RESPONSE OF HERBACEOUS VEGETATION TO PRESCRIBED BURNING IN THE HILL COUNTRY OF TEXAS

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ABSTRACT

The use of prescribed burning to control shrub growth in range and grassland areas has increased in recent years. A study was conducted in an oak savanna to determine maximum temperatures reached during burning, the effect of fuel moisture and fuel on these temperatures, and the response of forbs and grasses. Maximum temperatures varied from 104°F and 388°F at the base of live and post oaks, respectively, to 412°F in the grasslands surrounding the trees. Forb biomass increased dramatically in burn areas, whereas grass biomass decreased slightly in live oak areas and increased slightly in post oak areas. Standing dead biomass was 3-4 times greater in control plots than in burn plots.

Keywords: Prescribed burning, hill country, temperature, live oak **(Quercus fusiformis)**, post oak **(Quercus stellata)**, forbs, and grass.

INTRODUCITON

The use of prescribed burning to control shrub growth on rangeland has increased in recent years because of the acceptance of fire as a low cost management tool to control shrubs (Wink and Wright 1973, Hamilton and Scifres 1980, Ueckert 1980). Many investigatiors have studied the effects of prescribed burning on grass production because it directly affects cattle production. An important income supplement to cattle production in the Hill Country of Texas is deer production. Because deer prefer both forbs and succulent new grass growth (Cross 1984), forb production should also be considered when the effects of fire are assessed; very few studies, however, have considered this effect.

This study was conducted in an oak savanna. The specific objectives of the study were to determine: 1) maximum temperatures achieved during a burn, 2) the effect of fuel moisture and fuel load on fire temperature, and 3)the response of forbs and grasses to prescribed burning.

MATERIALS AND METHODS

Study Site and Sampling Positions

The study was conducted in Love Pasture at the Kerr Wildlife Management Area in Kerr County,Texas. The pasture is an oak savanna dominated by two oak species—live oak(**Quercus fusiformis**) and post oak (**Q. stellata**). (Nomenclature follows Correll and Johnston, 1970). Four pairs of trees of each species and the grassland surrounding them were selected. One vegetational unit of each pair was designated a control unit, the other a burn unit. Both vegetational units of every pair had similar micro-habitats. Five sampling positons were chosen along four transects that began at the base of each tree and radiated along each of the cardinal compass directions. Specifically, these were located at the base of the tree, and at 0.5 canopy radius, 1 canopy radius, 1.5 radii,(half-grassland), and 2 radii (grassland) from the base (Figure 1).

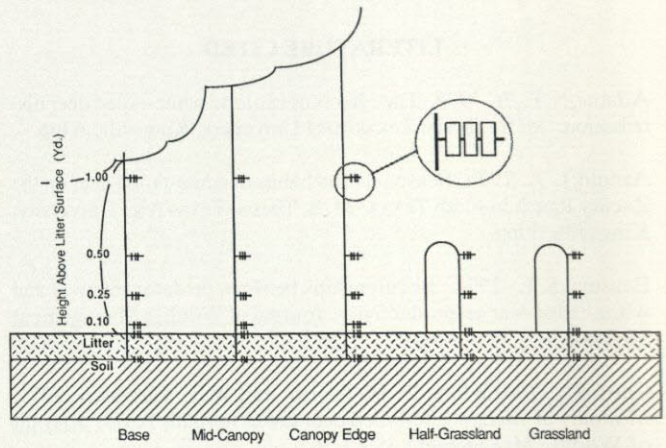

Figure 1. Vertically-stratified levels. Positions beneath tree canopies are at soil surface, litter surface, and 0.10, 0.25, 0.50 and 1.0 yds. above litter surface. Grassland positions are at soil surface, litter surface, 0.25 and 0.50 yds. above litter surface.

Temperature Measurement

Maximum temperatures reached during the burn were measured with the use of temperature recording slides. Frosted glass slides (1 in.x 3in.) were marked with 28 heat-sensitive crayons with melting points ranging from 100 to 550°F (Figure 2). These slides were then wrapped in aluminum foil to protect the marks from becoming obscured by ash; yet permitted rapid transfer of heat. At the base, mid-canopy and canopy positions, a set of three slides were placed at six vertically stratified levels. These levels were: soil surface, litter surface, and 0.1,0.25,0.5, and 1.0 yds. above the litter surface (Figure 1). Slides above the litter surface were hung on 0.2-in. diameter wire suspended from the tree canopy. Temperature slides were insulated from possible heat conduction through suspension wires by 0.01-in. thick glass slides and were oriented with marked surfaces directed toward the litter surface. In the two grassland sampling positions, temperatures at only four vertically stratified levels (soil surface, litter surface, and 0.25 and 0.50-yd. above the litter surface) were measured (Figure 1). These slides were connected to 0.2-in. diameter wire wickets.

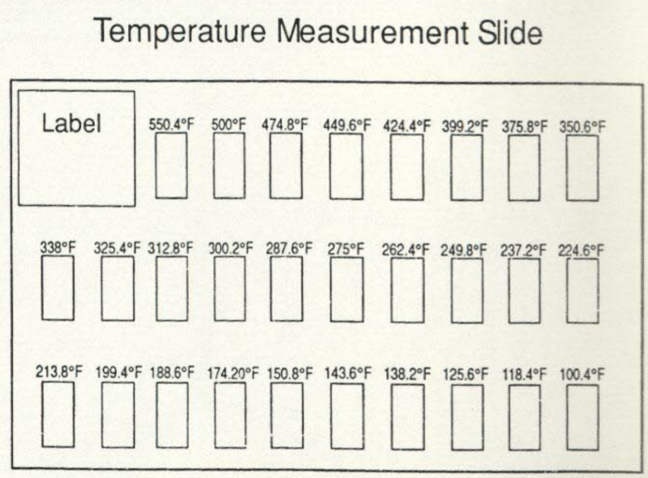

Figure 2. Temperature measurement slide. Slide dimensions are 1 x 3 in.

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The Burn

The pasture was burned in a striphead fire pattern between 12:30 and 1:15 p.m. on 1 February 1982 (Wright 1974). Controls were protected by a bulldozed 15 yd. fire lane. At the time of ignition, air temperature was 55°F, relative humidity was 42-48%, and wind speed was 10-32 mi./hr. from the SSW(Baccus, 1982).

Fuel Moisture and Fuel Load

On the day of the burn, fuel moisture samples were collected between 9:00 and 10:00 a.m. from each of five positions located diagonally between two vegetational transects from both burn and control units. Immediately prior to the fire, fuel moisture samples were again collected from controls. Samples consisted of a representative sampling of fuels present at each position collected in moisture-proof, heat-tolerent bags. To determine percent dry weight, samples were weighed, dried at 212°F for 24 hours and reweighed.

Pre- and postburn samples of fuel load were collected from burn units within five O.3 yd.^{2} frames located diagonally between two vegetational transects. These samples were sorted into four fine-fuel classes (grass, forbs, twigs, and leaves), and dried at 212°F to constant weight to determine fuel present at ignition and percent fuel oxidized by the fire (Table 1).

Vegetation

At mid-growing season following the burn (Jul. and early Aug. 1982), all standing biomass was collected from within a 0.3- yd.^{2} frame at each sampling position in both control and burn units. The material was sorted initially into live (green) and standing dead biomass. The live biomass was then hand-sorted into individual species by gross morphology and surface characteristics. Some specimens could only be classified to genus(e.g.**Aristida** spp). All specimens were oven-dried to constant weight at 176°F. Data collected were divided into two classes: forbs and grasses. An importance value (IV) for each species was determined from relative dominance and relative frequency within classes (Tables 2-5). Any forb of grass species with an IV $\geq 2\%$ was reported individually; others were combined into the categories 'other forbs' and 'other grasses'.

Statistical Methods

Analysis of variance (ANOVA) was performed on standing-dead biomass data collected from control and burn units for both species. Two-way ANOVA (Sokal and Rohlf, 1981) was performed on fuel moisture, total live biomass, and forb and grass biomass (see Tables,Hutcheson, 1986). Rows for two-way ANOVA were the control and burn; columns were the four pairs of vegetation units. All sample positions were pooled for analysis.

RESULTS

Temperature

Mean temperatures at each vertical stratified level were plotted for each position for both species (Figure 3). Temperatures were highest at the litter surface varied from a low of 138°F at the base sampling postion to 300°F at the half- grassland postion. For post oak burn units, temperatures at the litter surface varied from a low of 388° at the base sampling postion to 412°F at the half-grassland position. Mean temperature at the soil surface was considerably lower than that at the litter surface. For live oak burn units, temperatures at the soil surface varied from a low of 104°F at the base sampling position to 194°F at the grassland position, For post oak burn units, temperatures at the litter surface varied from a low of 266°F at the canopy edge to 316°F at the base sampling position. Mean temperatures above the litter surface dropped off dramatically.

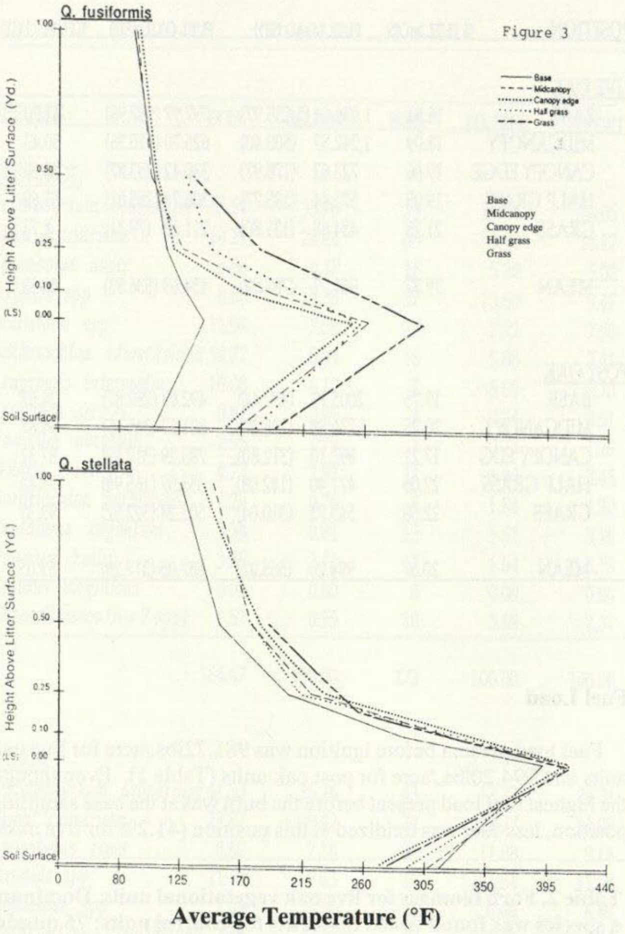

Figure 3. Temperature profiles. Average temperatures represent the mean of 48 readings (three slides in each of four directions from four different trees) at each vertically stratified level above litter surface (LS) for each position.

Fuel Moisture

A two-way ANOVA (Sokal and Rohlf, 1981) on initial fuel moisture readings indicated that there was no significant difference in fuel moisture between tree pairs or between treatments. A separate two-way ANOVA without Replication on each treatment also indicated no difference in fuel moisture readings between unit pairs or between positions. Fuel moisture samples obtained from control units immediately prior to the fire were therefore assumed to be indicative of fuel moisture conditions in vegetational burn units at time of ignition. Resampling was conducted only in controls just prior to ignition to minimize disturbance. Average fuel moisture was 20.4 and 19.4% in live oak and post oak vegetational units, respectively (Table 1).

Table 1. Fuel variables for live oak and post oak vegetational units. Fuel moisture reported as percent dry weight; fuel load and fuel oxidized reported in lbs./acre. SD stands for ± 1 standard deviation.

POSITION	% FUEL MOIS	FUEL LOAD (SD)	FUEL OXID (SD)	%FUEL OXID
LIVE OAK				
BASE	18.81	1,936.64 (1,255.97)	797.97 (987.96)	41.20
MIDCANOPY	18.09	1,242.57 (500.40)	626.70 (610.36)	50.43
CANOPY EDGE	19.66	723.62 (178.97)	330.42 (253.87)	45.66
HALF GRASS	19.05	571.44 (185.77)	306.74 (285.81)	53.68
GRASS	21.25	434.68 (131.80)	211.83 (79.11)	8.73
MEAN	19.37	981.72 (787.87)	454.69 (536.93)	46.32
POST OAK				
BASE	19.75	2005.11 (437.44)	492.69 (282.87)	24.57
MIDCANOPY	20.25	1,236.88 (238.27)	801.27 (345.65)	64.87
CANOPY EDG	17.22	897.10 (312.80)	783.29 (317.39)	87.31
HALF GRASS	22.06	471.40 (142.08)	355.57 (165.94)	75.43
GRASS	22.58	543.72 (310.04)	502.24 (322.52)	92.37
MEAN	20.37	994.20 (565.02)	587.05 (317.20)	59.05

Fuel Load

Fuel load present before ignition was 981.72lbs./acre for live oak units and 994.20lbs./acre for post oak units (Table 1). Even though the highest fuel load present before the burn was at the base sampling position, less fuel was oxidized at this position (41.2% for live oaks, 24.6% for post oaks) than any other position. This was caused by the splitting of the fire front at the base of these trees resulting in small unburned areas on the opposite sides of their trunks (Fonteyn et al. 1984). Only half of the fuel was oxidized (46.3% for live oaks, 59.1% for post oaks). Actual weights of fuel oxidized were greater under tree canopies than in grassland positions (Table 1).

Forbs and Grasses

There was a larger increase (63.7%) in mean forb biomass collected from burn units than from control units. A two-way ANOVA on forb biomass collected from live oak units indicated that burning caused a notable ($p=0.07$) change in forb biomass, whereas pair number and interaction were both insignificant ($p>0.10$). A two-way ANOVA on forb biomass from post oak units indicated that burning caused a significant ($p=0.01$) change in forb biomass; pair number was also significant ($p=0.02$),whereas interaction was insignificant ($p > 0.10$).

The increase in forb biomass (48.1) in live oak burn units was due primarily to **Desmanthus velutinus** and **Smila bonanox.** Although two other major species, **Tragia neptaefolia** and **Carex** spp., showed a change in relative dominance, there was little change in biomass (Table 2). The increase in forb biomass in post oak burn units (78.4%) was also primarily due to **D. velutinus** and **S. bonanox**. The biomass of T. neptaefolia increased slightly rather than decreased; **Carex** spp. decreased (Table 3).

Burn units showed a decrease in species richness of forbs. In live oak units, 22 forb species occurred in the control units and 17 in burn units. Three important species, **Rhynchosia texana, Abutilon icanum** and **Lespedeza procumbens,** did not occur in burn units (Table 2). There was also a decrease in species richness in forbs in post oak burn units: 25 species occurred in control units and 21 burn units (Table 3).

Mean grass biomass from live oak burn units decreased 28%. Even though a two-way ANOVA showed treatment effects to be significant, so also were pair number and interaction. Any clear difference due to treatment alone was obscured because of the large

Table 2. Forb biomass for live oak vegetational units. Dominance in lbs./acre. Frequency represents the number of quadrats in which a species was found (n=65 quadrats for control units; 75 quadrats for burn units). Importance is the mean of relative dominance and relative frequency.

SPECIES	DOM	REL DOM	FREQ	REL FREQ	IMPORT
CONTROL					
Desmanthus velutinus	4.12	31.81	14	10.22	21.01
Tragia neptaefolia	2.19	16.91	55	40.15	28.53
Carex sp.	3.32	25.63	25	18.25	21.94
Smilax Bonanox	0.71	5.48	5	3.65	4.56
Rhynchosia texana	0.20	1.54	2	1.46	1.50
Torilis arvensis	0.01	0.07	2	1.46	0.76
Abutilon icanum	0.06	0.46	1	0.73	0.59
Phyllanthus polygonoides	0.69	5.32	7	5.11	5.21
Oxalis dillenii	0.08	0.61	5	3.65	2.13
Lespedeza procumbens	0.54	4.16	6	4.38	4.27
Other Forbs (12 spp)	0.97	7.49	15	10.95	9.22
	12.95	100.00	137	100.00	100.00
BURN					
Desmanthus velutinus	9.50	49.63	29	16.02	32.82
Tragia neptaefolia	1.80	9.40	67	37.02	23.21
Carex sp.	3.01	15.73	41	22.65	19.19
Smilax Bonanox	2.85	14.89	7	3.87	9.37
Rhynchosia texana	0.00	0.00	0	0.00	0.00
Torilis arvensis	0.05	0.26	1	0.55	0.40
Abutilon icanum	0.00	0.00	0	0.00	0.00
Phyllanthus polygonoides	0.22	1.15	10	5.52	3.33
Oxalis dillenii	0.03	0.16	5	2.76	1.45
Lespedeza procumbens	0.00	0.00	0	0.00	0.00
Other Forbs (n = 10spp)	1.68	8.78	21	11.60	10.19
	19.14	100.00	181	100.00	100.00

Table 3. Forb biomass for post oak vegetational units. Dominance in lbs./acre. Frequency represents the number of quadrats in which a species was found (n=76 quadrats for control units; 79 quadrats for burn units). Importance is the mean of relative dominance and relative frequency.

SPECIES	DOM	REL DOM	FREQ	REL FREQ	IMPORT
CONTROL					
Desmanthus velutinus	5.45	39.66	27	17.20	28.43
Tragia neptaefolia	1.16	8.44	47	29.94	19.19
Carex sp.	4.33	31.51	34	21.66	26.58
Smilax Bonanox	0.07	0.50	5	3.18	1.84
Rhynchosia texana	0.68	4.94	4	2.55	3.74
Torilis arvensis	0.00	0.00	0	0.00	0.00
Abutilon icanum	0.57	4.14	2	1.27	2.70
Phyllanthus polygonoides	0.15	1.09	4	2.55	1.82
Oxalis dillenii	0.07	0.50	4	2.55	1.52
Lespedeza procumbens	0.50	3.63	3	1.91	2.77
Other Forbs (n = 16 spp)	0.72	5.24	27	17.20	11.22
	13.74	100.00	157	100.00	100.00
BURN					
Desmanthus velutinus	9.05	36.92	37	16.67	26.79
Tragia neptaefolia	1.21	4.93	53	23.87	14.40
Carex sp.	3.68	15.01	6	16.22	15.61
Smilax Bonanox	3.19	13.01	11	4.95	8.98
Rhynchosia texana	3.54	14.44	18	8.11	11.27
Torilis arvensis	1.35	5.50	15	6.76	6.13
Abutilon icanum	1.18	4.81	10	4.50	4.65
Phyllanthus polygonoides	0.00	0.00	0	0.00	0.00
Oxalis dillenii	0.04	0.16	5	2.25	1.20
Lespedeza procumbens	0.00	0.00	1	0.45	0.22
Other Forbs (n = 12 spp)	1.22	4.97	36	16.22	10.59
	24.51	100.00	222	100.00	100.00

interaction term. This apparent decrease was due primarily to the two major species **Schizachorium scoparium** and **Stipa leucotricha.** Four other important species, **Sporobolus asper, Aristida** spp., **Panicum obtusum** and **Bothriochloa barbinodis**, increased; the latter two more than doubling their dominance in control units (Table 4). There was no significant difference in grass biomass between post oak control and burn units.

Table 4. Grass biomass for live oak vegetational units. Dominance in lbs./acre. Frequency represents the number of quadrats in which a species was found (n=65 quadrats for control units; 75 quadrats for burn units). Importance is the mean of relative dominance and relative frequency.

SPECIES	DOM	REL DOM	FREQ	REL FREQ	IMPORT
CONTROL					
Scizachyrium scoparium	55.54	33.76	39	14.34	24.05
Stipa leucotricha	40.21	24.44	65	3.90	14.17
Sporobolus asper	6.86	4.17	16	5.88	5.02
Aristida spp	8.80	5.35	37	13.60	9.47
Bouteloua spp	11.98	7.28	21	7.72	7.50
Bothriochloa edwardsiana	14.72	8.94	16	5.88	7.41
Eragrostis intermedia	10.08	6.12	2	8.09	7.10
Eriochloa sericea	0.81	0.49	2	0.74	0.61
Panicum obtusum	2.95	1.79	2	0.74	1.26
Hilaria berlangeri	4.73	2.87	11	4.04	3.45
Bothriochloa barbinodis	1.25	0.76	5	1.84	1.30
Leptoloma cognatum	1.34	0.81	15	5.51	3.16
Panicum hallii	3.56	2.16	11	4.04	3.10
Elymus virginicus	0.00	0.00	0	0.00	0.00
Other Grasses (n = 7 spp)	1.57	0.95	10	3.68	2.31
	164.47	100.00	272	100.00	100.00
BURN					
Schizachyrium scoparium	41.53	35.26	43	13.23	24.24
Stipa leucotricha	22.87	19.42	74	22.77	21.09
Sporobolus asper	8.60	7.30	36	11.08	9.18
Aristida spp	11.34	9.63	44	13.54	11.59
Bouteloua spp	7.49	6.36	21	6.46	6.40
Bothriochloa edwardsiana	2.55	2.16	5	1.54	1.84
Eragrostis intermedia	3.97	3.37	25	7.69	5.53
Eriochloa sericea	0.63	0.53	2	0.62	0.57
Panicum obtusum	6.85	5.81	4	1.23	3.51
Hilaria berlanger	1.69	1.43	18	5.54	3.48
Bothriochloa barbinodis	7.60	6.45	30	9.23	7.83
Leptoloma cognatum	0.58	0.49	11	3.38	1.93
Panicum hallii	0.46	0.39	4	1.23	0.82
Elymus virginicus	0.00	0.00	0	0.00	0.00
Other Grasses (n = 4 spp)	1.51	1.28	8	2.46	1.87
	117.75	100.00	325	100.00	100.00

Table 5. Grass biomass for post oak vegetational units. Dominance in lbs./acre. Frequency represents the number of quadrats in a which species was found (n=76 quadrats for control units; 79 quadrats for burn units). Importance is the mean of relative dominance and relative frequency.

SPECIES	DOM	REL DOM	FREQ	REL FREQ	IMPORT
CONTROL					
Schizachyrium scoparium	62.90	35.22	43	11.68	23.45
Stipa leucotricha	25.80	14.44	73	19.84	17.13
Sporobolus asper	28.54	15.98	32	8.70	12.33
Aristida spp	7.86	4.40	33	8.97	6.68
Bouteloua spp	7.86	4.40	26	7.07	5.73
Bothriochloa edwardsiana	9.36	5.24	39	10.60	7.92
Eragrostis intermedia	5.95	3.33	32	8.70	6.01
Eriochloa sericea	16.48	9.22	24	6.52	7.87
Panicum obtusum	6.76	3.78	53	3.66	3.72
Hilaria berlangeri	0.60	0.33	14	3.80	2.06
Bothriochloa barbinodis	1.51	0.84	3	0.82	0.82
Leptoloma cognatum	0.31	0.17	8	2.17	1.18
Panicum hallii	1.20	0.67	6	1.63	1.14
Elymus virginicus	2.14	1.19	3	0.82	1.00
Other Grasses (n = 7 spp)	1.19	0.66	19	5.16	2.91
	178.57	100.00	368	100.00	100.00
BURN					
Schizachyrium scoparium	46.71	25.56	35	8.93	17.25
Stipa leucotricha	31.18	17.06	79	20.15	18.60
Sporobolus asper	29.34	16.05	37	9.44	12.74
Aristida spp	4.57	2.50	36	9.18	5.84
Bouteloua spp	16.74	9.16	37	9.44	9.29
Bothriochloa edwardsiana	9.49	5.19	37	9.44	7.32
Eragrostis intermedia	5.43	2.97	27	6.89	4.92
Eriochloa sericea	19.89	10.88	22	5.61	8.24
Panicum obtusum	7.31	4.00	12	3.06	3.53
Hilaria berlangeri	0.42	0.22	5	1.28	0.74
Bothriochloa barbinodis	1.26	0.68	4	1.02	0.85
Leptoloma cognatum	0.15	0.08	8	2.04	1.05
Panicum hallii	0.43	0.23	7	1.79	1.00
Elymus virginicus	4.77	2.61	20	5.10	3.86
Other Grasses (n = 6 spp)	4.96	2.71	26	6.63	4.66
	182.74	100.00	392	100.00	100.00

Even though burn vegetational units showed a decrease in species richness of grasses, the change occurred in the relatively unimportant group 'other grasses'. Twenty grass species occurred in live oak control units, 17 in burn units. Twenty-two grass species occurred in post oak control units, 20 in burn units.

Standing Dead Biomass

Standing dead biomass for both groups was 3-4 times greater in control units than burn units. In live oak units, standing dead biomass was 61.12lbs/acre for burn units (31% of total standing crop) and 225.60 lbs/acre for control units (56% of total standing crop). In post oak units, standing dead biomass was 43.68lbs/acre for burn units (17% of total standing crop) and 145.38lbs/acre for control units (43% of total standing crop).

DISCUSSION

Temperature

Daubenmire (1968) noted considerable time has been spent developing techniques and instrumentation to record fire temperatures. Many of the recorded temperatures are not comparable, however, and are at best, relative temperatures that usually have not been positively related to the organisms in question (Vogl 1974). Vogl (1979) stated that highest temperatures are usually well above the ground at the apex of flames and are rapidly dissipated by winds. Davis and Martin (1960) found higher temperatures are usually produced at ground level by slower moving fires. This study indicated that the highest temperatures at all postions (under the canopy of trees and in the grassland) occurred at the litter surface where fuel was oxidized. Temperatures above and below this level showed a substantial decrease.

Fuel

Response of minor vegetation following fire is influenced by added nutrients. Van Wagner and Methven in 1978 found nutrient effects are probably best gaged by the quantity of organic matter ashed. Quanitity of fuel oxidized is a clearer indicator of added nutrients than fuel load or percent fuel oxidized because the quantity of fuel oxidized is directly related to the amount of nutrients added to the soil, whereas the percent of fuel load that is oxidized varies with the fuel load present. In the present study, for example, even though percent fuel oxidized varied from mid-canopy to canopy edge under post oaks, the amount of fuel oxidized was approximately the same.

Vegetation

Vegetative growth of perennial species on most postburn sites occurs more rapidly and vigorously than growth on unburned sites (Duval 1962). In the present study, all important species except **Torilis arvenis** were perennials, and prescribed burning enhanced some species and decreased others.

Forbs: Late-spring burning significantly reduces the biomass of perennial forbs, whereas burning in winter and early spring favored them (Towne and Owensby 1984). Garza and Blackburn (1985) found that forb basal cover was low and similar for burned and unburned plots. They also reported early winter burning favored the growth of forbs, whereas spring burning favored the production of grasses. The present study indicated winter burning increased forb biomass and did not adversely affect grass production.

Grasses: Whisenant, et al. (1984) determined Texas wintergrass (**Stipa leucotricha**) increased more after fall burning than after spring burning and speculated that the increase was due to a reduction in competition from annual forbs and grasses. They found that spring burning, however, generally favored perennial grasses. Significantly higher production of sideoats grama (**Bouteloua curtipendula**)was found on burned than unburned plots (Schacht and Stubbendieck 1985). The present study determined that **Stipa leucotricha** and **Bouteloua** spp. biomass decreased in live oak vegetational units and increased in post oak units after winter burning. However, winter burning seemed to decrease total grass biomass in live oak vegetational units, but not in post oak vegetational units.

Standing dead biomass: Trilica and Schuster (1969) noted burning reduced forage yields for two years. Other determined that any differences in total foliar cover were due to standing dead materials (Garza and Blackburn 1985). Differences in total biomass in the present study may also be attributable to standing dead materials, because total standing crop decreased 65%, whereas total live vegetation decreased only 7% in control and burn units. Cox (1985) determined that even though standing dead biomass was the predominant vegetational component for most of the year in a **Sporobolus wrightii** grassland in Arizona, it desappeared following precipatation. In the present study, the decrease in standing dead biomass by burning may have contributed to the increase in forb biomass by reducing cover, and thus increasing insolation, and by the addition of available nutrients to the soil.

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