3 percent. Thus, the soils were highly permeable, but the surfaces dried rapidly following rains during the growing season. Organic matter content was less than 0.25 percent in the surface soil.

Fuel Characteristics

Fuel loads were highly variable within burned areas, ranging from none (bare soil) to heavy stands of grass and running live oak with understory mulch accumulated to as deep as 6 centimeters. Preburn mulch loads averaged 2,600 to 3,000 kilograms per

TABLE 1. SOIL CHEMICAL AND PHYSICAL CHARACTERISTICS TO 30 CM DEEP FROM UPLANDS ON THE ARANSAS NATIONAL WILDLIFE REFUGE NEAR AUSTWELL, TEXAS

Depth (cm)	pH	Organic matter (%)	Textural components (%) Sand	Silt	Clay	Textural class
0-8	5.6	0.21	92	3	5	Sand
8-15	5.7	0.04	92	3	5	Sand
10-30	5.9	0.02	91	3	6	Sand

hectare, regardless of the time of burning. Total standing fine fuel averaged 3,000 kilograms per hectare in the spring and about 6,000 kilograms per hectare in the fall. Running live oak, the major coarse fuel, yielded 2,200 to 3,000 kilograms per hectare at all burning dates. Other woody species did not contribute significantly to fuel loads except in small isolated areas. In general, the dormant grasses and mulch burned readily and ignited live oak stems 1 meter or less in height. However, very few of the large live oak trees (7 meters or taller) were damaged by the fires. Likewise, mottes of plants greater than 1 meter but less than 7 meters tall did not burn uniformly or completely.

Environmental Conditions During Burning

The burns in 1974 and 1976 were conducted under partly cloudy skies with north winds averaging 12 kilometers per hour and gusting to 19 kilometers per hour. Air temperature during the burns was approximately 29 degrees centigrade. Relative humidity averaged 69 to 75 percent during the burns in 1974 and 1976. Soil moisture content averaged 6 percent in the upper 15 centimeters and at the time of the burn in 1974, and surface (2 centimeters) soil temperature averaged 21 degrees centigrade. Soils were saturated and scattered pools of standing water occurred during the burn in 1976. The surface soil temperature immediately prior to the burn was 19 degrees centigrade. According to Refuge records, the spring burn (1975) was conducted on a bright day with air temperature of 26 degrees centigrade and a wind speed of 19 kilometers per hour.

Green Grass Standing Crop

Annual rainfall distribution on the Coastal Prairie is usually characterized by peaks in the spring to early summer and during the fall. Thus, these periods were chosen for evaluation of vegetation recovery following burning in this study. Although rainfall for 60 days following the burn in the fall 1974 totaled almost 53 centimeters, winter rainfall was low (about 12 centimeters total for December, January, and February) (Table 2). Moreover, only 1.1 centimeters total of rainfall were received during March and April. Therefore, green grass standing crop in April 1975 was significantly lower on the area burned in the fall of 1974 than on unburned, thicketized savannah (Figure 1). Rainfall totaled over 20 centimeters for May and June 1975 (Table 2), and by July

TABLE 2. MONTHLY RAINFALL (CM) RECEIVED AT AUSTWELL, TEXAS, NEAR THE ARANSAS NATIONAL WILDLIFE REFUGE FROM 1974 THROUGH 1977

Month	1974	1975	1976	1977	Avg.
January	T[1]	4.4	1.2	7.3	3.2
February	2.8	1.9	0.2	3.6	2.1
March	7.6	0.3	1.5	3.0	3.1
April	1.3	0.8	11.7	11.5	6.3
May	6.1	11.8	16.4	21.8	14.0
June	7.9	8.4	18.8	11.1	11.6
July	0.8	6.7	27.5	2.5	9.4
August	14.0	16.9	3.1	5.0	9.8
September	16.5	10.6	9.1	10.8	11.8
October	8.8	7.2	14.1	8.1	9.6
November	43.8	3.9	11.1	13.8	18.2
December	5.4	5.2	20.3	0.4	7.8
TOTAL	115.0	78.1	135.0	98.9	106.9

[1]Trace.

grass standing crop on areas burned the previous fall tended to exceed that of the unburned area (Figure 1). Soil water content was also higher on the burned than on the unburned areas in July 1975 (Table 3).

Cumulative rainfall for the period July through November exceeded 45 centimeters (Table 2). Consequently, standing crop of green grass was no different between burned and unburned areas in December although there was a tendency for higher

TABLE 3. SOIL-WATER CONTENT (%) AT THREE DEPTHS (CM) AT SEVERAL DATES IN 1975, 1976, AND 1977 ON THE UNBURNED AND BURNED STUDY AREAS OF THE ARANSAS NATIONAL WILDLIFE REFUGE NEAR AUSTWELL, TEXAS

Soil depth (cm)	1975 July	1975 December	1976 February	1976 April	1976 July	1977 February
Unburned						
0-8	10	16	14	9	27	38
8-15	10	13	11	8	24	30
15-30	10	17	12	8	25	30
Avg[1]	10	16	12	8	25	32
Fall burn, 1974						
0-8	23	13	5	10	19	14
8-15	15	10	8	10	16	18
15-30	15	11	7	7	22	24
Avg	17	11	7	9	20	20
Spring burn, 1975						
0-8	18	12	9	8	14	36
8-15	14	10	9	7	10	30
15-30	14	10	8	7	14	26
Avg	15	11	9	7	13	30
Fall burn, 1975						
0-8			10	7	16	34
8-15			12	10	16	29
15-30			11	10	18	26
Avg			11	9	17	30

[1]Weighted average across soil depths.
[2]Reburned in November 1976.

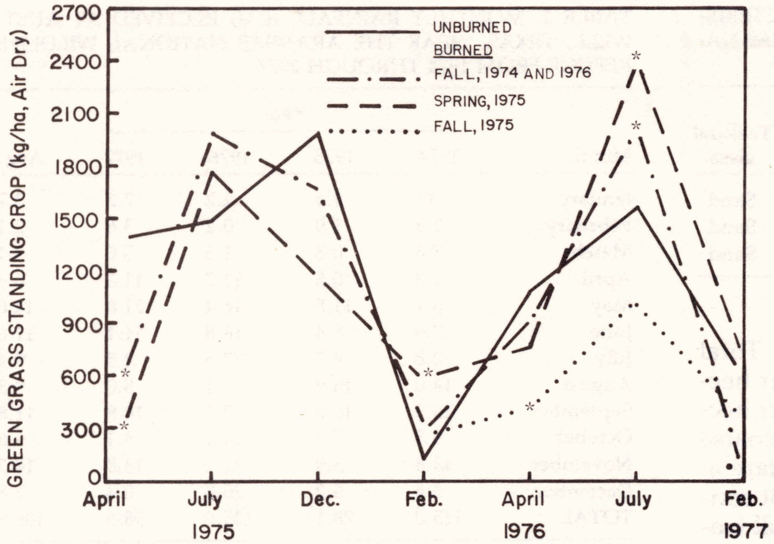

Figure 1. Green grass standing crop (kg/ha) at various dates after burning thicketized savannah on the Aransas National Wildlife Refuge near Austwell, Texas. Asterisked means from burned areas are significantly different from that of the unburned area at the 95 percent level at that sampling date.

green grass standing crop on unburned areas (Figure 1). Apparently, the insulation by the heavy unburned mulch layers helped stablize soil moisture and probably buffered against temperature extremes, retarding soil water losses (Table 3). Only about 7 centimeters of rainfall were received on the study area from December 1975 through February 1976 (Table 2). Thus, in February 1976, soil water content of unburned areas was higher than that of burned areas, especially at the 15 to 30 centimeter depth (Table 3). Yield of green grass was depressed during the winter, as would be expected, regardless of burning treatment (Figure 1). Standing crop by February 1976, on the area burned in the fall 1974, was only slightly higher than that on the unburned area.

Spring greenup along the coast usually occurs in early March, and removal of the mulch insulation by fire normally encourages early renewal of shoot growth, even under less than optimum soil moisture conditions. However, rainfall was only 1.5 centimeters in March (Table 2), and there was no difference between burned and unburned areas in green grass standing crop in April 1976 (Figure 1). Soil water contents were uniformly low in April, regardless of burning treatment (Table 3).

By mid-summer 1976, the standing crop of green grass on areas burned in the fall of 1974 exceeded the yield from unburned areas (Figure 1). Rainfall was relatively high from mid-spring to mid-summer 1976, totaling over 74 centimeters for the period April through July, about 55 percent of the annual precipitation (Table 2). Based on weighted averages to 30 centimeters deep, soil water content of the unburned area was 25 percent contrasted to 20 percent on the area burned in the fall 1974 (Table 3). Long-term effects of reburning in November 1976 of the area burned in the fall 1974 were not evaluated. Final evaluations in February 1977 reflected the usual winter depression in green grass standing crop.

Green grass standing crop on the area burned in the fall of 1975 followed the same seasonal trends as described following burns in the fall of 1974 except that yields were depressed during the spring and summer of 1976 (Figure 1). Rainfall was considerably lower for the 90-day period following burning in the fall of 1975 (about 16 centimeters), especially during November, than following burning in the fall of 1974 (Table 2). Thus, regrowth following the fire in the fall of 1975 developed more slowly than after the 1974 burn. The effects of the dry period following burning in the fall of 1975 were not compensated by the relatively high rainfall from mid-spring to mid-summer, 1976. This is an important consideration since relative availability of moisture in late winter and early spring determines the extent of spring growth following late fall and winter burns in this area, especially on sandy soils. The same relationship, although less severe relative to grass yield depression, was reported by Gordon and Scifres (1977) who burned Coastal Prairie approximately 30 kilometers north of the Aransas Refuge. Their research was conducted on heavy clay soils which have greater soil water storage capacity than the sandy soils on the Aransas Refuge.

Green grass standing crop on thicketized savannah burned in the spring of 1975 followed the same general trends as on areas burned in the fall of 1974. The area burned in the spring of 1975 supported significantly more standing green grass than the unburned area in February 1976 (Figure 1). Although there was little difference in green grass standing crop among burning treatments in April 1976, areas burned in the spring of 1975 supported more standing crop in July 1976 than did unburned areas. The areas burned in the fall 1974 or spring 1975 were apparently in the appropriate condition, relative to grass regrowth, to take maximum advantage of favorable moisture conditions in the spring and summer of 1976.

These data demonstrate the importance of the timeliness and amount of rainfall relative to recovery of herbaceous range species following burning. Although average rainfall for the 4-year study period generally reflected long-term trends, there was considerable variation among years and among seasons within years (Table 2). These variations had a pronounced influence on the recovery of grasses after burning. The potential positive influence of the relatively wet fall of 1974 on grass growth was apparently offset by the dry spring in 1975. Conversely, the relatively wet periods during the fall of 1976 and the spring in 1977 promoted green grass standing crops on burned areas, compared with unburned areas, during the summer of 1977. Based on these data, success from range burning on the Coastal Prairie, as reflected by promotion of green grass standing crop, was influenced less by season of burning (fall compared to spring in this study) than by rainfall conditions following the fires.

Botanical Composition of Grass Stands

Although changes in production of forages is an important indicator of success from burning, the value of that forage for grazing must also be considered for assessment of the overall effectiveness of fire as a range management tool. On unburned thicketized live oak savannah, the standing crop of green grass was composed primarily of gulfdune paspalum, little bluestem, Heller panicum, thin paspalum, and hairyawn muhly, with the relative proportion of species varying somewhat among times of evaluation. These species, especially little bluestem and Heller panicum, were favored by burning (data not shown). Following the burn in the fall of 1974, gulfdune paspalum, little bluestem, and Heller panicum produced most of the standing crop. Little bluestem is an excellent range forage species for cattle grazing. Gulfdune paspalum and Heller panicum are considered fair forage species for grazing. In July 1975, gulfdune paspalum and Heller panicum jointly produced 36 percent of the forage by weight (data not shown). In July 1975, these two species accounted for 64 percent of the forage by weight on areas burned in the fall of 1974, which dramatically increased the proportion of the forage composed of species considered fair for grazing (Table 4). The same shift in species composition occurred on areas burned in the spring of 1975 when gulfdune paspalum and Heller panicum accounted for 54 percent of the forage in July 1975. Adaptability of these two species to burning apparently allowed them to increase the year following burning at the expense of excellent forage species such as little bluestem. However, little bluestem tended to increase in importance during the second growing season following the burns.

In April 1976, gulfdune paspalum and Heller panicum accounted for 64 percent of the green grass standing crop on unburned areas (Table 4). Only 12 percent of green grass standing crop was contributed by little bluestem. Species of poor grazing value such as hairyawn muhly contributed 24 percent to the

TABLE 4. COMPOSITION (%) OF GREEN GRASS STANDING CROP BASED ON WEIGHT BY SPECIES GROUPED BY GRAZING VALUE FOR CATTLE FOLLOWING BURNING OF THICKETIZED LIVE OAK SAVANNAH ON THE ARANSAS NATIONAL WILDLIFE REFUGE NEAR AUSTWELL, TEXAS

	Evaluation date			
	1975	1976		1977
Grazing value	July	April	July	February
Unburned				
Excellent/good	44	12	25	40
Fair	39	64	56	59
Poor	17	24	19	1
Fall burn, 1974[1]				
Excellent/good	30	28	39	41
Fair	66	62	58	58
Poor	4	10	3	1
Spring burn, 1975				
Excellent/good	33	43	44	49
Fair	63	44	53	18
Poor	4	13	3	23
Fall burn, 1975				
Excellent/good		29	20	38
Fair		60	77	57
Poor		11	3	5

[1]Reburned November 1976.

standing green grass crop. Although gulfdune paspalum and Heller panicum afforded the bulk of the forage in April 1976 on areas burned during the fall 1974, the amount of green grass standing crop contributed by little bluestem more than doubled the amount on unburned areas with a concomittant decrease in species of poor grazing value. At the same time, 43 percent of the grass biomass on areas burned in the spring of 1975 was furnished by little bluestem in conjunction with small amounts of big bluestem (1 percent) and yellow Indiangrass (8 percent). Botanical composition of green grass standing crop in April 1976 on areas burned in the fall of 1975 was similar to that at the first evaluation of the area burned in the fall of 1974 (Table 4). About 28 percent of the forage was furnished by little bluestem with 1 percent contributed by Florida paspalum. Sixty percent of the forage composition consisted of species of fair grazing value, primarily gulfdune paspalum and Heller panicum, but it also included brownseed paspalum (5 percent) and thin paspalum (1 percent).

By February 1977, there was little difference in the botanical composition of the green grass standing crops on the unburned area and those burned in the fall 1974 or the fall 1975 (Table 4). About 40 percent of the standing crop was furnished by little bluestem with most of the remainder composed of forages of fair grazing value for cattle, primarily gulfdune paspalum and Heller panicum. Only 1 to 5 percent of the standing green grass crop was represented by forages of poor grazing value such as hairyawn muhly, bushybeard bluestem, and sheep panicum. However, areas burned in the spring of 1975 supported a green grass standing crop of which almost half by weight was composed of forages rated as excellent or good grazing for cattle, including little bluestem, silver bluestem, and yellow Indiangrass. There was also an increase in the proportion of grasses of poor grazing value, primarily hairyawn muhly. However, burning in the spring appeared to promote little bluestem over gulfdune paspalum and Heller panicum, compared with burning in the fall.

In general, burning tended to improve the botanical composition of the green grass standing crop for two growing seasons by increasing production of little bluestem. However, species such as big bluestem and yellow Indiangrass, excellent forage species for cattle grazing and a part of the climax vegetation for these sites, were also present in small amounts on burned areas. These tall grasses did not occur in the samples from unburned areas. Other grasses characteristic of the coastal zone such as Pan American balsamscale, Carolina jointtail, and several *Paspalums* were also encountered following burning but did not occur in detectable amounts on unburned areas.

Shifts in botanical composition proceeded relatively slowly following burning of these sites. The relatively slow response may be attributed to limiting moisture conditions during the growing season on the sandy soils and the absence of livestock grazing. Therefore, repeated burns followed by wet springs may be required before species such as little bluestem are increased significantly in these stands. Species diversity of grass stands was generally increased for the first 6 months to 1 year following burning but tended to be reduced after 2 years, probably in response to increased competition from live oak and mulch accumulations (data not shown).

Forb Standing Crop

There was a general increase in forb standing crop following burning of thicketized live oak savannah, regardless of date of burning or evaluation (Figure 2). Forb standing crop in April 1975 following burning in the fall 1974 was 745 kilograms per hectare contrasted to only 63 kilograms per hectare on unburned areas. Although the data could not be analyzed statistically, there also tended to be greater forb standing crops on burned than on unburned areas during July 1975. Cumulative forb standing crop, assuming negligible phenological overlap of the forb populations among sampling times, was 1611 kilograms per hectare from April 1975 to February 1977 on the burned areas contrasted to only 357 kilograms per hectare on the unburned, thicketized savannah. Over the entire study period, burning in the fall of 1974 increased the forb standing crop fivefold compared to that of unburned areas.

Although burning in the spring generally increased the forb standing crop compared to unburned thicketized savannah, forb production on areas burned in the spring were consistently lower than on areas burned in the fall (Figure 2). Cumulative standing crop for the study period from the areas burned in the spring was 672 kilograms per hectare, about 47 percent of that produced on areas burned in the fall. Since most of the forbs emerged in the early spring, burning at that time apparently directly reduced the forb crop by destroying seedlings. In contrast, burning in the fall apparently "opens" the grassland to establishment of forbs the following spring.

Forb response following burning in the fall of 1975 followed trends comparable to those on the area burned in the fall of 1974. However, forb production in 1976 was consistently higher on areas burned in the fall of 1975 compared to that following the burn in the fall of 1974 (Figure 2). This difference was attributed to the relatively wet spring in 1976 (Table 2) and to age of the burns. The "flush" of forb growth is apparently restricted to the spring following burning in the fall. Forb growth is apparently then reduced by the competition from other vegetation which de-

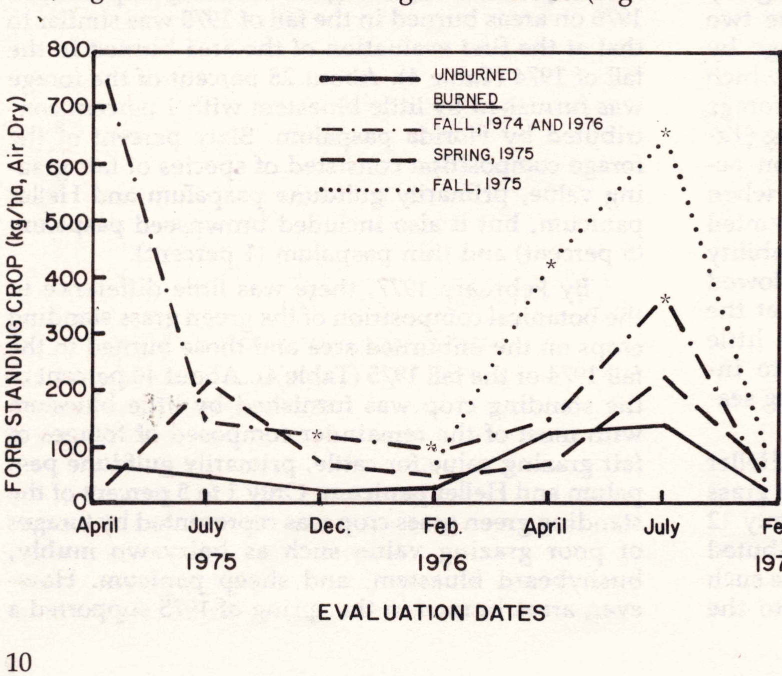

Figure 2. Forb standing crop (kg/ha) at various dates after burning thicketized savannah on the Aransas National Wildlife Refuge near Austwell, Texas. Asterisked means within a date of evaluation are significantly different from that of the unburned area at the 95-percent level. Statistical analysis was not possible for data collected in April or July, 1977.

velops on the burned areas. The mulch cover on unburned areas probably slowed warming of the soils in early spring, delayed seed germination, and restricted light penetration to new seedlings.

Botanical Composition of Forb Stands

Forb communities were more diverse on burned areas than on unburned areas, and there was a tendency for more forb species to occur on areas burned in the spring than in the fall (Table 5). Plains wildindigo, spadeleaf, hairypod pepperweed, sawtooth frogfruit, and American snoutbean usually accounted for 65 to 75 percent of the forb standing crop on unburned thicketized savannah in the spring. During July of the hot, dry summers, Coulter conyza and hairy bonamia accounted for 90 percent of the standing forb crop in 1975 and 86 percent in 1976. Spadeleaf, an inconspicuous species growing beneath the taller vegetation, was one of the most abundant forbs during the winter. It usually accounted for 50 to 70 percent of the cool-season forb standing crop.

Burning in the fall of 1974 dramatically increased the proportion of the forb standing crop contributed by legumes, especially plains wildindigo, until February 1977 (Table 6). Plains wildindigo was one of the more conspicuous forbs on the burned area because of its shrubby appearance and showy flowers. It is evidently highly preferred by white-tailed deer in the early spring (Springer, 1977). Prairie senna also occurred at all sampling dates except April 1976 and February 1977 on the area burned in the fall of 1974. Another desirable legume for white-tailed deer, American snoutbean, occurred on the burned area from spring until late winter. Plains wildindigo and prairie senna also increased following burning in the spring of 1975, compared to unburned areas (Table 6).

The same trends in forb composition occurred in 1976 on the areas burned in the fall 1975. Plains wildindigo, prairie senna, and western ragweed increased on the burned area, compared to unburned areas. There was also a high proportion of Coulter conyza on the area burned in the fall of 1975 compared to the area burned at the same time in 1974. Coulter conyza is an indicator of disturbance.

TABLE 5. NUMBER OF FORB SPECIES OCCURRING IN VEGETATION SAMPLES AT VARIOUS TIMES AFTER BURNING THICKETIZED LIVE OAK SAVANNAH ON THE ARANSAS NATIONAL WILDLIFE REFUGE NEAR AUSTWELL, TEXAS

		Date of burn		
Date of evaluation	Unburned	Fall[1] 1974	Spring 1975	Fall 1975
---1975---				
April	10	15	11	
July	2	13	12	
December	4	9	7	
---1976---				
February	4	8	8	8
April	5	13	6	19
July	2	16	10	12
---1977---				
February	2	8	3	9

[1]Reburned in November 1976.

TABLE 6. PERCENTAGE OF FORB STANDING CROP CONTRIBUTED BY PLAINS WILDINDIGO, AMERICAN SNOUTBEAN, AND PRAIRIE SENNA ON SEVERAL DATES AFTER BURNING THICKETIZED LIVE OAK SAVANNAH ON THE ARANSAS NATIONAL WILDLIFE REFUGE NEAR AUSTWELL, TEXAS

		Date of burn		
Date of evaluation	Unburned	Fall[1] 1974	Spring 1975	Fall 1975
---1975---				
April	6	85	46	
July	0	86	83	
December	73	24	0	
---1976---				
February	0	2	1	0
April	1	20	34	13
July	0	17	2	11
---1977---				
February	7	0	0	0

[1]Reburned in November 1976.

Mulch Yield

Mulch yield was significantly reduced by burning thicketized live oak savannah, regardless of date of evaluation (Figure 3). Mulch yield varied with date of sampling but tended to increase from initial date of the burns until termination of the study. Mulch on the area burned in the fall of 1975 decreased slightly during 1976 but increased, compared to other post burn evaluations, in February 1977. Apparently, decomposition of the thin layers of mulch remaining after burning was enhanced by wet conditions from April to July 1976, followed by mulch deposition after flush of grass production in late summer and early fall.

By July 1976, mulch on the unburned area weighed almost 3000 kilograms per hectare whereas the mulch yield was about 1400 kilograms per hectare on the areas burned in the fall of 1974 or spring of 1975 (Figure 3). Although the mulch weight increased only slightly on burned areas from July 1976 to February 1977, the mulch load was adequate to allow reburning by fall 1978.

Total Herbaceous Standing Crop

Total herbaceous standing crop (green + dead) was greater, regardless of evaluation date on unburned than on burned live oak savannah (Figure 4). As the vegetation matured on the burned areas in the absence of grazing by livestock, total herbaceous standing crop steadily increased. By February 1977, total standing herbaceous crop on the area burned in the spring of 1975 was not significantly different from that of the unburned area, indicating the rate of

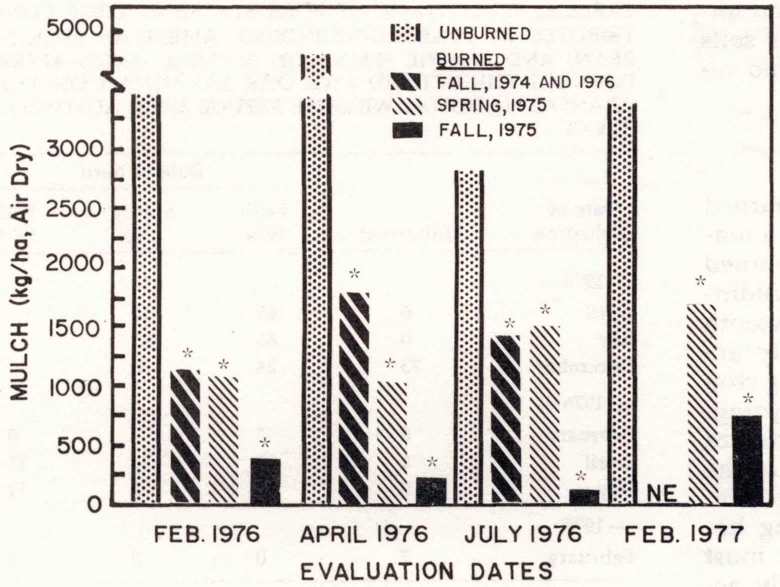

Figure 3. Mulch (kg/ha) at various dates after burning thicketized savannah on the Aransas National Wildlife Refuge near Austwell, Texas. Asterisked bars indicate that mean values are significantly different from that of unburned areas at the 95-percent level. NE indicates area not evaluated.

contribution of standing dead material by the coarse perennial grasses. Vegetation burned in the fall of 1974 followed the same trend as on the area burned in the spring until it was reburned in the fall 1976.

These data reinforce the interpretation of botanical composition changes that burning could be repeated at about 3-year intervals, rainfall permitting, to maintain herbaceous stands at a successionally optimum level. Grazing use would eventually reduce the standing dead herbaceous vegetation on unburned areas and would be expected to delay its accumulation on burned areas.

Density of Running Live Oak

Since live oak spreads by vegetative reproduction from lateral roots, most of the study area is typified by scattered mottes of live oak connected by dense stands of oak stems less than 1 meter tall. Response of running live oak in the interspaces among the mottes was emphasized in this study since it covered the majority of the area.

Initial top kill of live oak after burning the interspaces exceeded 95 percent, regardless of the date of burning. However, stem densities at 6 to 12 months after burning exceeded preburn stem densities (Figure 5). Burning apparently breaks apical dominance which allows rapid development of new live oak shoots from the lateral roots. Live oak stem density by February 1976 significantly increased after burning in the fall of 1974 and following burning in the spring of 1975, compared to that of unburned areas. By April 1976, stem density on areas burned in the fall of 1975 had increased significantly, compared to preburn densities.

By April 1976, the rate of increase in live oak stem densities began to stabilize on all areas except the most recent burn installed in the fall of 1975 (Figure 5). During July 1976, a decrease in density of green live oak stems was recorded on areas burned during the fall of 1974 or spring of 1975. Apparently, the mulch accumulations, competition for moisture, and the effects of shading from herbaceous species,

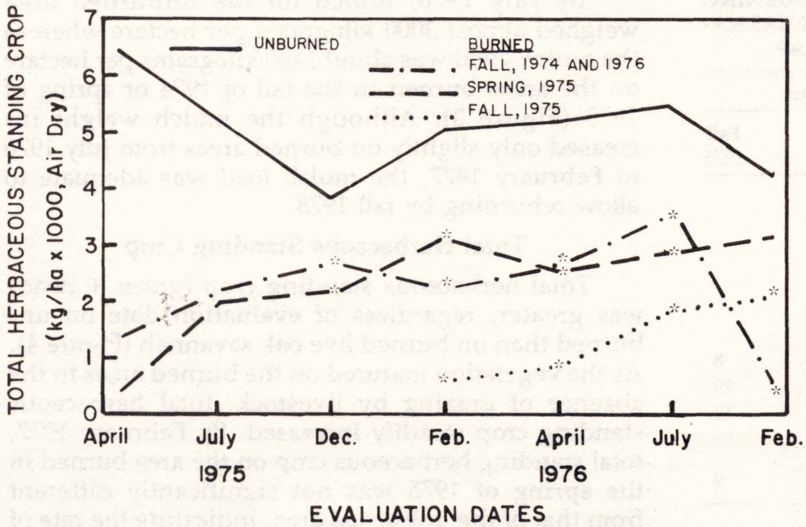

Figure 4. Total herbaceous standing crop (kg/ha) at various dates after burning thicketized savannah on the Aransas National Wildlife Refuge nea. Austwell, Texas. Asterisked means within a date of evaluation are significantly different from that of the unburned area at the 95-percent level.

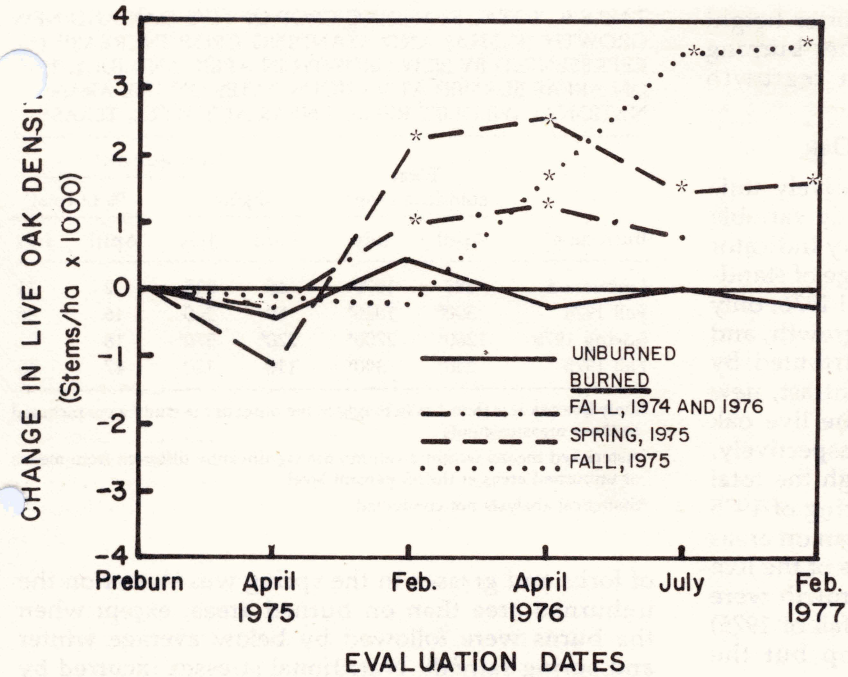

Figure 5. Density (thousands of stems/ha) of live oak on thicketized live oak savannah burned at various dates on the Aransas National Wildlife Refuge near Austwell, Texas. Asterisked means indicate significant difference from unburned areas at the 95-percent level within an evaluation date.

especially mid- and tall grasses, caused the decrease in live oak densities. Several factors must have interacted to cause reduction in the densities of live oak stems on the areas burned in the fall of 1974 or spring of 1975, rather than solely the dry summer growing conditions during 1976. Stem densities on the area burned during the fall of 1975 increased during that time period. Since the area burned in the fall of 1974 was reburned in the fall of 1976, no additional live oak counts were taken.

Height Change of Running Live Oak

Live oak heights in the interspaces among the mottes on the unburned area were relatively stable during the study period with minor differences attributed to sampling error (Table 7). Regrowth rate of live oak burned in the spring of 1975 was somewhat more rapid than following burning in the fall of 1975. However, live oak stems on burned areas were shorter at all evaluation dates than those on unburned areas, regardless of date of burning. Therefore, live oak regrowth would not be expected to achieve preburn heights within 24 months after burning.

Percentages of regrowth stems in height classes illustrate the progression of stem elongation with time after burning (Table 8). The percentage of live oak stems in the taller classes on the area burned in the spring of 1975 were roughly equivalent to that recorded on areas burned in the fall of 1974, regardless of evaluation date. These data indicate that live oak regrowth rate is most rapid during the spring. Consequently, time of burning, fall or spring in this study, will probably have little effect on regrowth heights after the first growing season following burn-

TABLE 7. MEAN HEIGHTS (CM) OF LIVE OAK STEMS 1 METER IN HEIGHT OR LESS ON THICKETIZED LIVE OAK SAVANNAH BURNED AT VARIOUS DATES ON THE ARANSAS NATIONAL WILDLIFE REFUGE NEAR AUSTWELL, TEXAS

	Evaluation dates[1]			
	1976			1977
Burn date	February	April	July	February
Unburned	45	52	41	39
Fall 1974[2]	16	19	23	[3]
Spring 1975	23	29	30	24
Fall 1975	4	12	16	17

[1]… means within dates from burned areas were significantly different at the 95% level from those of the respective unburned area.

[2]Reburned in November 1976.

[3]Regrowth was not sampled after the reburn in November 1976.

TABLE 8. PERCENTAGE OF LIVE OAK STEMS BY HEIGHT CLASS IN FEBRUARY, APRIL, AND JULY OF 1976 AFTER BURNING ON SEVERAL DATES ON THE ARANSAS NATIONAL WILDLIFE REFUGE NEAR AUSTWELL, TEXAS

	Evaluation date	Height class (cm)				
Burn date	(1976)	0-5	6-10	11-20	21-40	≧41
Unburned	February	0	1	6	30	63
	April	0	0	4	27	69
	July	0	3	11	28	59
Fall 1974[1]	February	9	3	42	38	8
	April	1	13	42	35	0
	July	1	5	30	47	17
Spring 1975	February	4	12	31	32	21
	April	1	13	21	42	23
	July	0	5	20	47	28
Fall 1975	February	72	24	4	0	0
	April	13	33	40	14	0
	July	11	16	52	20	1

[1]Reburned in November 1976.

ing. The percentage of stems in the shorter height classes generally decreased with time after burning indicating a well-defined, maximum regrowth height for running live oak.

Standing Crop of Running Live Oak

Although density of stems was relatively uniform, standing crop of live oak was highly variable over the study area. Therefore, the primary indicator of the effects of burning was the percentage of standing crop made up of new growth. In April 1976, only 2 percent of unburned live oak was new growth, and 11 percent of the total weight was contributed by new growth in July 1976 (Table 9). In contrast, new growth afforded 16 and 26 percent of the live oak standing crop in April and July 1976, respectively, after burning in the fall of 1974. Although the total standing crop on areas burned in the spring of 1975 was greater at both evaluations in 1976 than on areas burned in the fall of 1974, the percentages of the live oak standing crop represented by new growth were similar. The most recently-burned area (fall of 1975) supported the least total standing crop but the greatest percentage of live oak standing crop as new growth on each sampling date. The area burned in the fall of 1975 was heavily utilized by wildlife, especially white-tailed deer which browsed as many as 50 percent of newly emerged live oak sprouts during the 1976 growing season. Springer (1977) reported that browse was the most important food, as a percentage of the annual diet, of white-tailed deer on the Aransas Refuge. Moreover, live oak was the most commonly occurring browse in their diet, especially during the winter months.

TABLE 9. TOTAL STANDING CROP OF LIVE OAK AND NEW GROWTH (KG/HA) AND STANDING CROP INCREASE (%) REPRESENTED BY NEW GROWTH IN APRIL AND JULY, 1976 ON AREAS BURNED AT VARIOUS DATES ON THE ARANSAS NATIONAL WILDLIFE REFUGE NEAR AUSTWELL, TEXAS[1]

	Total standing crop[2]		New growth[2] kg/ha		New growth[2] % of total[3]	
Burn date	April	July	April	July	April	July
Unburned	880	1970	60	215	2	11
Fall 1974	300*	1020*	50	260	16	26
Spring 1975	1200*	2700*	220*	570*	18	21
Fall 1975	230*	390*	110	120	47	30

[1]Only live oak less than 1 m in height at the onset of the study were included in these measurements.

[2]Asterisked means within a column are significantly different from means of unburned areas at the 95-percent level.

[3]Statistical analysis not conducted.

DISCUSSION

Prescribed burning generally improved vegetation of thicketized live oak savannah for use by livestock and wildlife. Few of the large oak (7 meters or taller) trees were damaged by the fires. Likewise, scattered mottes of plants 1 to 7 meters tall were not effectively burned, apparently because of lack of a continuous distribution of fine standing fuel. Coarse understory fuel (shrubs and vines) carried fires at ground level through some mottes. Occasional crown fires resulted from a combination of high fuel loads in surrounding vegetation, adequate combustible climbing plants in the crowns of these trees or mottes, and moderate to high (16- to 48-kilometers-per-hour) gusts of wind. However, grasses, forbs, and live oak plants less than 1 meter tall in the interspaces among the mottes burned completely and uniformly except on a few isolated small areas, usually swales, where the fuel was discontinuous.

Accumulations of mulch and dead standing plants on the unburned area apparently acted as a buffer against variations in the microenvironment with changes in weather. Burning removed accumulated mulch and standing dead herbaceous material, leaving mostly ash and mineral soil which promoted early warming of the soil in the spring. Thus, growth of forbs and grasses in the spring was slower on the unburned area than on burned areas, except when the burns were followed by below average winter and spring rainfall. Nutritional stresses incurred by wildlife and livestock in the winter might be relieved earlier in the spring on burned areas than on unburned areas, especially in years of average or higher rainfall.

Forb production was stimulated by burning, regardless of time of treatment, but was most responsive to fires in the fall. Difference in forb production between spring and fall burning was attributed to direct fire damage from spring fires. Maximum forb standing crop occurred from mid-spring to mid-summer, regardless of burning treatment. Burning in the fall or spring also increased numbers of forb species and promoted the occurrence of legumes, especially plains wildindigo and American snoutbean. More diverse forb communities provide a broader range of nutritious forage for selection by wildlife and domestic grazing animals. Burning in the spring, as opposed to burning in the fall, would not be advisable when maximum numbers of forb species and maximum forb production early in the year are desirable for improvement of wildlife habitat.

Standing crop of green grass followed predictable seasonal fluctuations on the burned areas with reductions during the winter months and increases during the spring and summer. However, burned areas generally produced more green grass than did unburned areas during the summer months. This was attributed to mulch accumulations and the standing dead plants which reduced space and light for initiation of new growth on unburned areas. Earlier initiation of grass growth the growing season after burning on burned than unburned areas was attributed to earlier warming of the blackened soil surfaces. However, standing crop in the spring was greater on unburned areas than on burned rangeland when rainfall was below average during the winter and early spring. This was especially true in April

1976 after dry conditions the previous winter. Apparently, the mulch cover insulated the soil surfaces on unburned areas against moisture loss. In addition, regrowth on burned areas may have exerted a greater demand for soil water than growth on unburned areas. Spring burning generally resulted in less grass production than did fall burning, apparently because of fire damage to newly emerging grasses in the spring.

More species of grasses occurred for two growing seasons on burned than on unburned areas. In general, grass species desirable for livestock grazing occurred more frequently and composed more of the forage by weight on burned than on unburned areas. However, improvement in botanical composition of the grass stand on these sandy sites was somewhat lower than observed in other studies on the Coastal Prairie after burning clay sites. Maximum potential improvement in the species composition of grass stands on these sandy sites may not be achieved until several burns have been applied. Grasses on burned areas were more succulent and more available to grazing animals after the dead standing herbaceous material was removed.

Preburn densities of live oak averaged approximately 152,000 stems per hectare, with a range of 68,000 to 276,000 stems per hectare, on the study area. Live oak densities were considerably lower on the unburned areas the growing season following the fires than on burned areas because the fires stimulated resprouting by breaking apical dominance. Also, the removal of the mulch and standing herbaceous crop may have released some live oak regrowth. The apparent intolerance of live oak sprouts to shade was verified by observations within the oak mottes. The mottes with dense canopy cover (greater than 75 percent cover) contained few live oak sprouts, if any, in the understory. Mottes with open canopies (less than 50 percent cover) and few understory plants supported substantially more live oak sprouts than those with heavy canopies.

Live oak regrowth stem densities increased for 2 years after burning and then declined to preburn densities. No causative agent for the mortality of the regrowth live oak stems was ascertained. Although a second burn might initiate the cycle again, subsequent burns should ultimately reduce live oak regrowth stem densities by increasing the competitive stress from herbaceous vegetation.

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