EFFECTS OF BRUSH PILE BURNING ON SOIL NUTRIENTS AND MICROBES IN THE EDWARDS PLATEAU OF TEXAS

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ABSTRACT

On the Edwards Plateau of Texas, Juniperus Ashei piles can occupy as much as 15% of the pasture land and therefore decrease stocking rates. These brush piles are often removed by high intensity fires. Revegetation of burned areas is a very slow process taking several years to occur. A study was undertaken to determine the effect of brush pile burning on soil nutrients and microbes. After burning, the amount of soil nutrients either remained the same or increased. The microbial population was reduced.

INTRODUCTION

On the Edwards Plateau of Texas, range managers use bulldozers equipped with chain drags and other implements to clear stands of cedar, **Juniperus Ashei** Buchh. Once uprooted, individual cedar trees are stacked in large brush piles. These brush piles can cover 15% of the pastureland, and therefore decrease stocking rates (Kerr Wildlife Management Area, unpublished data). Range managers remove them with high intensity fires.

Studies of brush pile burns have been conducted in southeastern Utah. Buckhouse and Gifford (1976a,b) investigated sediment production and infiltration rates, and analyzed the chemical composition of overland flow. Gifford (1981) found that debris pile burning had a greater effect on soils under burned debris piles than in adjoining grassland. He reported that the first year after burning there is a significant increase in electrical conductivity, phosphorus, potassium, percent nitrogen, and percent organic carbon to a depth of 4.0 in.

No studies of the effect of brush pile burning on the edaphic enviroment have been conducted in Texas. Therefore, a study was initiated to determine the effects of brush pile burning on soil microbes and on soil pH, total carbon, total nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron, manganese, copper, and sodium to a depth of 1.0 in.

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MATERIALS AND METHODS

Study Area

The study was conducted in Buck Pasture on the Kerr Wildlife Management Area (KWMA), Kerr County, Texas. KWMA, a 6500 ac. facility of the Texas Parks & Wildlife Department enclosed entirely by an 8-ft. deer-proof fence, is centrally located on the Edwards Plateau at an elevation of 1899 to 2201 ft. It consists of 15 pastures and ten 96-ac. research plots. The topography is rolling hills. Mean annual temperature is64°F with a January average of 48°F and a July average of 80°F (Hunter, 1983). The plant community was described by Hunter (1983) and Cross (1984).

The soil series of Buck Pasture is Eckrant (Lithic Haplustoll); the range site is Low Stoney Hill. Soils beneath brush piles are clay textured with Cation Exchange Capacities (CEC) of 38 meq/100 g. (CEC was determined by the method developed in 1977 by Polemio and Rhodes). Soil pH was measured as a 1:2, soil:water suspension. In 1972, most of the cedar (**Juniperus Ashei**) and other brush in this pasture was cleared by chaining and stacked into piles by bulldozers. Five brush piles of various sizes were selected in 1983; they exhibited minimal decomposition (Table 1). The piles were burned during Spring 1983 on 23 Feb., 2, 30, and 31 Mar., and 15 Apr. Relative humidity, air temperature, and wind speed were recorded at the time of brush pile burning (Table 2).

Temperature and Heat Production Measurements

Soil temperatures of the brush piles were measured using pairs of thermocouples. One of each pair was placed at the soil surface and the other at a depth of 1 in. In each sample pile, 1 pair of thermocouples was placed in the center and 1 pair at each cardinal position within the pile area. Temperature readings were taken every 2 min. for 5 h. Initial temperature readings were taken immediately after ignition.

Total heat production of each brush pile was determined using water-can fire analogs described by George (1969) and Gifford (1981). Four cans were placed within each brush pile area, 1 adjacent to each surface thermocouple. An additional can was placed outside of the pile to determine water loss by evaporation. Calculations to determine total heat production were based on Gifford (1981).

Soil Collection and Analyses

Samples were collected before burns, immediately after burns, and one year later. Litter was removed before sampling and samples were taken to 2.5 in. depths under each brush pile and in adjacent grassland sites. Samples were placed in paper sacks, air-dried and analyzed at Southwest Texas State University and the Extension Soil Testing Lab at Texas A&M University, College Station, Texas.

Total carbon was determined by wet combustion with chromic acid (Allison, 1982). Total nitrogen was determined by the micro-Kjeldahl method described by Bremner (1982). Acetanilide (T.H.A.M.) was used as a check of recovery of organic nitrogen. Samples were digested by block digestion, and a LabConCo distillation apparatus was used to distill the digested soil samples.

Exchangeable potassium, sodium, calcium, and magnesium were analyzed by the ammonium acetate method (Thomas, 1982). Phosphorus was analyzed according to the method described by Olsen and Sommers (1982) where the Weak Bray extractant (0.025 N HCL + 0.03 N NH_4F) was used in a 50:1 solution/soil ratio. Zinc, iron, manganese and copper were extracted with DTPA (Linsay and Norvell, 1978).

Microbe Analysis

Samples were taken from beneath 5 brush piles and from grassland adjacent to the piles. Brush-pile samples were collected immediately before and after burning; grassland samples were collected before pile ignition. Four sub-samples each from each brush pile and adjacent grassland were mixed in paper bags and refrigerated. Percent moisture was determined from separate samples collected immediately before and after burning (Baccus, 1984).

A plate-count method was used to determine microbial populations (Allen, 1951). A sterile medium was inoculated with saline dilution of the soil samples and poured into Petri plates. After five days of incubation at 86°F, microbial colonies were counted.

RESULTS AND DISCUSSION

Temperature and Heat Production

Brush pile 2, one of the smallest in volume (28.5 yd^3) and fuel density, had the highest surface soil temperature (833°F). The highest subsurface soil temperature was recorded for brush pile 5, which was one of the largest in size and highest in density (Table 1). Gifford (1981) reported a mean high temperature of 550°F at 1.0-in. soil depth beneath a pinyon-juniper pile. Brush pile 3 had median values of both volume and fuel density. Its soil surface temperature (684 to 932°F) had greater variation than the subsurface temperature (185 to 239°F).

The smallest brush pile, brush pile 4, with a volume of 27.2 yd^3 and a medium fuel density, had the highest energy release rate (Table 1). Gifford (1981) measured total energy expended at 46 locations within a burned pinyon-juniper debris site in Utah. In his study, one of the burned debris piles, composed of ">6 trees", released 1,126,900 to >1,598,400 calories. In the present study, brush pile 3, a medium-size pile, had an energy release rate of 464,692 +/- 337,311 cal./h. or a total energy release of 2,323,460 calories (Table 1).

Table 1. Physical description, burn temperature, and approximate energy release rates of brush piles (CI = 95%).

Brush Pile No	Volume (Yd^3)	Density of Fuel	Temperature (°F) Surface	1.0 in Depth	Energy Release Rate (cal./h.)
1	134	Low	626 ± 293	223 ± 108	$387,339 \pm 226,693$
2	29	Low	833 ± 171	174 ± 52	$351,870 \pm 113,251$
3	39	Medium	808 ± 156	212 ± 59	$464,692 \pm 337,311$
4	27	Medium	649 ± 120	172 ± 70	$695,542 \pm 953,424$
5	129	High	714 ± 70	291 ± 223	$461,098 \pm 232,239$

Total Carbon

Neuenschwander et al. (1974) reported that soil organic carbon in tobosagrass (**Hilaria mutica** Benth.) communities increased after a March burn and returned to normal levels within 6 years. Ueckert et al. (1978) reported a significant increase in soil organic carbon within 2 months after a burn in the upper 1.5 in. of soil. They suggested the increase was the result of surface cracking of clay soil, resulting from low precipitation, that promoted the incorporation of unburned charcoal, ash and residual litter into the soil surface layers. Gifford (1981) reported a significant increase in organic carbon at 1.0-2.0, 2.0-3.0, and 3.0-4.0 in. soil depths on burned debris sites. He did note, however, a small yet significant, decrease in organic carbon at the 0-1.0 in. soil depth. In the present study, burning did not significantly decrease total carbon under the brush piles. Before burning, perhaps due to litter from the brush piles, soils beneath these piles contained significantly higher percentages of total carbon than grassland soils (Table 3). The decrease in total carbon beneath brush piles after burning may indicate a loss of organic carbon by combustion.

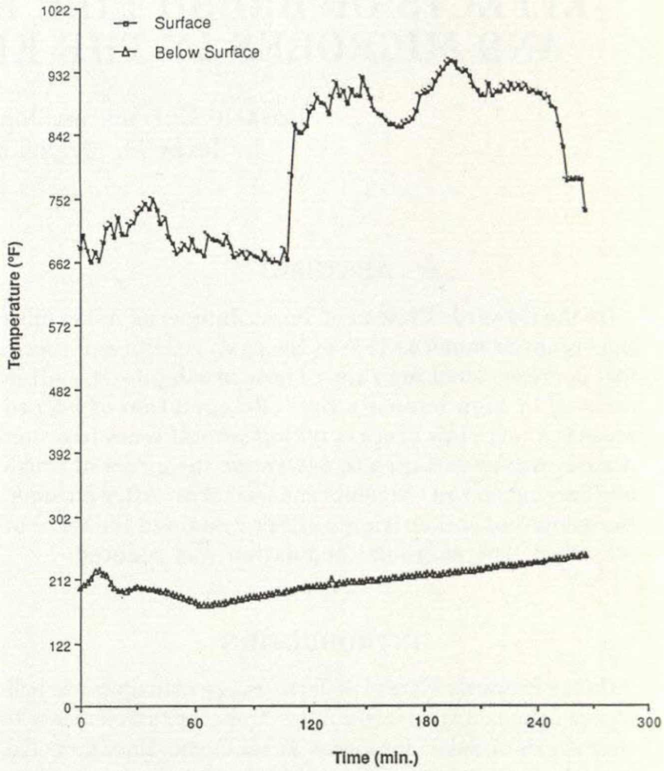

Figure 1. Soil temperatures at surface and 1.0-in. depth in a 1983 spring burn of brush pile no. 3 at Kerr Wildlife Management Area.

Table 2. Weather data of 5 brush pile burns. Data ranges are based on observations taken every hour for a period of 5 hours for every burn.

Date of Burn	Brush Pile No.	Relative Humidity (%)	Ambient Temperature (°F)	Wind Speed (Mi/Hr)	Wind Direction
23 Feb 83	1	28 - 37	66 - 75	----	----
02 Mar 83	3	29 - 54	71 - 79	0 - 14	S
30 Mar 83	4	35 - 45	64 - 79	0 - 10	N - NW
31 Mar 83	2	19 - 54	72 - 91	0 - 14	SE - SW
15 Apr 83	5	9 - 16	63 - 81	0 - 8	SE - NE

----denotes no observations.

Nutrients

Total nitrogen. Increased total nitrogen and nitrate-nitrogen after burning have been observed in Virginia, Montana, and Utah (Christensen, 1976, Nimir and Payne, 1978, and Gifford, 1981). Sharrow and Wright (1977) reported a decrease in total nitrogen at 1.0-2.0 and 2.0-5.0 in. soil depths in burned tobosagrass communities near Colorado City, Texas. Buckhouse and Gifford (1976b) observed no significant differences in soil nitrate-nitrogen after chaining or grazing and burning. In the present study there were no significant differences in total nitrogen between grassland and brush pile soils before or after burning (Table 3).

Phosphorus. Buckhouse and Gifford (1976b) observed a significant increase in phosphorus following burning in the debris-in-place treatment. Gifford (1981) reported a significant increase in phophorus in debris and grassland sites one year after burning. Phosphorus also increased significantly under brush piles after burning in this study. Brush pile soils contained significantly higher amounts of phophorus than grassland soils one year after burning indicating cedar litter is a good source of this element.

Potassium. Buckhouse and Gifford (1976b) observed a significant increase in potassium on a debris-in-place site in southeastern Utah. This increase persisted a full year after burning. Ueckert et al. (1978) reported significant increases in potassium levels in the upper 1.0-in. of soil in a mesquite-tobosagrass community after burning. Gifford (1981) reported a significant increase in potassium for two years after burning in both debris piles and adjacent grassland sites. However, after one year, the increase in potassium was more pronounced in debris pile soils than grassland soils. Differences the second year were less noticeable. In the present study, soil potassium in brush pile soils did not change significantly immediately after burning, but did have a significant increase one year later. However, there were no significant differences in potassium between grassland and brush pile soils one year after burning.

Calcium, Magnesium, Zinc, Iron, and Maganese. Buckhouse and Gifford (1976b) studied the effects of grazing and debris burning on pinyon-juniper sites in Utah. They found significant yearly variations in calcium levels, but no significant differences between treatments. Christensen (1976) studied short-term effects of mowing and burning on soil nutrients in two vegetational types in Big Meadows, Shenandoah National Park, Virginia. Significant increases in potassium, calcium, and magnesium occurred in the burn treatment; there were no detectable changes in these nutrients in the mowed treatment. There were also no detectable changes in these nutrients in the present study.

Copper. In brush pile soils, copper increased significantly immediately after burning. One year after the burn, the amount of copper in brush pile soils remained significantly higher than before burning.

Sodium. Buckhouse and Gifford (1976b) reported significant yearly fluctuations in sodium concentrations after separate treatments of debris burning and grazing in southeastern Utah. They found no differences in sodium concentrations between treatments. Ueckert et al. (1978) reported an increase in sodium after burning tobosagrass communities but detected no differences between burned and unburned plots. The present study parallels Ueckert et al. (1978) in that sodium increased one year after burning in both grassland and brush pile soils, but no significant differences were noted between grassland and brush pile soils.

Soil Bacteria and Actinomycetes

Burning greatly reduced the number of soil bacteria and actinomycetes under brush piles. Before the burn, brush pile soils contained 2.6 +/- 0.5 X 10^6 microbes per gram of soil. Immediately after the burn the number of microbes was 0.37 +/-0.9 X 10^6 microbes per gram of soil. Grassland soils contained 2.4 +/-0.5 X 10^6 microbes per gram of soil. The percent moisture in soil under brush piles was 25.1 +/-8.7 before burning and 11.7 +/-9.7 immediately after burning. The high heat from burns not only severly dried soils but also exposed those initially beneath brush piles to drying conditions.

Table 3. Soil nutrients to a depth of 1 in. (CI = 95%).

Nutrient	Grassland		Under Brush Piles		
	Before the burn	One Year After the burn	Before the burn	Immediately Aftertheburn	One Year After the burn
Total C (%)	8.0 ± 2.2	----	10.9 ± 1.60	9.4 ± 1.4	----
Total N (%)	0.53 ± 0.09	0.54 ± 0.23	0.68 ± 0.13	0.62 ± 0.07	0.56 ± 0.07
Phosphorus (ppm)	10.0 ± 18.2	28.0 ± 18.2	16.0 ± 4.8	40.0 ± 14.7	85.0 ± 22.2
Potassium (ppm)	478 ± 69.2	497 ± 78.2	470 ± 69.3	469 ± 54.5	606 ± 95.0
Calcium (× 10^3 ppm)	29.3 ± 10.2	38.0 ± 19.5	31.2 ± 16.5	30.2 ± 13.4	37.3 ± 13.9
Magnesium (× 10^2 ppm)	9.7 ± 3.0	10.7 ± 1.50	8.36 ± 2.30	8.36 ± 2.60	10.0 ± 2.50
Zinc (ppm)	0.93 ± 0.12	1.04 ± 0.52	1.43 ± 0.24	1.44 ± 0.27	1.21 ± 0.34
Iron (ppm)	6.94 ± 0.71	6.57 ± 1.30	8.13 ± 1.50	7.69 ± 0.52	7.00 ± 1.10
Manganese (ppm)	9.54 ± 0.87	10.0 ± 0.00	10.0 ± 0.0	10.0 ± 0.0	10.0 ± 0.0
Copper (ppm)	0.26 ± 0.06	0.31 ± 0.03	0.32 ± 0.08	0.73 ± 0.19	0.53 ± 0.09
Sodium (ppm)	103 ± 5.70	126 ± 0.30	110 ± 10.0	112 ± 7.90	134 ± 9.60
pH	7.90 ± 0.09	7.90 ± 0.09	7.80 ± 0.08	7.80 ± 0.08	7.80 ± 0.08

----denotes no observations.

CONCLUSIONS

Revegetation of cedar piles after burning is a very slow process and takes several years to occur. Results from this and other studies indicate that after burning, the amount of soil nutrients either remains the same or increases. Thus, nutrients cannot be limiting the re-establishment of vegetation in burned sites. Other factors such as destruction of the seed bank by the high intensity burns or lack of seedling establishment in the resultant rapidly drying soil conditions may be responsible for prolonging revegetation.

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