SOME ENVIRONMENTAL RESPONSES TO BURNING AND THEIR EFFECTS ON FLOWERING IN *ANDROPOGON GERARDI*

by

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B. A., Midland Lutheran College, 1977

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas
1979

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ACKNOWLEDGEMENTS

I would like to thank my major professor, Dr. Michael P. Johnson, for his advice, guidance, and support throughout the study. The other members of my committee, Dr. Peter P. Wong and Dr. Lloyd C. Hulbert critically reviewed the manuscript and offered helpful suggestions. Dr. Peter Wong provided the Weston photometer and the equipment and advice needed to determine soil nitrogen. Dr. Lloyd C. Hulbert provided the soil core sampler and obtained the mowers and equipment needed for burning. Dr. H. Derrick Blocker loaned me the gasoline powered vacuum. Special thanks goes to Joe Gelroth and especially Diane Harakal and Jerry Wilson for their help in setting up the treatments, and later in determining flowerstalk production. My husband, Gene, deserves special thanks for his help in setting up the treatments and in every phase of data collection and analysis, and for providing encourgement and support when it was needed most.

INTRODUCTION

Fire plays an important role in maintaining the tallgrass prairie. It has many effects on the warm season grasses, including *Andropogon gerardi*. Many studies have shown that burning increases the yield or amount of herbage on prairie sites (Aikman, 1955; Aldous, 1929; Aldous, 1934; Curtis and Partch, 1948; Hadley and Kieckhefer, 1963; Hulbert, 1969; Kucera and Ehrenreich, 1962; McMurphy and Anderson, 1965; Old, 1969; Owensby, Paulsen, and McKendrick, 1970). Earlier resumption of growth on burned sites was observed in studies by Aikman (1955), Aldous (1934), Ehrenreich (1959), Ehrenreich and Aikman (1963), and Kucera and Ehrenreich (1962). Other effects of burning include increases in: stem density (Dokken and Hulbert, 1978; Hulbert, 1969), plant height (Dix and Butler, 1954; Ehrenreich and Aikman, 1957; Ehrenreich and Aikman, 1963; Hulbert, 1969), nutritive content of vegetation (Aldous, 1934), caloric content (Hadley and Kieckhefer, 1963), cover, and vigor of grasses (Kucera and Koelling, 1964). Changes in root biomass have been observed as a result of changes in burning frequency (Hadley and Kieckhefer, 1963).

An increase in flowering in many warm season grasses, including *A. gerardi*, (number of flowerstalks per unit area or percentage of plants flowering) has been found in many studies (Aikman, 1955; Blake, 1935; Burton, 1944; Cornelius, 1950; Curtis and Partch, 1948; Dix and Butler, 1954; Ehrenreich, 1959; Ehrenreich and Aikman, 1957; Ehrenreich and Aikman, 1963; Hadley and Kieckhefer, 1963; Kucera and Ehrenreich, 1962; Old, 1969). Studies by Aikman (1955), Ehrenreich and Aikman (1963), and Hadley and Kieckhefer (1963) have shown that flowering begins earlier on burned plots. Ehrenreich (1959) observed taller flowerstalks on burned plots.

Several studies have been done which have shown that removal of the litter increases flowerstalk production (Aikman, 1955; Curtis and Partch, 1950; Ehrenreich, 1959; Kucera and Ehrenreich, 1962; Old, 1969). Aikman (1955), Ehrenreich (1959), and Kucera and Ehrenreich (1962) compared burned and unburned plots, and attributed the increase in flowerstalk production to the removal of litter by fire. Kucera and Ehrenreich (1962) further concluded that the increase was due to the increased soil temperature, decreased shading and increase in available nutrients caused by increased microbial activity following litter removal. Ehrenreich (1959) states that the increase in soil temperature resulting from litter removal caused the increase in flowerstalk production. Curtis and Partch (1950) used several treatments involving litter removal, addition of ash, and direct heat of the fire. They concluded that litter removal was most important and ash added a small further increase. However, they did not consider heat differences important even though burned plots produced more flowerstalks than unburned plots with all other conditions the same. Old (1969) thought that litter removal was important because of the increased temperatures that it caused. She found that ash was not important in increasing flowerstalk production. Old (1969) also found that factors affecting the early growth of the plant were more important in determining flowerstalk production than those affecting later plant growth. Dokken and Hulbert (1978) found that all stem density, including flowerstalks, was related to the amount of standing dead present.

Fire has several direct effects on the environment: 1) it removes standing dead, litter, and any living material present; 2) it provides ash from the organic material burned; 3) it causes a color change in the surface exposed to sunlight; and, 4) it produces heat. Each of these direct effects may in turn have several indirect effects on the system. The objective of this study was to determine the relative importance of these direct effects in increasing flowerstalk production in *Andropogon gerardi*.

The organic material present before burning may have several inhibitory effects. It may offer physical resistance to plants growing through it. Burning removes the organic material and may remove these inhibitory effects. Removal of the organic material may have several other effects as well. Hulbert (1969), Old (1969), and Steiger (1930) have found an increase in the amount of light reaching the soil surface following removal of standing dead, litter, and mulch. In addition to removing the inhibitory effects of shading, the greater absorbtion of radiation at the soil surface also serves to increase daytime temperatures. Ehrenreich (1959) and Hopkins (1954) found that soil temperature was inversely related to the amount of litter and duff. Ehrenreich and Aikman (1963), Hensel (1923), Hulbert (1969), Kucera and Ehrenreich (1962), Old (1969), Steiger (1930), and Weaver and Rowland (1952) have found increases in mean temperatures at the soil surface. Hulbert (1969) has found these increases to a depth of 2 dm. Hensel (1923) found increases in both maximum and minimum temperatures, while Kucera and Ehrenreich (1962) have found an increase in maximum temperature but a decrease in minimum temperature. Ehrenreich and Aikman (1963) found an increase in maximum air temperature and a decrease in minimum air temperature over burned plots. In all cases the temperature differences between daytime maximums and night time minimums were more extreme on burned plots. Without the insulating effects of the litter more heat can be absorbed during the day, this raising daytime temperatures, but more heat may also be radiated at night, and thus night time temperatures may be lower. Removal of the organic matter causes a decrease in soil moisture (Aldous, 1934; Anderson, 1965; Ehrenreich and Aikman, 1963; Elwell, Daniel, and Fenton, 1941; Hopkins, 1954; Hulbert, 1969; McMurphy and Anderson, 1963; McMurphy and Anderson, 1965; Russel, 1939; Steiger, 1930) supposedly by increased runoff, increased transpiration, and increased evaporation.

During burning the organic matter is broken down and provides ash to the system. The ash may be rich in limiting nutrients, or at least release these nutrients to the system. The most limiting nutrient is often nitrogen. Much of the nitrogen may be lost as volatile gases at the time of burning. However, the available nitrogen may be increased. Fowells and Stephenson (1934) have found an increase in available nitrogen in forest soils following burning. They found an increase in the rate of nitrification which led to an increase in the available soluble mineral nutrients for some time. In addition, they have found that the ash and partially burned organic matter are more easily decomposed than the organic matter before burning. This further increases the amount of available nitrogen in the system.

Burning causes a color change in the surface exposed to sunlight. The organic material is light in color, the soil surface is dark, and the ash makes the surface even darker. The darker surface absorbs more light than the organic material (Ehrenreich and Aikman, 1963) and therefore the soil temperature may be increased (Ehrenreich, 1959; Ehrenreich and Aikman, 1963). This increase in soil temperature may increase the rate of evaporation (Ehrenreich and Aikman, 1963). It may also increase transpiration by increasing the growth rate of plants. These would also lead to a decrease in soil moisture.

Finally, burning produces heat which kills many plant species, mainly cool season and woody species. Aldous (1929, 1934), Kucera and Koelling (1964), and Owensby and Anderson (1967) found that late burning is effective in removing brush and weeds from prairie and is favorable to A. gerardi. Curtis and Partch (1948) have found that burning greatly reduces the competitive ability of blue grass (Poa pratensis and P. compressa) while favorably affecting A. gerardi. Hensel (1923) found that weedy species decreased after burning. Kucera, Ehrenreich, and Brown (1963) and Bragg and Hulbert (1976) found that burning would control woody species and keep them from invading the prairie. Owensby et al. (1973) have found that burning restricts red cedar. These include many of the competitors of A. gerardi. Some species may produce allelopathic chemicals (Hulbert, 1978; Rice and Parenti, 1978). Many of these are heat labile and would be destroyed by burning. The heat of the fire may increase the loss of volatile nitrogen from the system, but it may also stimulate microbial decay of the organic matter left. Fowells and Stephenson (1934) found an increase in microbial activity for some time following a fire in a forest ecosystem. This increase in microbial activity would help to offset the loss of volatile nitrogen and might even lead to an increase in available nitrogen.

METHODS

Experimental Design

The study was designed to be a three-way factorial experiment. The treatments used to test the effects of fire include the first nine treatments in Table 1. These treatments include all possible combinations of the presence and absence of litter, burning *per se*, and ash. By using all possible combinations of these factors, the effects of each factor can be determined regardless of the other factors present. Interactions between two factors can also be detected. If interactions are present and not detected the effects of some factors may be masked, or the effects of one factor may be attributed to another factor. In this study "burning *per se*" will be used to mean some intrinsic effects of fire other than litter removal, addition of ash, and color change, while "burning" will be used to mean the treatment of fire applied to some plots and its effects. "Burning *per se*" therefore refers to those effects resulting from burning which cannot be attributed to litter removal, color change, or ash production.

Study Site

The study was carried out on the southern part of Konza Prairie Research Natural Area (KPRNA) located 12 km south of Manhattan, Kansas. The area encompasses 3487 hectares of native tallgrass prairie in the Kansas Flint Hills. The area was purchased by the Nature Conservancy, and is managed as a research area by the Division of Biology at Kansas State University. The southern 371 hectares in which this study was done were acquired in 1971.

The area includes several burning treatments with one treatment on each watershed. The plots for this study were located within one of these treatments, treatment 4G (management plan of 28 December 1977). The area was last burned 30 April 1975.

Table 1. Summary list of treatments used and their abbreviations.

Treatment	Abbreviations
Unaltered control	LIT, STAND
Mowed, mulch left	MOW, MUL
Mowed, mulch left, ash added	MOW, MUL, ASH
Burned (late), ash left	BL, ASH
Burned (late), ash left, litter added	BL, ASH, LIT
Burned (late), ash removed	BL
Burned (late), ash removed, littered added	BL, LIT
Mowed, mulch removed	MOW
Mowed, mulch removed, ash added	MOW, ASH
Burned (early), ash left	BE, ASH
Burned (early), ash left, litter added	BE, ASH, LIT
Burned (early), ash left, sand added	BE, ASH, SAND

The plots were located on Tully soil, a fine, mixed, mesic Pachic Argiustoll. This is a lowland area bounded on the west by a ravine and on the north and east by a ridge (Fig. 1). The area was selected because it contained an area of Tully soil large enough to include all of the plots. This would reduce any variations between plots due to soil differences. It is dominated by A. gerardi and Sorghastrum nutans. Litter accumulation and standing dead were heavy, but woody vegetation in the area was rare. It was felt that any effects of litter removal would be more obvious in an area of heavy litter accumulation than in an area with little litter accumulation, such as annual burn areas.

Application of Treatments

The treatments were applied to square, 5 m x 5 m plots. A one meter strip of each side of the plots was not sampled to eliminate edge effects. All plots were separated by a 1.5 m wide mowed strip which served as a fire guard for burned plots and defined the borders of all plots. The plots were arranged in a checkerboard pattern with every other plot unused (Fig. 2). Since the area slopes from the ridge toward the ravine, every other plot was eliminated in an effort to reduce the possible effects of runoff from one treatment into another. In this way the proximal runoff for all treatments came from an unmodified plot.

Because the dead plant material cannot be added to burned plots and be the same as in the untouched control in this study other plots were mowed and the cut material left in place, with the intention that this litter will be the same as litter added to burned plots. Unfortunately, due to breakdown of the small sickle-bar mower which was used to cut the vegetation added to the burned plots, the mowed plots were cut with a rotary mower which cut the material into short pieces 5 to 10 cm long. This rotary-mower cut mater-

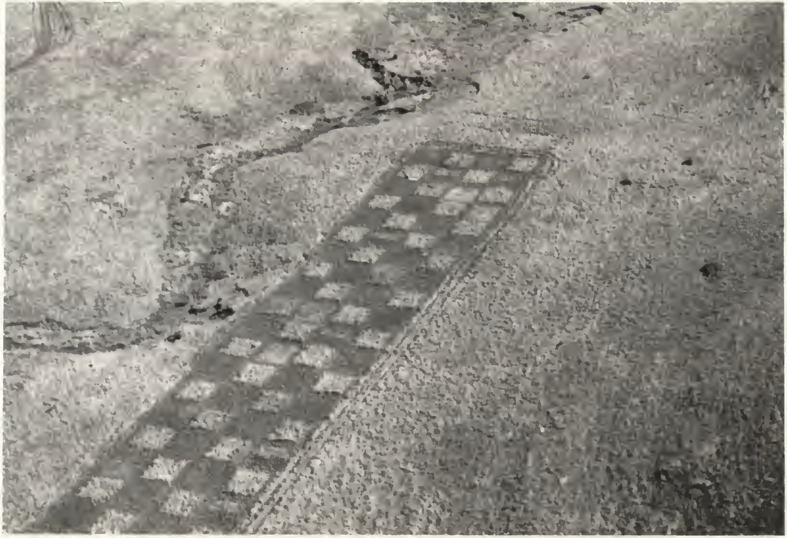


Fig. 1. Aerial photograph of plots on Konza Prairie Research Natural Area.

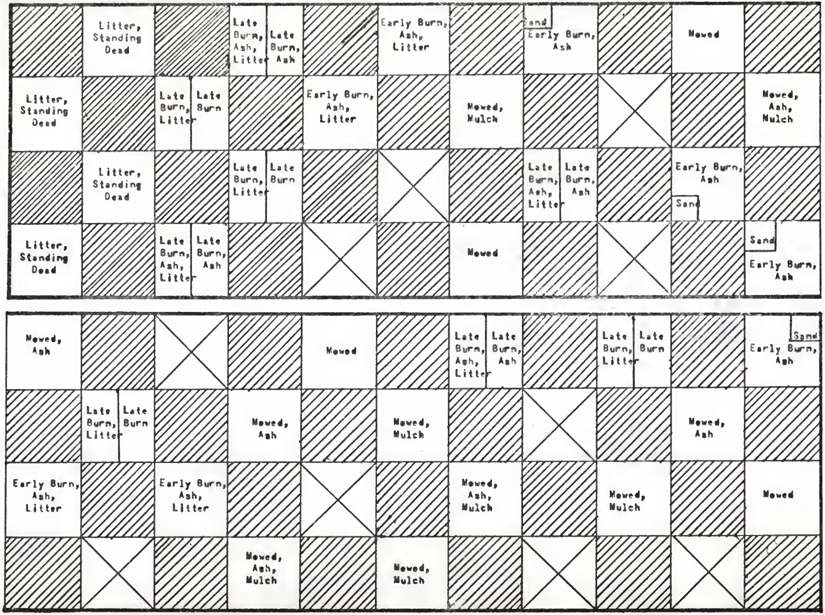


Fig. 2. Arrangements of plots and treatments within the grid. Factors listed in each treatment are factors present on that plot.

ial is called mulch; the sickle-bar cut material is called litter. Both matted down more than on the control, but the mulch quickly became more matted than the litter. Mulch and litter both were used to determine if the form of organic material had any effect, since no standing dead could be added back to the burned plots. It was felt that ash should be placed directly on the soil surface as it is in burned plots. The heavy accumulation of organic matter in the control plots, combined with strong winds at the time ash was applied, made this extremely difficult to do, so ash was not added to control plots.

Three other treatments were added to these original nine (Table 1). The plots originally planned for the three-way factorial experiment were burned 27 April 1978. However, a hard rain the following night made it impossible to vacuum the ash from these plots. A second set of plots was burned 11 May 1978. The ash was vacuumed from these plots the same day, and was added to the mowed plots on 13 May 1978. The early burned plots could then be used to determine the effects of the time of burning. When the second set of plots was burned there was not enough area to have full plots for each treatment. Therefore, late burned plots were done as split plots with litter on the north half of the plots. The area drains in an east to west direction so litter was placed on the north half of the plots to prevent drainage from one treatment into the next.

Sand was added to one corner (2 m x 2 m) of each of the early burned, ash left plots on 12 May 1978, so that some comparison of surface color could be made. A smaller plot size was used to minimize the area affected by sand after the study was completed.

Four replications of each treatment were used with the exception of: 1) mowed, mulch removed, ash added; and, 2) mowed, mulch left, ash added.

Only three replications of these treatments were used, since not enough ash was available to cover four replications of these treatments. The treatments were completely randomized to the plots (Fig. 2) through the use of a random numbers table. When the second set of plots was burned the plots originally planned for the unaltered controls were used. These controls were then added to the north end of each row. It was felt that it was more important to have the burning treatments randomized to the plots than the controls since the unused plots and the area surrounding the grid could be used as unaltered controls.

All mowed plots were mowed 26 April 1978 with a rotary blade mower. All burned plots were burned against the wind. Ash was removed by vacuuming with a gasoline powered vacuum. The mower used on the mowed plots mulched the organic material into small pieces 5 to 10 cm long. The organic material added to the burned plots had been cut with a sickle-bar mower and had not been mulched. It had been cut at 2 to 3 cm above the ground but was otherwise left intact. In both cases no standing dead was present; only litter or mulch was present, but the material in the burned plots was more erect and looser than that in the mowed plots. In the unaltered control plots both standing dead and litter were present. The sickle-bar mower was not used for all mowing because of equipment failure.

Variables Measured

Soil Moisture

Soil moisture was measured by taking a soil core 1.5 m deep. The core was divided into 15, 10 cm sections. Every other section (0 - 10 cm, 20 - 30 cm, 40 - 50 cm, 60 - 70 cm, 80 - 90 cm, 100 - 110 cm, 120 - 130 cm, 140 - 150 cm) was then weighed, oven-dried to a constant weight at 105°C, and reweighed. The percent moisture in each sample was calculated. Because of the large amount of work required per sample, and the large area trampled in sampling, samples were only taken once during the season and were only taken on the most extreme treatments: control and burned, ash left. Soil moisture was determined on three of the unused early burned plots, on unburned areas within 2 m of these plots and on four randomly located control areas outside of the grid. Two types of unburned areas were sampled in order to determine if burning could affect soil moisture in adjacent plots.

Soil Nitrogen

Available nitrate and nitrite nitrogen was determined for those soil core samples not used for soil moisture: 10 - 20 cm, 30 - 40 cm, 50 - 60 cm, and 70 - 80 cm. $nM(NO_2^- + NO_3^-)$ was determined for these samples by the method of Lowe and Hamilton (1967). One gram of soil was suspended in 5 ml of water and the soil was allowed to settle. Ten grams of soybean nodules were ground in 40 ml of a buffer solution containing .05 M K_2HPO_4 and .05 M KH_2PO_4. The nodule suspension was centrifuged to remove plant cells and the precipitate discarded. The bacteroid suspension was then re-centrifuged and the supernatant discarded. The bacteroid precipitate was resuspended in 15 ml of buffer solution.

To determine nitrate and nitrite, 0.1 ml of bacteroid solution was added to 0.3 ml of soil solution and incubated for 1.75 hours. In this process nitrate is converted to nitrite. One ml alcohol and 0.1 ml zinc acetate were added. The solution was centrifuged for 10 minutes and the precipitate was discarded. One ml 0.02% N-1 naphthylenediamine and 1 ml 2% sulfanilamide in 2.4 N HCl were added to the supernatant, giving a total volume of 3.5 ml. The absorbance at 540 nm was then determined. Total available nitrate and nitrite was determined by the following equation:

$$nM(NO_2^- + NO_3^-)/\text{ g soil} = 70.9(\text{Absorbance at } 540 \text{ nm})(5 \text{ ml}/ 0.3 \text{ ml})$$

Soil Temperature

Soil temperatures were taken several times throughout the growing season. Surface soil temperatures were approximated with a mercury thermometer; 10 cm and 30 cm deep temperatures were taken with dial thermometers. One temperature at each depth was taken per plot on each of 7 dates. Temperatures were taken along transects on the north sides of the plots at locations determined by coordinates from a random numbers table.

Light

A Weston photometer with a quartz filter photoelectric cell was used to measure the amount of visible light reaching the surface of the plots, the amount of light reflected by the surface exposed to the sunlight, the amount passing through the litter or mulch (when present), and the amount reflected from the soil surface under the litter or mulch. The numbers given are the means of four readings for each measurement on each treatment. From this the percent of the total sunlight absorbed by the exposed surface and the percent absorbed by the soil surface under the litter or mulch could be calculated.

Seed Production

Seed production was measured in several ways. Flowerstalk density and height were measured along a transect located at random within the plots. In most plots a belt transect 40 cm wide and 3 m long was used. However, in some plots with very low flowerstalk production, such as the unaltered controls, the entire plot was sampled. Twenty inflorescences were collected along the transect, and head weight and seeds/ inflorescence were determined from these. Seeds/ m^2 was calculated from seeds/ inflorescence and flowerstalks/ m^2. Flowerstalks/ m^2 was used instead of flowerstalks/ plant because the tillering habit of _A. gerardi_ made it impossible to tell what was one plant. Seed production increases with an increase in the number of flowerstalks or the number of seeds/ inflorescence. To reduce the within treatments variability, percent canopy coverage of _A. gerardi_ was estimated, and flowerstalks/ m^2 of canopy cover was calculated. Canopy coverage was estimated on 10 m^2 quadrats on 14 September 1979 and 17 September 1979. Percent canopy coverage was visually estimated according to the following classes: 1) 0 - 1%, 2) 1 - 5%, 3) 5 - 25%, 4) 25 - 50%, 5) 50 - 75%, 6) 75 - 95%, and 7) 95 - 100%. Flowerstalks/ m^2 was then divided by the midpoint of the canopy coverage class determined for that plot.

RESULTS

Flowerstalk Production

The only factor tested in the three-way (litter, ash, and burning *per se*) factorial analysis of variance, which significantly affected flowerstalk production, was burning *per se* (Appendix 1). The only biological variables significantly affected by any of the treatments were stems/ m^2 (P=0.0887) and seeds/ m^2 (P=0.0885). Since seeds/ m^2 is a function of stems/ m^2 and seeds/ inflorescence it would be expected to follow the same pattern as stems/ m^2 because seeds/ inflorescence did not change.

The early burned plots were used in a two-way factorial analysis of variance to test the effects of litter removal and burning *per se*. The litter on the burned plots was not mulched and was more like the organic material on the unaltered control plots than that on the mowed, mulch left plots. Therefore, the two-way analysis was done using the unaltered control plots instead of the mowed plots with mulch. This could not be done in the three-way factorial analysis of variance since there were no control plots with ash added. Both litter removal and burning *per se* had significant effects on flowerstalk production (P=0.0689 and P=0.0010, respectively) (Appendix 1).

The amount of *A. gerardi* initially in the plots was highly variable. When stems/ m^2 of canopy cover was used in the analysis, none of the conclusions about the hypotheses on stems/ m^2 were changed, but the values of P were considerably lower. In the three-way factorial analysis of variance burning *per se* was still the only significant factor (P=0.0005) (Appendix 1). In the two-way factorial analysis of variance both litter removal and burning *per se* had significant effects (P=0.0220 and P=0.0002, respectively) (Appendix 1).

The color change caused by sand, the time of the burn, and whether or not the plots had been mowed (i.e. position of litter) did not significantly affect any of the biological variables.

Soil Temperature

The physical variables in the environment had a much lower within treatment variability and were much more sensitive to the effects of fire than the biological variables. The three-way (litter, ash, and burning *per se*) factorial analysis of variance indicates that litter removal significantly raised surface soil temperatures and temperatures 10 cm deep throughout the growing season (Fig. 3g). The effect on temperatures 30 cm deep is less clear, but the data indicate the same trend (Fig. 3g). Burned plots had significantly lower soil surface temperatures and 10 cm deep temperatures until 4 June 1978 (Fig. 3h). There were significant litter and burning *per se* interactions whenever burned plots had significantly lower temperatures. On plots without litter there were no significant differences between burned and unburned plots (Fig. 3i). On plots with litter burned plots had lower temperatures (Fig. 3i). This is probably due to the litter present and not actually due to burning *per se*. The litter on the burned plots was not mulched and seemed to provide better coverage than the mulch on the mowed plots.

The two-way (litter and burning *per se*) factorial analysis of variance using early burned plots indicates that both litter removal and burning *per se* resulted in significantly increased temperatures at all depths (Fig. 3j,k). There were also some significant interactions. In plots without litter burned plots were not significantly different from unburned plots (Fig. 3 l). In plots with litter burned plots had significantly greater temperatures than unburned plots (Fig. 3 l). This may have been a result of differences in the

Fig. 3a-f. Plots of mean soil temperature vs. date for each treatment at each depth. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, BE = early burned, ■ = surface temperature, ● = 10 cm temperature, and ▲ = 30 cm temperature.

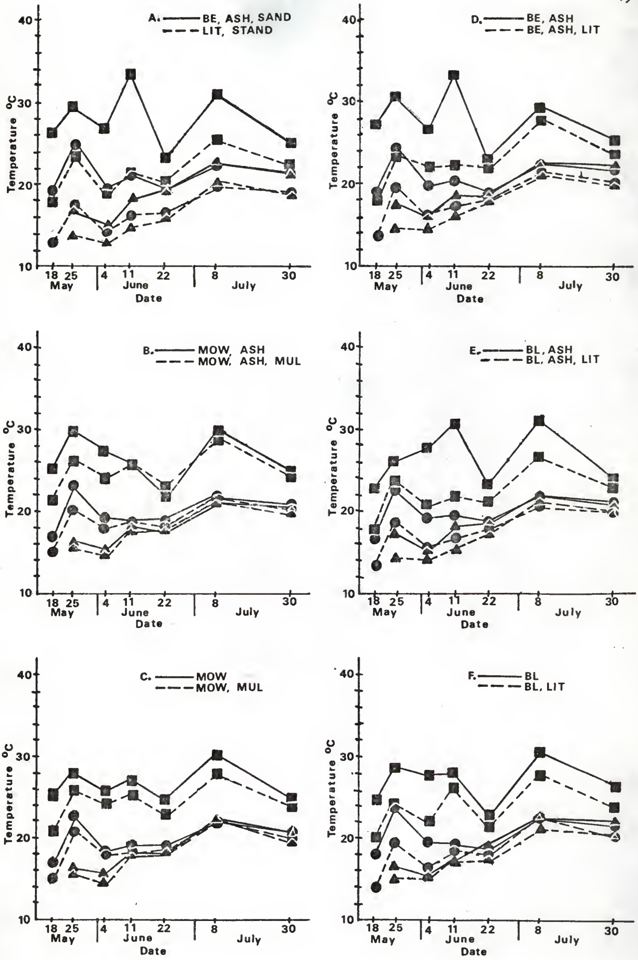
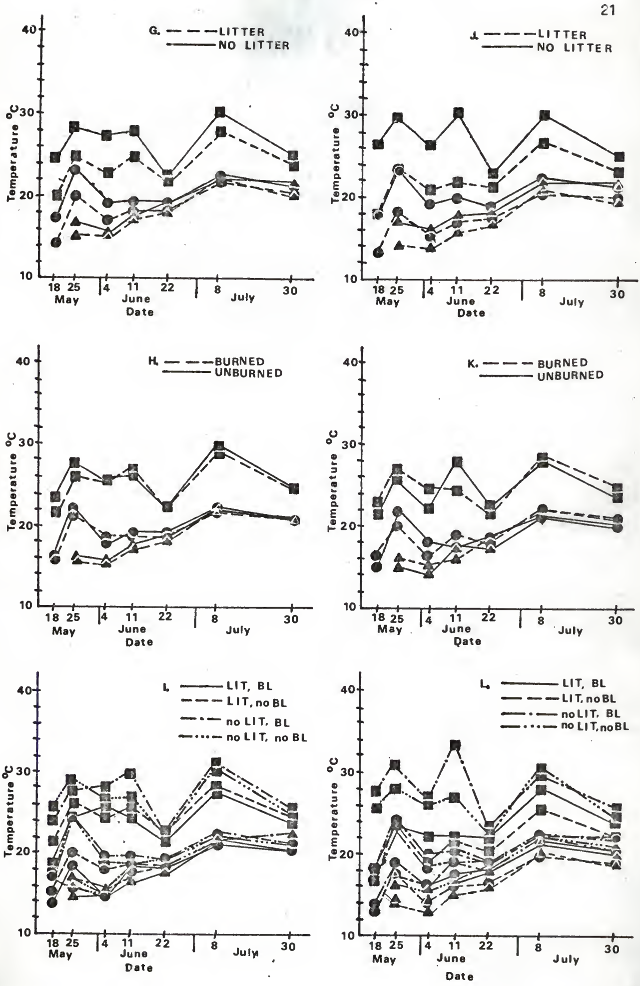

A. BE, ASH, SAND
LIT, STAND
D. BE, ASH
BE, ASH, LIT
B. MOW, ASH
MOW, ASH, MUL
E. BL, ASH
BL, ASH, LIT
C. MOW
MOW, MUL
F. BL
BL, LIT
Temperature °C
10
20
30
40
18 25
May
4 11 22
June
8 30
July
Date

Fig. 3g-1. Plots of mean soil temperature vs. date for each factorial effect which significantly affected soil temperature. g-i. Mean temperatures for treatments used in the three-way factorial analysis of variance. j-l. Mean temperatures for treatments used in the two-way factorial analysis of variance. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, BE = early burned, ■ = surface temperature, ● = 10 cm temperature, and ▲ = 30 cm temperature.


G. LITTER
NO LITTER
J. LITTER
NO LITTER
H. BURNED
UNBURNED
K. BURNED
UNBURNED
I. LIT, BL
LIT, no BL
no LIT, BL
no LIT, no BL
L. LIT, BL
LIT, no BL
no LIT, BL
no LIT, no BL
Temperature °C
Date
May
June
July
18 25 4 11 22 8 30
10 20 30 40

the litter on the two treatments and not a result of the burning *per se*.

Mowing the plots but leaving the mulch caused a significant increase in all temperatures compared to the control (Fig. 3a,c). Soil surface and 10 cm deep temperatures were significantly higher in the early burned plots than in the late burned plots (Fig. 3d-f). Sand (soil color) had no significant effect on any soil temperatures compared to the early burned, ash left, litter added plots (Fig. 3a,d).

Soil Moisture and Nitrogen

No significant difference in soil moisture between unburned areas away from burned plots or adjacent to burned plots was observed (Table 2). Burned areas had significantly less moisture than adjacent unburned areas to a depth of 30 cm ($P<0.05$) and less than distant unburned areas to a depth of 70 cm ($P<0.05$).

No significant differences in soil nitrogen between treatments were observed (Table 3). These findings are consistent with the findings of Koelling and Kucera (1965).

Light

Litter and mulch absorbed over 90% of the sunlight on plots with litter or mulch. The soil surface on plots with litter or mulch absorbed all of the light it received. On burned plots with litter the soil surface absorbed 0.33% of the sunlight. On mowed plots with mulch the soil surface received and absorbed 3.33% of the sunlight. On plots without litter or mulch the soil surface received and absorbed greater than 92% of the sunlight (Table 4).

Table 2. Percent soil moisture. Burned = sites in burned plots; Close = sites immediately adjacent to, but not in, burned plots; Away = sites some distance away from burned plots. * = differences significant at the .05 level. NS = no significant difference at the .05 level.

Depth (cm)	Away		Close		Burned	Away vs. Burned
0 - 10	27.99	NS	21.54	*	14.04	*
20 - 30	20.76	NS	20.28	*	12.50	*
40 - 50	20.86	NS	18.56	NS	14.49	*
60 - 70	20.10	NS	16.34	NS	14.56	*
80 - 90	17.70	NS	15.04	NS	12.59	NS
100 - 110	17.54	NS	16.17	NS	14.49	NS
120 - 130	17.78	NS	17.96	NS	15.83	NS
140 - 150	18.90	NS	19.01	NS	17.96	NS

Table 3. $nM(NO_2^- + NO_3^-)$ in soil samples. Burned = sites in burned plots; Close = sites immediately adjacent to, but not in, burned plots; Away = sites some distance away from burned plots. * = differences significant at the .05 level. NS = no significant difference at the .05 level.

Depth (cm)	Away		Close		Burned	Away vs. Burned
10 - 20	39.63	NS	52.08	NS	27.66	NS
30 - 40	33.98	*	48.67	*	33.01	NS
50 - 60	41.92	NS	34.20	NS	31.70	NS
70 - 80	37.37	NS	43.26	NS	37.56	NS

Table 4. Percent of total sunlight absorbed by the soil surface. MOW = mowed, B = burned, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present.

Treatment	Incoming (foot-candles)	Reflected %	Absorbed by litter %	Passed through %	Absorbed by soil %
B	5100	3.92	-	-	96.08
B, LIT	5200	8.08	91.59	0.33	0.33
B, ASH	8000	4.38	-	-	95.62
B, ASH, SAND	7200	5.00	-	-	95.00
MOW, MUL	3000	6.33	90.34	3.33	3.33
MOW	9100	7.69	-	-	92.31

DISCUSSION

The soil moisture and soil temperature results in this study generally agree with the findings in the published literature. However, the bioligical results do not. In most studies the authors have assumed that litter removal by fire was the most important factor affecting flowerstalk production (Aikman, 1955; Curtis and Partch, 1950; Ehrenreich, 1959; Kucera and Ehren Ehrenreich, 1952; Old, 1969). This assumption has been based on other studies, such as Weaver and Rowland (1952) showing that litter removal by mowing and/ or raking caused a significant increase in flowerstalk production.

Curtis and Partch (1950) had only six treatments and therefore did not have all possible combinations of the presence and absence of litter removal, burning per se, and ash. In addition, the study was done in an arboreteum on transplanted clumps of A. gerardi in pure stands. They found that burned plots had greater flowerstalk production than clipped plots, but the difference was not as great as between plots with and without litter. They seemed to overlook this finding and only mentioned it in passing. Because they were working in an arboreteum they were able to measure flowerstalks/ square inch of basal clump area. This resulted in a very low within treatments variability.

In this study the within treatments variability was extremely high, particularly because the dry summer resulted in low flowerstalk production in all treatments. Estimating percent canopy coverage by A. gerardi reduced the variance considerably. In future studies canopy coverage should be estimated before and after burning.

The control plots in this study were not randomized in the grid with the other plots. No differences between the control plots and the area around the grid or the unused plots within the grid could be observed. However in future studies all plots should be randomized when possible.

Time of burning did not cause a significant difference in flowerstalk production. However, the effects of litter removal and burning were more easily observed on the early burned plots. Therefore burned plots in future studies should be burned on a date near the earlier date to reduce the intratreatment variance.

In the three-way factorial analysis of variance mechanical litter removal had no significant effect on seed production while burning per se caused a significant increase in flowerstalk production. In the two-way factorial analysis of variance both litter removal and burning caused significant increases in flowerstalk production. Although the difference is not significant, the increase in flowerstalk production due to burning per se was greater than the increase due to litter removal ($0.10 < P < 0.20$).

Four direct effects of fire were listed in the introduction: 1) it removes the organic material present; 2) it produces ash from the organic material burned; 3) it causes a color change in the surface exposed to sunlight; and, 4) it produces heat. The first three effects could be factored out and their relative importance determined. In this study none of these three appeared to be very important in increasing flowerstalk production. Some effect of burning per se was the most important factor. If there is some selective advantage to increasing seed production following burning because of the set of environmental conditions pecululiarly associated with fires, then the plant must be able to determine when a fire has occurred. Many of the effects of fire could be produced by a variety of other environmental disturbances, such as grazing. Some effect of burning per se would seem to be the most reliable indicator of the entire set of direct and indirect effects of fire to follow. While there may be some other direct effects of not mentioned here, the heat of the fire itself seems to be the most likely factor of burning per se to which the plants could make a flowering response.

The results of this study suggest for the first time that burning per se may be important as an environmental cue for seed production. A possible explanation is that a heat labile inhibitor to flowering exists in *A. gerardi*. The heat of the fire does not penetrate very deep into the soil (Hensel, 1923). The inhibitor would need to reside or be effective in the crown of the plant. The existence of a heat labile inhibitor is also consistent with the observation that flowering does occur but in lower frequency in the absence of fire (Rice and Parenti, 1978). Such inhibitors may also breakdown with time or simply with an increase in soil temperature, but not to the extent of breakdown that is produced by fire. It is also possible that there is a flower-stimulating chemical whose concentration is increased by burning.

Late July, August, and September of 1978 were very dry months. Seed production was initiated but not completed. If seed production on all plots had been greater, as it would be in a wetter season, the results of this study may have been different. Long term studies in which data were collected over several years and a wide variety of climatic conditions would allow a more accurate assessment of the relative importance of the various environmental effects of fire in increasing flowering and seed production.

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APPENDICES

Explanation of Appendices

Appendix 1 gives the comparisons used to test each hypothesis and the significance levels for each response measured. A coefficient of 0 indicates that a treatment combination was not used in the comparison. The treatment combination means receiving a coefficient of 1 are compared to those receiving a coefficient of -1. For the main effects the treatment combinations with the factor present (litter, ash, burning *per se*) are given coefficients of 1 and those with the factor absent are given coefficients of -1. For the interactions the coefficients for the treatment combinations are determined from the products of the coefficients for the main effects involved. The null hypothesis in each case is that the factorial effect (main effect or interaction) is zero. Whether a response is increased or decreased by a factor can be determined from examination of the treatment combination means. The means of each response for each treatment combination are given in Appendix 2.

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Seeds/ Head	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.4218
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.9387
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.6588
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.1232
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.6784
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.6347
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.5334
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.6460
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.1974
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.1339
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.1421
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.8315
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.3954

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, EL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	EL, LIT	EL, LIT, ASH	EL	EL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Head Weight	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.3359
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.2447
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.4859
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.4420
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.3420
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.7403
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.8493
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.6797
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0309
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.0895
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.3170
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.2337
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.2753

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Stem Height	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.1940
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.7102
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.2438
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.8325
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.3881
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.2619
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.6147
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0434
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.1436
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.0298
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.3667
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.1474
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.9837

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
		Comparison Coefficients												
Seeds/ m^2	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.5755
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.0885
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.7931
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.8965
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.5844
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.7677
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.1075
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0804
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0001
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.1562
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.5459
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.4318
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.1815

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Stems/ m^2	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.4069
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.0887
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.9933
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.8095
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.7816
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.9300
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.2169
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0689
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0010
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.3193
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.6638
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.5994
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.2296

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Stems/ m^2 of canopy cover	*Three-way factorial analysis of variance*													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.7198
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.0005
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.1315
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.8247
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.2991
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.1569
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.0711
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0220
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0002
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.4653
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.8521
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.7709
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.1443

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Surface Temperature 5-18-78 4:00 pm Cloudy	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	<0.0001
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.0214
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.2675
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.5556
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.9708
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.2055
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.6761
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	<0.0001
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.2304
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.5118
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.4545
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.0860
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0331

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Surface Temperature 5-25-78 5:00 pm mostly cloudy, windy	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.0024
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.0904
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.9409
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.8077
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.9477
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.1831
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.4415
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0001
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.3672
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.3205
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.5182
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.0855
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.2142

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Surface Temperature 6-4-78 3:45 pm clear, sunny	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	<0.0001
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.0528
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.9365
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	<0.0001
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.0253
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.0988
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.7587
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	<0.0001
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0001
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.0161
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.8312
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.0072
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	<0.0001

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Surface Temperature 6-11-78 11:45 pm clear, sunny	*Three-way factorial analysis of variance*													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.0108
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.4726
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.6642
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.0547
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.2714
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.9324
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.0811
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0001
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0296
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.0943
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.9384
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.4841
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0806

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Surface Temperature 6-22-78 10:30 am clear, sunny	*Three-way factorial analysis of variance*													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.3640
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.2306
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.3831
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.0595
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.6196
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.9423
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.7178
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0066
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0857
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.3823
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.9550
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	1.0000
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0093

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Surface Temperature 7-8-78 12:15 pm clear, sunny	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.0001
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.7309
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.9513
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.1496
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.9206
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.7601
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.2092
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0004
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.4792
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.0600
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.2407
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.0977
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0555

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
Surface Temperature 7-30-78 11:30 am cloudy	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.0100
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.6919
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.0691
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.1297
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.3070
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.0636
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.6127
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0004
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0575
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.4796
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.5947
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.5504
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0220

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
10 cm Temperature 5-18-78 4:00 pm cloudy	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	<0.0001
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.0094
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.0509
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.0001
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.7011
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.0024
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.7838
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	<0.0001
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	<0.0001
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.0178
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.9453
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.0013
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	<0.0001

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
10 cm Temperature 5-25-78 5:00 pm mostly cloudy, windy	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	<0.0001
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.0220
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.2906
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.0174
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.2605
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.1753
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.1473
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	<0.0001
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0010
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.5169
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.3609
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.0505
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	<0.0001

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

		Comparison Coefficients												
Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
10 cm Temperature 6-4-78 3:45 pm clear, sunny	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	<0.0001
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.0001
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.2315
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.0001
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.1578
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.0028
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.4489
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	<0.0001
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	<0.0001
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.0479
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.6974
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.8688
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	<0.0001

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
10 cm Temperature 6-11-78 11:45 am clear, sunny	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.0009
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.8241
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.2533
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.0473
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.1197
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.6078
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.0360
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	<0.0001
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0012
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.9023
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.6337
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.6903
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0002

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
10 cm Temperature 6-22-78 10:30 am clear, sunny	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.0029
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.1646
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.1579
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.2851
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.6277
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.9905
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.9528
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	<0.0001
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0016
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.0007
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.3774
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.5659
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	<0.0001

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
10 cm Temperature 7-8-78 12:15 pm clear, sunny	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.0008
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.3137
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.0927
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.1529
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.4784
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.8274
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.5141
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	<0.0001
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0070
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.0087
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.5947
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.3386
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	<0.0001

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
10 cm Temperature 7-30-78 11:30 am cloudy	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	<0.0001
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.3736
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.4071
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.0358
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.7971
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.0964
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.9426
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	<0.0001
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0001
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.5559
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.2790
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.8204
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0032

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
30 cm Temperature 5-25-78 5:00 pm mostly cloudy, windy	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.0001
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.2441
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.6201
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.0168
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.2284
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.5460
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.2718
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	<0.0001
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0158
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.4028
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.2560
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.7188
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0029

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
30 cm Temperature 6-4-78 3:45 pm clear, sunny	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.0487
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.7254
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.2299
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.8739
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.6184
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.3555
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.3384
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	<0.0001
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0415
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.2540
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.0672
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.6172
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0104

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
		Comparison Coefficients												
30 cm Temperature 6-11-78 11:45 am clear, sunny	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.2674
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.2508
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.9556
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.0445
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.0110
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.2162
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.7346
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0011
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0106
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.5619
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.8744
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.8231
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0005

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Comparison Coefficients

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
30 cm Temperature 6-22-78 10:30 am clear, sunny	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.0080
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.7783
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.4434
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.1544
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.3415
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.5366
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.3231
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0027
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0196
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.0668
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.2025
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.3792
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0004

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
30 cm Temperature 7-8-78 12:15 pm clear, sunny	*Three-way factorial analysis of variance*													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.3465
	Burning per se	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.6850
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.2637
	Litter x Burning per se	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.3172
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.6203
	Burning per se x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.8923
	Litter x Burning per se x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.9401
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0127
	Burning per se	-1	0	0	0	0	0	0	-1	0	1	0	1	0.1386
	Litter x Burning per se	-1	0	0	0	0	0	0	1	0	-1	0	1	0.3786
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.9252
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.7234
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.0276

Appendix 1. Comparison coefficients used to test each hypothesis and their significance levels for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7. For a more complete explaination of the tables see page 32.

Dependent Variable	Factor	LIT, STAND	MOW, MUL	MOW, MUL, ASH	BL, LIT	BL, LIT, ASH	BL	BL, ASH	MOW	MOW, ASH	BE, ASH	BE, ASH, SAND	BE, ASH, LIT	P
		Comparison Coefficients												
30 cm Temperature 7-30-78 11:30 am cloudy	Three-way factorial analysis of variance													
	Litter	0	1	1	1	1	-1	-1	-1	-1	0	0	0	0.0001
	Burning *per se*	0	-1	-1	1	1	1	1	-1	-1	0	0	0	0.6891
	Ash	0	-1	1	-1	1	-1	1	-1	1	0	0	0	0.3975
	Litter x Burning *per se*	0	-1	-1	1	1	-1	-1	1	1	0	0	0	0.7475
	Litter x Ash	0	-1	1	-1	1	1	-1	1	-1	0	0	0	0.7475
	Burning *per se* x Ash	0	1	-1	-1	1	-1	1	1	-1	0	0	0	0.1111
	Litter x Burning *per se* x Ash	0	1	-1	-1	1	1	-1	-1	1	0	0	0	0.6524
	Two-way factorial analysis of variance													
	Litter	1	0	0	0	0	0	0	-1	0	-1	0	1	0.0001
	Burning *per se*	-1	0	0	0	0	0	0	-1	0	1	0	1	0.0088
	Litter x Burning *per se*	-1	0	0	0	0	0	0	1	0	-1	0	1	0.9773
	Other													
	Sand (Color)	0	0	0	0	0	0	0	0	0	-1	1	0	0.0977
	Time of Burning	0	0	0	0	1	0	-1	0	0	1	0	-1	0.2963
	Mowing	-1	1	0	0	0	0	0	0	0	0	0	0	0.1536

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

Dependent Variable	Treatment Responses											
	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
Seeds/ Head												
Plot 1	32.5	49.7	39.4	31.2	42.9	29.2	38.1	39.0	47.0	34.4	24.1	37.7
Plot 2	-	32.6	34.6	44.6	36.9	34.6	35.1	43.1	39.7	37.5	39.1	49.2
Plot 3	-	30.9	44.0	56.6	45.3	40.3	41.2	34.4	35.4	43.8	41.4	52.0
Plot 4	-	42.4		39.4	45.5	34.0	43.0	48.7		45.6	28.4	41.3
Mean	32.5	38.9	39.3	42.9	42.6	34.5	39.3	41.3	40.7	40.3	33.2	45.0
Head Weight (g)												
Plot 1	0.0887	0.1903	0.1675	0.1126	0.1029	0.1148	0.0934	0.1811	0.1809	0.1210	0.0793	0.1617
Plot 2	-	0.1030	0.1116	0.1189	0.1360	0.0922	0.1298	0.1378	.1788	0.0696	0.0691	0.2132
Plot 3	-	0.0823	0.1541	0.2193	0.1528	0.1249	0.1527	0.0802	0.0999	0.1816	0.1796	0.2204
Plot 4	-	0.1857		0.1178	0.1288	0.0584	0.1079	0.1027		0.1855	0.1101	0.2011
Mean	0.0887	0.1403	0.1444	0.1421	0.1301	0.0976	0.1209	0.1254	0.1532	0.1394	0.1095	0.1991

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

Dependent Variable	Treatment Responses											
	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
Stem Height												
Plot 1	80.7	67.5	85.6	72.2	90.8	74.6	71.4	98.7	67.5	90.0	108.1	108.5
Plot 2	70.0	78.4	86.0	73.8	97.4	75.4	86.7	80.6	86.9	43.8	56.5	97.3
Plot 3	97.0	80.2	88.3	81.7	79.0	71.6	73.1	76.8	72.3	85.0	89.5	102.3
Plot 4	74.2	95.1		79.4	87.7	64.7	89.9	69.9		88.6	84.5	104.6
Mean	80.5	80.3	86.6	76.8	88.7	71.6	80.3	81.5	75.6	76.8	84.6	103.2
Seeds/ m^2												
Plot 1	68.6	154.6	499.2	686.4	314.5	954.0	558.9	1119.8	255.4	560.9	1038.0	590.8
Plot 2	0.0	174.0	280.2	356.8	762.7	288.2	772.2	524.5	564.5	937.5	1094.2	567.7
Plot 3	0.0	271.6	479.3	886.1	422.6	214.6	398.7	244.4	306.5	1166.8	745.9	1456.0
Plot 4	0.0	612.3		697.1	409.5	396.8	1331.4	108.0		1094.1	369.7	936.3
Mean	17.2	303.1	419.6	656.6	477.3	463.4	765.3	499.2	375.5	939.8	811.9	887.7

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

Dependent Variable	Treatment Responses											
	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
Stems/ m²												
Plot 1	2.1	3.1	12.7	22.0	7.3	32.7	14.7	28.8	5.4	16.3	43.0	15.7
Plot 2	0.2	5.3	8.1	8.0	20.7	8.3	22.0	12.2	14.2	25.0	28.0	11.6
Plot 3	0.1	8.8	10.9	15.7	9.3	11.7	9.7	7.1	8.7	26.7	18.0	28.0
Plot 4	1.3	14.4		17.7	9.0	14.5	31.0	2.2		24.0	13.0	22.7
Mean	0.9	7.9	10.6	15.8	11.6		19.3	12.6	9.4	23.0	25.5	19.5
Stems/ m² of canopy cover												
Plot 1	2.48	4.98	12.99	35.20	11.73	38.44	23.47	29.49	6.40	16.75	44.10	16.07
Plot 2	0.35	8.53	9.54	21.33	24.32	22.21	25.88	12.48	16.73	29.41	32.94	13.59
Plot 3	0.13	10.33	12.80	41.79	10.98	14.21	11.38	7.29	10.20	27.35	18.46	28.72
Plot 4	1.36	14.81		28.27	9.23	18.67	31.79	5.92		38.40	20.80	26.67
Mean	1.10	9.65	11.77	31.65	14.05	23.37	23.15	13.80	11.10	28.00	29.07	21.27

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

Dependent Variable	Treatment Responses											
	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
Surface Temperature(°C) 5-18-78, 4:00 pm												
Plot 1	18.1	20.6	22.1	19.9	19.0	30.0	21.8	24.1	24.3	25.2	26.0	18.0
Plot 2	16.8	21.0	23.2	19.8	17.1	23.3	25.9	24.4	25.4	33.0	27.6	18.0
Plot 3	18.2	22.4	19.6	20.2	18.9	24.0	22.8	31.4	26.5	26.0	26.0	17.8
Plot 4	18.2	20.8		20.8	16.6	22.0	22.6	22.4		26.2	26.2	19.9
Mean	17.8	21.2	21.6	20.2	17.9	24.8	23.3	25.6	25.4	27.6	26.4	18.4
Surface Temperature(°C) 5-25-78, 5:00 pm												
Plot 1	24.0	24.6	25.0	24.8	23.6	34.8	27.0	30.0	29.5	27.9	29.7	23.4
Plot 2	23.7	25.7	25.6	25.0	24.9	26.9	28.2	27.3	27.6	39.6	33.6	23.0
Plot 3	23.1	28.6	29.0	24.6	24.2	27.9	26.0	29.7	33.5	26.2	28.0	23.1
Plot 4	23.6	25.0		24.0	23.4	25.9	25.4	26.0		29.5	27.0	24.4
Mean	23.6	26.0	26.5	24.6	24.0	28.9	26.6	28.2	30.2	30.8	29.6	23.5

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

Dependent Variable	Treatment Responses											
	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
Surface Temperature (°C) 6-4-78, 3:45 pm												
Plot 1	19.9	23.9	24.3	22.0	20.6	27.3	28.9	25.6	28.8	26.5	26.2	21.5
Plot 2	19.0	25.0	24.0	22.1	22.1	27.1	29.0	27.3	28.1	27.2	28.1	23.4
Plot 3	18.6	24.8	24.7	22.3	20.2	31.0	27.1	25.9	26.0	26.0	26.0	23.0
Plot 4	19.0	24.9		23.0	21.2	27.0	28.0	25.3		28.0	28.0	22.2
Mean	19.1	24.6	24.3	22.3	21.0	28.1	28.2	26.0	27.6	26.9	27.1	22.5
Surface Temperature (°C) 6-11-78, 11:45 am												
Plot 1	22.0	24.1	24.2	33.3	24.0	22.2	33.1	26.6	25.7	33.0	33.0	23.0
Plot 2	21.7	22.9	27.6	25.0	21.7	32.0	26.1	24.8	26.4	28.0	30.6	21.6
Plot 3	21.1	29.8	26.3	22.3	22.0	29.6	34.0	29.0	26.1	31.4	34.0	24.5
Plot 4	21.6	25.8		24.9	21.7	30.0	31.8	28.7		42.1	36.2	20.8
Mean	21.6	25.6	26.0	26.4	22.3	28.4	31.2	27.3	26.1	33.6	33.4	22.5

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

	Treatment Responses											
Dependent Variable	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
Surface Temperature(°C) 6-22-78, 10:30 am												
Plot 1	20.6	22.7	21.0	20.6	21.0	21.6	23.0	21.8	22.0	22.1	2.2	21.6
Plot 2	20.0	21.0	23.7	21.7	21.3	23.2	20.5	21.8	22.8	22.0	21.7	21.8
Plot 3	20.9	24.0	24.0	22.2	22.0	22.7	24.2	22.0	21.3	24.4	24.3	22.4
Plot 4	20.3	23.8		22.0	20.7	24.5	22.3	25.6		24.9	25.0	22.6
Mean	20.4	22.9	22.9	21.6	21.2	23.0	22.5	22.8	22.0	23.3	23.3	22.1
Surface Temperature(°C) 7-8-78, 12:15 pm												
Plot 1	26.1	27.9	27.3	28.2	27.7	29.9	32.0	26.6	30.1	30.0	29.4	26.8
Plot 2	24.6	27.2	30.6	27.8	25.9	29.0	29.1	30.1	32.2	29.7	28.9	29.7
Plot 3	26.7	29.0	29.0	27.6	28.1	33.7	32.4	34.0	28.0	27.8	31.7	28.1
Plot 4	25.0	28.1		28.0	25.4	30.6	32.3	32.1		31.0	34.4	27.1
Mean	25.6	28.0	29.0	27.9	26.8	30.8	31.4	30.7	30.1	29.6	31.1	27.9

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

	Treatment Responses											
Dependent Variable	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
Surface Temperature(°C) 7-30-78, 11:30 am												
Plot 1	22.2	24.9	23.0	23.9	22.8	25.4	24.9	23.2	25.2	25.1	24.2	23.1
Plot 2	22.8	23.8	26.4	24.4	23.0	26.2	23.8	24.2	24.9	24.8	25.5	23.8
Plot 3	22.6	24.7	24.2	24.0	24.4	26.1	26.8	25.7	24.3	25.9	25.6	24.0
Plot 4	22.0	23.8		24.0	22.4	28.2	21.6	26.9		27.0	25.8	24.7
Mean	22.4	24.3	24.5	24.1	23.1	26.5	24.3	25.0	24.8	25.7	25.3	23.9
10 cm Temperature(°C) 5-18-78, 4:00 pm												
Plot 1	13.2	15.9	15.6	13.7	13.6	19.2	17.0	17.2	17.9	18.9	19.9	19.3
Plot 2	12.7	14.7	15.4	13.8	13.1	18.4	17.1	17.2	17.9	19.8	13.7	13.3
Plot 3	12.9	15.4	15.0	14.8	13.6	17.5	17.0	16.8	16.3	19.0	19.0	13.5
Plot 4	13.0	14.3		14.7	13.2	17.6	17.1	17.4		19.3	19.3	13.9
Mean	12.9	15.1	15.3	14.2	13.4	18.2	17.0	17.1	17.4	19.2	19.2	13.8

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

Dependent Variable	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
	Treatment Responses											
10 cm Temperature(°C) 5-25-78, 5:00 pm												
Plot 1	18.2	19.9	20.1	19.0	18.7	25.7	23.2	24.5	24.6	23.8	25.8	18.5
Plot 2	17.0	21.2	21.0	19.4	18.8	23.1	23.1	22.6	23.3	25.2	25.1	18.1
Plot 3	18.0	22.5	20.0	19.9	19.3	23.7	22.9	22.4	23.4	23.8	24.6	19.4
Plot 4	18.0	20.6		20.0	19.0	22.6	22.6	22.1		25.6	25.0	19.9
Mean	17.8	21.0	20.4	19.6	18.9	23.8	22.9	22.9	23.8	24.6	25.1	19.0
10 cm Temperature(°C) 6-4-78, 3:45 pm												
Plot 1	14.4	18.0	17.7	16.2	15.7	19.1	19.2	18.0	19.0	19.3	20.4	16.1
Plot 2	14.2	17.6	18.4	16.4	15.4	19.8	19.1	18.2	19.9	19.3	19.4	16.6
Plot 3	14.2	18.8	18.1	16.8	15.9	20.1	19.1	19.2	19.0	20.0	18.8	16.5
Plot 4	14.3	18.0		17.1	16.1	19.9	19.0	19.0		20.6	20.1	16.4
Mean	14.3	18.1	18.1	16.6	15.8	19.7	19.1	18.6	19.3	19.8	19.7	16.4

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

Dependent Variable	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
	Treatment Responses											
10 cm Temperature (°C) 6-11-78, 11:45 am												
Plot 1	16.1	18.5	18.0	20.3	17.2	17.4	20.0	18.5	18.8	20.1	20.5	17.1
Plot 2	16.2	17.8	19.2	18.9	16.8	19.5	18.8	18.5	18.8	19.5	20.3	16.8
Plot 3	16.2	19.1	18.4	17.6	17.6	19.8	20.7	20.1	18.9	21.0	21.2	18.2
Plot 4	16.1	18.8		17.9	16.6	20.3	20.0	19.7		22.1	21.8	18.0
Mean	16.1	18.5	18.5	18.7	17.0	19.2	19.9	19.2	18.8	20.7	20.9	17.5
10 cm Temperature (°C) 6-22-78, 10:30 am												
Plot 1	16.8	19.3	18.0	17.8	18.1	19.0	18.6	17.9	18.7	18.6	19.1	18.1
Plot 2	16.2	18.5	18.3	18.6	17.8	18.3	18.7	18.8	19.2	18.7	18.8	18.3
Plot 3	16.9	18.6	18.9	18.9	18.5	19.0	19.0	19.8	18.7	18.7	19.4	18.7
Plot 4	16.9	18.6		17.9	17.5	19.6	18.9	19.6		19.8	19.7	18.5
Mean	16.7	18.7	18.4	18.3	18.0	19.0	18.8	19.0	18.9	18.9	19.2	18.4

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

Dependent Variable	Treatment Responses											
	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
10 cm Temperature (°C) 7-8-78, 12:15 pm												
Plot 1	19.8	22.1	20.8	21.3	20.8	21.8	22.3	21.0	21.8	22.0	22.4	21.6
Plot 2	19.9	21.5	22.2	21.3	20.7	21.9	21.7	22.2	23.0	22.1	22.0	21.3
Plot 3	20.0	22.1	21.6	21.9	21.4	22.6	22.9	23.2	21.3	22.3	22.1	21.8
Plot 4	19.7	21.8		21.6	20.3	23.1	22.0	23.0		23.1	23.9	21.4
Mean	19.8	21.9	21.5	21.5	20.8	22.3	22.2	22.3	22.0	22.4	22.6	21.5
10 cm Temperature (°C) 7-30-78, 11:30 am												
Plot 1	19.0	20.3	19.8	20.6	19.4	22.2	21.8	20.0	21.3	21.9	20.8	20.3
Plot 2	18.9	20.2	21.4	20.3	20.0	21.2	20.4	20.7	20.8	21.2	21.6	20.2
Plot 3	19.2	20.9	20.5	20.4	20.3	22.8	21.9	21.2	21.0	21.9	21.7	20.6
Plot 4	19.3	19.9		20.4	20.1	21.3	21.2	21.8		22.9	22.1	20.8
Mean	19.1	20.3	20.6	20.4	19.9	21.9	21.3	20.9	21.0	22.0	21.5	20.5

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

Treatment Reponses

Dependent Variable	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
30 cm Temperature (°C) 5-25-78, 5:00 pm												
Plot 1	14.5	16.4	16.1	15.6	14.0	16.9	17.5	16.4	16.1	18.0	17.0	15.5
Plot 2	14.0	16.6	16.7	15.6	14.0	16.1	17.3	16.2	17.6	18.4	16.7	13.0
Plot 3	13.1	15.4	14.9	16.0	15.5	16.5	16.4	17.4	16.0	16.5	18.2	14.4
Plot 4	14.5	15.2		14.0	13.5	17.5	17.3	16.0		18.7	17.0	16.0
Mean	14.0	15.9	15.9	15.3	14.2	16.7	17.1	16.5	16.6	17.9	17.2	14.7
30 cm Temperature (°C) 6-4-78, 3:45 pm												
Plot 1	14.0	15.1	14.5	15.8	13.5	15.3	15.9	16.1	16.0	16.2	15.0	15.5
Plot 2	12.0	14.5	15.9	13.6	15.0	16.1	14.9	16.1	14.6	16.5	15.1	14.1
Plot 3	12.1	16.0	14.5	14.0	13.6	16.4	16.3	14.9	16.2	16.2	14.9	13.8
Plot 4	13.9	14.0		18.7	14.7	14.9	14.6	16.4		16.5	15.1	15.1
Mean	13.0	14.9	15.0	15.5	14.2	15.7	15.4	15.9	15.6	16.3	15.0	14.6

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

Treatment Responses

Dependent Variable	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
30 cm Temperature(°C) 6-11-78, 11:45 pm												
Plot 1	14.0	17.8	17.0	20.0	16.5	15.7	17.5	15.3	17.0	19.1	18.0	15.0
Plot 2	16.1	17.9	18.4	17.1	14.9	17.5	18.5	16.6	18.7	18.7	19.0	17.1
Plot 3	16.5	19.6	18.1	17.7	17.0	18.5	19.1	18.4	19.5	18.7	18.1	17.1
Plot 4	14.6	17.9		15.7	15.0	19.1	18.5	17.5		18.6	19.5	16.7
Mean	15.3	18.3	17.8	17.6	15.8	17.7	18.4	16.9	18.4	18.8	18.6	16.5
30 cm Temperature(°C) 6-22-78, 10:30 am												
Plot 1	15.4	19.4	17.5	17.0	18.1	19.9	18.4	17.1	18.0	18.2	19.6	17.5
Plot 2	16.5	18.9	17.1	18.5	16.8	17.8	19.2	17.8	20.0	18.3	19.6	18.5
Plot 3	17.1	17.4	19.1	19.0	18.4	19.1	18.3	19.6	19.0	18.0	19.7	18.5
Plot 4	15.4	18.7		17.1	16.5	20.5	19.5	19.1		20.1	19.0	17.7
Mean	16.1	18.6	17.9	17.9	17.4	19.3	18.8	18.4	19.0	18.6	19.5	18.0

Appendix 2. Treatment means for each variable measured. STAND = standing dead present, LIT = litter present, MUL = mulch present, ASH = ash present, SAND = sand present, MOW = mowed, BL = late burned, and BE = early burned. For a summary of variables measured see page 7.

	Treatment Responses											
Dependent Variable	LIT STAND	MOW MUL	MOW MUL ASH	BL LIT	BL LIT ASH	BL	BL ASH	MOW	MOW ASH	BE ASH	BE ASH SAND	BE ASH LIT
30 cm Temperature (°C) 7-8-78, 12:15 pm												
Plot 1	21.1	23.0	20.5	21.5	21.3	21.5	21.6	21.5	22.2	21.1	21.0	22.5
Plot 2	20.4	20.6	22.6	21.1	21.3	23.4	21.3	22.5	21.3	22.6	21.0	20.0
Plot 3	19.3	24.0	22.0	21.4	20.4	23.1	22.7	21.3	21.0	22.5	23.4	21.2
Plot 4	20.1	20.6		21.5	21.8	21.7	21.5	23.5		24.0	25.1	22.6
Mean	20.2	22.0	21.7	21.4	21.2	22.4	21.8	22.2	21.5	22.5	22.6	21.6
30 cm Temperature (°C) 7-30-78, 11:30 am												
Plot 1	19.5	20.0	19.4	21.1	18.7	21.5	21.9	20.7	21.8	22.5	20.2	19.9
Plot 2	18.2	19.7	21.5	19.5	20.5	21.7	20.0	21.6	20.6	21.4	22.5	20.1
Plot 3	18.5	21.1	19.5	20.2	19.6	23.3	22.4	20.6	22.0	22.4	20.8	19.9
Plot 4	19.9	18.9		20.7	20.5	22.0	20.0	21.8		23.3	21.9	21.0
Mean	19.0	19.9	20.1	20.4	19.8	22.1	21.1	21.2	21.5	22.4	21.3	20.2

SOME ENVIRONMENTAL RESPONSES TO BURNING AND THEIR EFFECTS ON FLOWERING IN *ANDROPOGON GERARDI*

by

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B. A., Midland Lutheran College, 1977

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1979

Fire plays an important role in maintaining the tallgrass prairie. It has several direct effects on the environment. 1) It removes organic material: living, standing dead, and litter. 2) It provides ash from the organic material burned. 3) It causes a color change in the surface exposed to sunlight. 4) It provides heat. The objective of this study was to determine the relative importance of these direct effects in increasing flowerstalk production in Andropogon gerardi.

The study was carried out on Konza Prairie Research Natural Area near Manhattan, Kansas. Twelve treatments were used. Nine of these treatments included all possible combinations of removal of organic material, addition of ash, and direct heat of the fire. Three additional treatments allowed for study on the effects of time of burning and surface color. Soil moisture and available soil nitrogen were measured on the most extreme treatments: unaltered control and early burned, ash left. Soil temperatures were measured at three depths: surface, 10 cm, and 30 cm throughout the season. The amount of light reaching the soil surface and absorbed by it was measured. Flowerstalk production was measured in several ways: 1) stems/ m^2, 2) stem height, 3) seeds/ head, 4) head weight, 5) seeds/ m^2, and 6) flowerstalks / m^2 of canopy cover of A. gerardi.

Soil moisture was significantly less on burned plots to a depth of 70 cm ($P<.05$) when compared to unaltered controls several meters from the burned plots and to a depth of 30 cm ($P<.05$) when compared to unaltered controls within 2 m of the burned plots. No significant differences between the two controls were observed ($P>.05$). No significant differences in available soil nitrogen were observed ($P>.05$). When organic material was removed soil temperatures were significantly higher at all depths throughout the growing season ($P<.05$). The addition of ash, change in surface color, and direct heat of the fire did not significantly affect soil temperatures ($P > .05$). Removal of organic material increased the percent of total sunlight reaching the soil surface, and therefore the amount absorbed by it. Without litter 100% of total sunlight reached the soil surface and $> 90\%$ was absorbed. With litter $< 5\%$ of total sunlight reached the soil surface and $< 5\%$ was absorbed. The addition of ash, the change in surface color, and the heat of the fire did not change the amount of light reaching the surface or the amount absorbed by it. Flowerstalk height, head weight, and seeds/ head were not significantly affected by any of the direct effects of fire ($P > .10$). When the analysis was done using the late burned plots, flowerstalks/ m^2 ($P=.0887$), seeds/ m^2 ($P=.0885$), and flowerstalks / m^2 of canopy cover ($P= .0005$) were significantly increased by burning. When the early burned plots were used in the analysis, flowerstalks/ m^2 was significantly increased by both removal of the organic material ($P=.00689$) and burning ($P=.0010$) as were seeds/ m^2 ($P=.0804$ and $P=.0001$, respectively) and flowerstalks/ m^2 of canopy cover ($P=.0220$ and $P=.0002$, respectively). Addition of ash and change in surface color did not significantly affect flowerstalk production. Thus the direct heat of fire or some factor of burning not tested here appears to be the most important factor in increasing flowerstalk production in _A. gerardi_.