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Response of big bluestem (Andropogon gerardii Vitman) to specific date of spring burning.

Tracy Lea Benning

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Response of Big Bluestem (*Andropogon gerardii* Vitman) to Specific Date of Spring Burning

A Thesis
Presented to the
Department of Biology
and the
Faculty of the Graduate College
University of Nebraska

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
University of Nebraska at Omaha

by
Tracy L. Benning
May 1989

THESIS ACCEPTANCE

Acceptance for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Arts, University of Nebraska at Omaha.

Committee

Name	Department
Ann Antlfinger	Biology
David M. Sutherland	Biology
Charles R. Gildersleeve	Geography-Geology

Thomas B. Bragg
Chairman

26 April 1989
Date

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Introduction

The tallgrass prairie of central North America has been described as a fire-derived and fire-maintained ecosystem (Stewart 1951) in which fires occurred intermittently and throughout the year (Jackson 1965). Because of the importance of fire to this ecosystem, its effects have been widely studied and summarized in reviews by Ehrenreich (1959), Daubenmire (1968), Vogl (1974), and Hulbert (1986). The effect of burning during different seasons has been studied with varying results. Winter burns reduce herbage production of warm-season dominants and shift vegetational composition by differentially favoring cool-season species (e.g. Towne and Owensby 1984). Mid- to late-season fires also damage the C_4 dominants. At this time, these species are growing rapidly and the meristems are elevated above the soil surface. Thus, they are subject to greater injury from burning. During summer and fall, the plants may also be stressed by low soil moisture (Risser et al. 1981). Late summer fires have been shown to cause shifts in community composition away from warm-season dominants (Ewing and Engle 1988).

Mid- to late-spring burning is the time during which most controlled experimental fires in the tallgrass prairie have been conducted. For prairies dominated by warm-season species, growth and production of many of the dominants are stimulated by spring burning (Curtis and Partch 1950, Dix and Butler 1954, Ehrenreich 1959, Kucera and Ehrenreich 1962, Hadley and Kieckhefer 1963, Hulbert 1969, Hadley 1970, Hover and Bragg 1981). This response is the primary reason for the extensive use of spring burning for cattle grazing and may also account for the research focus on burning at this time of the year. While spring burning does not adversely affect warm-season species, it does reduce the vigor of cool-season plants, therefore maintaining the tallgrass climax composition (Anderson et al. 1970). Aldous (1934) was the first to expand research to include evaluating the effects of burning at different spring dates on the tallgrass prairie. Subsequent studies on timing effects showed that late spring burning, rather than burns at earlier spring dates, favored dominant species such as big bluestem (*Andropogon gerardii* Vitman) over other species (Towne and Owensby 1984).

Big bluestem is the dominant species throughout much of the tallgrass prairie and has been the focus of considerable research. Spring burning has been shown to affect herbage production, biomass, litter accumulation, and caloric content of shoots and roots of this species (Dix and Butler 1954, Aikman 1955, Hadley and Kieckhefer 1963, Towne and Owensby 1984). Of specific interest to this study, spring burning has been reported to increase big bluestem flower stalk density and height (Curtis and Partch 1950, Kucera and Ehrenreich

1962, Hulbert 1969). The increases in these two traits are greater with late spring burning than with earlier burns (Henderson et al. 1983, Towne and Owensby 1984), perhaps because later burns place a greater stress on the plants (Risser et al. 1981, Bragg 1988) or because the plant at a certain stage of development is more vulnerable. Stress has been suggested as a possible explanation for significant differences in inflorescence density and height observed in plants transplanted only one week apart (Bragg 1988). Together, these data suggest that there may be a relatively narrow temporal window or range of environmental conditions that account for the differential response of big bluestem to spring burning. The objective of this study was to refine our understanding of this effect. The working hypothesis was that the response of big bluestem to spring burning is significantly different between closely timed burns. In addition, this significant difference should occur only in late spring.

Methods and Materials

Study Site

The study was conducted at Allwine Prairie Preserve, a 65 ha re-established grassland research area in Douglas County approximately 30 km northwest of Omaha, Nebraska (Bragg 1978) (Appendix Fig. 1). The area used for this study supported a plant community dominated by big bluestem (45% cover). It was last burned in late April of 1987. The study area was located on a nearly level hilltop with Marshall silty clay loam soils of the Typic Hapludolls subgroup, Mollisol soil order (Elder 1969). Average monthly temperatures range from -2 C in January to 26 C in July. Precipitation from 1958 through 1987 averaged 77 cm annually, most occurring during the growing season (U.S. Dept. of Commerce 1988).

Experimental Design

A 61 x 61 m study area, centrally located on the upland, was divided into 49, 7 x 7 m treatment plots in March 1988. Adjacent plots were separated by a 2 m mowed strip. The time period for the study, 6 April through 20 May, was chosen to overlap the earliest and latest dates of spring burning routinely used for the tallgrass prairie region in Nebraska.

Plots were randomly assigned treatment dates with burn treatments to be applied at four day intervals. For each burned plot, a separate unburned plot was identified. Each burned-unburned pair was replicated once, for a total of 4 treatment plots per date. The time between burns was 4 days in order to detect rapid, short-term effects. This burn frequency also allowed for some delays caused by weather which are inevitable in Nebraska during the spring.

Individual big bluestem plants were randomly selected from each of the plots (10/plot). Each plant was flagged. Big bluestem plants were identified using standing dead from the previous growing season. Pre-burn leaf growth was recorded by centering each plant in a 10 x 10 cm microplot and measuring the length of all new leaves appearing within it. Leaf length was determined by measuring from the soil surface to the tip of the leaf. The use of microplots was necessary to set boundaries for sampling of this rhizomatous species. After the completion of these and other pre-burn measurements (see below), each plot was burned using a backfire. Backfires were used to insure a more uniform burn, to enhance treatment effects, and to facilitate fire control. Regrowth in the burned plots and growth of leaves in the unburned plots was monitored until all leaves within all 10 microplots reached a leaf length of 20 cm.

Soil moisture on the burn date was determined gravimetrically using the percent dry weight method (Ball 1986). Two soil samples were randomly taken from each treatment plot immediately prior to burning. Each sample was divided into 0-5 cm and 5-10 cm depth increments. Soil temperature at 5 cm and 10 cm depths at three different locations within each of the 4 plots was also recorded immediately prior to burning. In addition, soil temperatures were recorded in all previously burned plots as well as 12 randomly selected unburned plots starting with the treatment date and continuing through 20 June. On this date, plot soil temperatures in all plots were effectively identical. Season-long measurement of soil temperature and soil moisture was not considered necessary because other studies have shown that burning results in lower soil moisture and increased soil temperatures throughout the growing season (e.g. Hulbert 1969).

The response of big bluestem to the burning treatment was measured in October 1988. Ten 30 x 50 cm microplots were randomly placed along a diagonal transect in each of the 48 treatment plots. Within each microplot, the number of flowering stems of big bluestem was recorded and used to calculate the mean flower stem density for each treatment plot. Flowering stem height, measured from the soil suurface to the tip of the tallest inflorescence, was recorded for 40 randomly selected stems taken from within each of the burned plots. As many flowering stems as could be located were sampled in the unburned plots. The number of flowering stems in the unburned plots was not adequate to provide either sample sizes of 40 or equal sample sizes.

Statistical Analysis

Flowering stem height and density differences among dates were analyzed with a one-factor ANOVA. The date means were compared using the Newman-Keuls multiple range test (Zar 1984). The General Linear Model (GLM) procedure of SAS (SAS Institute Inc., 1985) was used to perform the analyses. Burned and unburned plots were analyzed separately. Linear regressions of flowering stem height and density versus soil moisture were performed using the SAS regression procedure.

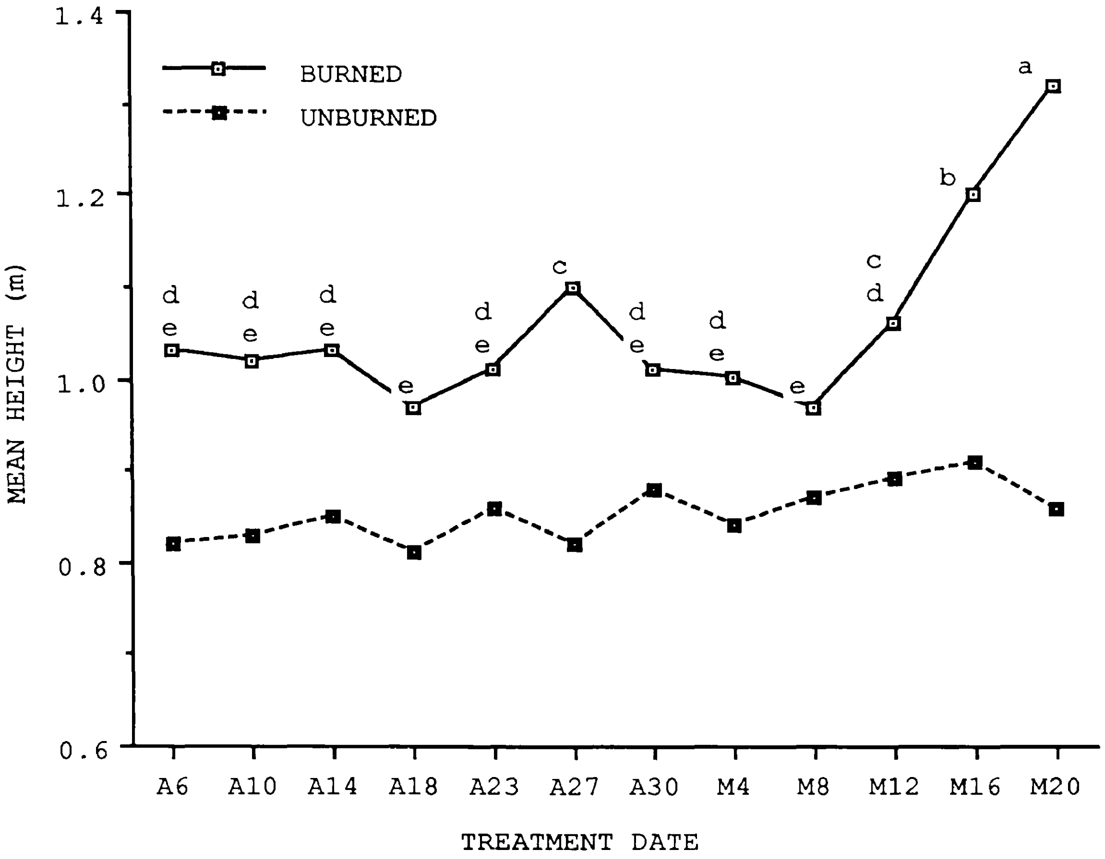
Results and Discussion

Effect of Closely Timed Burns

The results of this study support the hypothesis that big bluestem's response to burning changes significantly among closely timed spring burns (Figs. 1 and 2). In general, the effect of burn date on big bluestem is reflected in significant differences in flowering stem height and density (Tables 1 and 2). No significant differences were detected among dates for unburned plots.

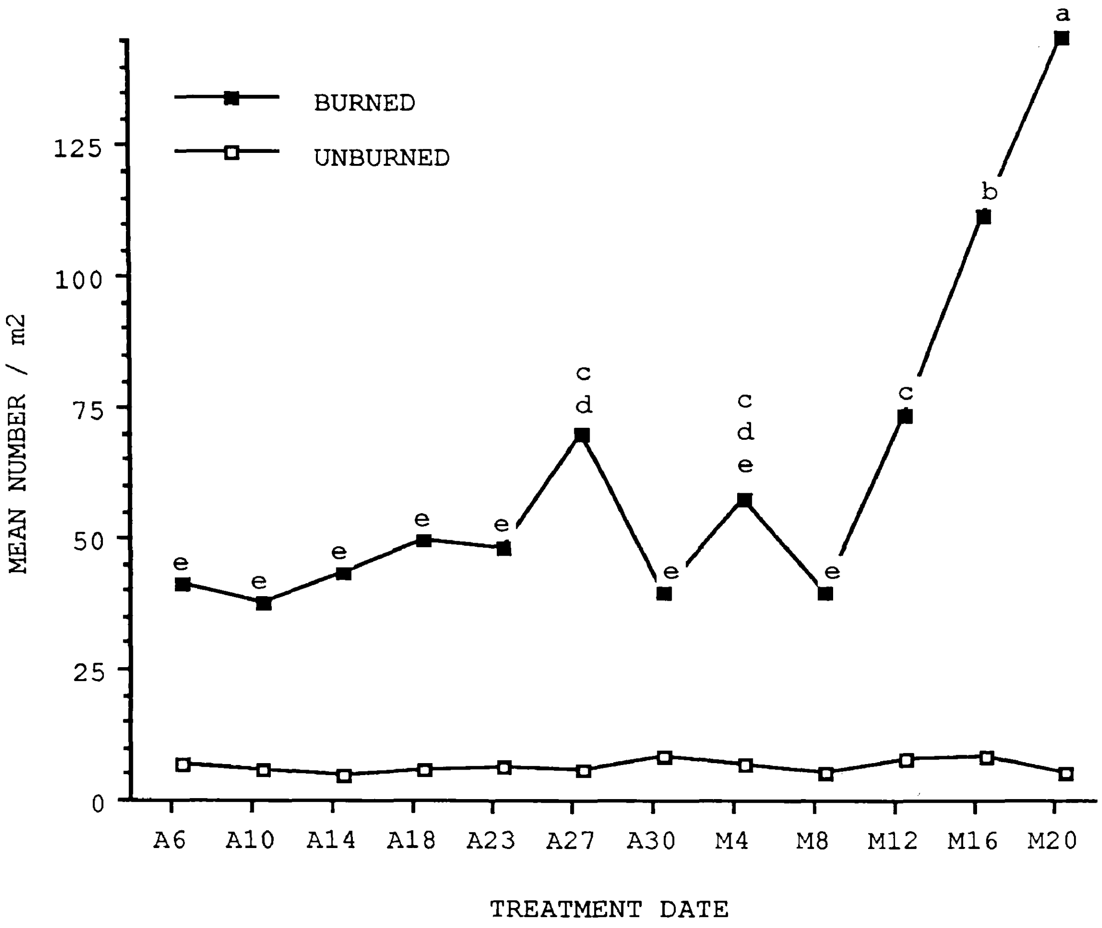
Of particular importance to this study, were the specific dates at which differences occurred. In April, no significant differences between burn treatment dates were observed until 27 April when a noticeable, but temporary, increase in both height and density was recorded. The mean flowering stem height and density for 27 April differed significantly from both 23 April and 30 April but not from 12 May, the last date before significant increases in both plant traits. From 30 April to 12 May, the mean response of big bluestem was not significantly different. Burning on 16 May and 20 May produced the highest mean densities (109.3 and 143.4 flowering stems / m^2, respectively) and the tallest flowering stems (1.2 and 1.3 m, respectively) (Appendix Tables 1 and 2). These two treatment dates were significantly

Fig. 1. Average flowering stem height for each treatment date. A=April, M=May, numbers following A/M indicate treatment date. Means with the same letter are not significantly different with Newman-Keuls multiple range test ($p < 0.05$).



1.4
1.2
1.0
0.8
0.6
MEAN HEIGHT (m)
BURNED
UNBURNED
a
b
c
d
d
e
d
e
d
e
e
d
e
c
d
e
d
e
e
A6
A10
A14
A18
A23
A27
A30
M4
M8
M12
M16
M20
TREATMENT DATE

Fig. 2. Average number of flowering stems per square meter for each treatment date. A=April, M=May, numbers following A/M indicate treatment date. Means with the same letter are not significantly different with Newman-Keuls multiple range test ($p < 0.05$).



BURNED
UNBURNED
MEAN NUMBER / m2
0
25
50
75
100
125
A6
A10
A14
A18
A23
A27
A30
M4
M8
M12
M16
M20
TREATMENT DATE
e
e
e
e
e
c
d
e
c
d
e
e
c
b
a

TABLE 1. ANOVA of the effect of date on flowering stem density in burned and unburned treatments.

DENSITY:	TRT=UNBURNED				
SOURCE	DF	AOV SS	F VALUE	PR>F	R MSE
DATE	11	7.64583	1.19	0.2961	0.76467
DATE*PLOT	12	10.95	1.56	0.1049	
ERROR	216	126.3			
TOTAL	239	144.895			

DENSITY:	TRT=BURNED				
SOURCE	DF	AOV SS	F VALUE	PR>F	R MSE
DATE	11	5563.983	27.07	0.0001	4.32306
DATE*PLOT	12	528.4	2.36	0.0073	
ERROR	216	4036.8			
TOTAL	239	10129.183			

TABLE 2. ANOVA of the effect of date on height of flowering stems. Unburned samples were analyzed using the GLM procedure (SAS).

HEIGHT: TRT=UNBURNED

SOURCE	**DF**	**SS**	**MS**	**F VALUE**	**PR>F**
DATE	11	0.25952737	0.0235934	1.43	0.1571
ERROR	293	4.82398607	0.01646412		
CORR. TOTAL	304	5.08351344			

HEIGHT: TRT=BURNED

SOURCE	**DF**	**SS**	**MS**	**F VALUE**	**PR>F**
DATE	11	9.43164365	0.85742215	45.16	0
ERROR	948	17.99933125	0.01898664		
CORR. TOTAL	959	27.4309749			

different from each other and from all other treatment dates. These results are similar to those of Henderson et al. (1983) and Towne and Owensby (1984) though their studies were of time periods of more than 3 weeks and were not focused on short-intervals.

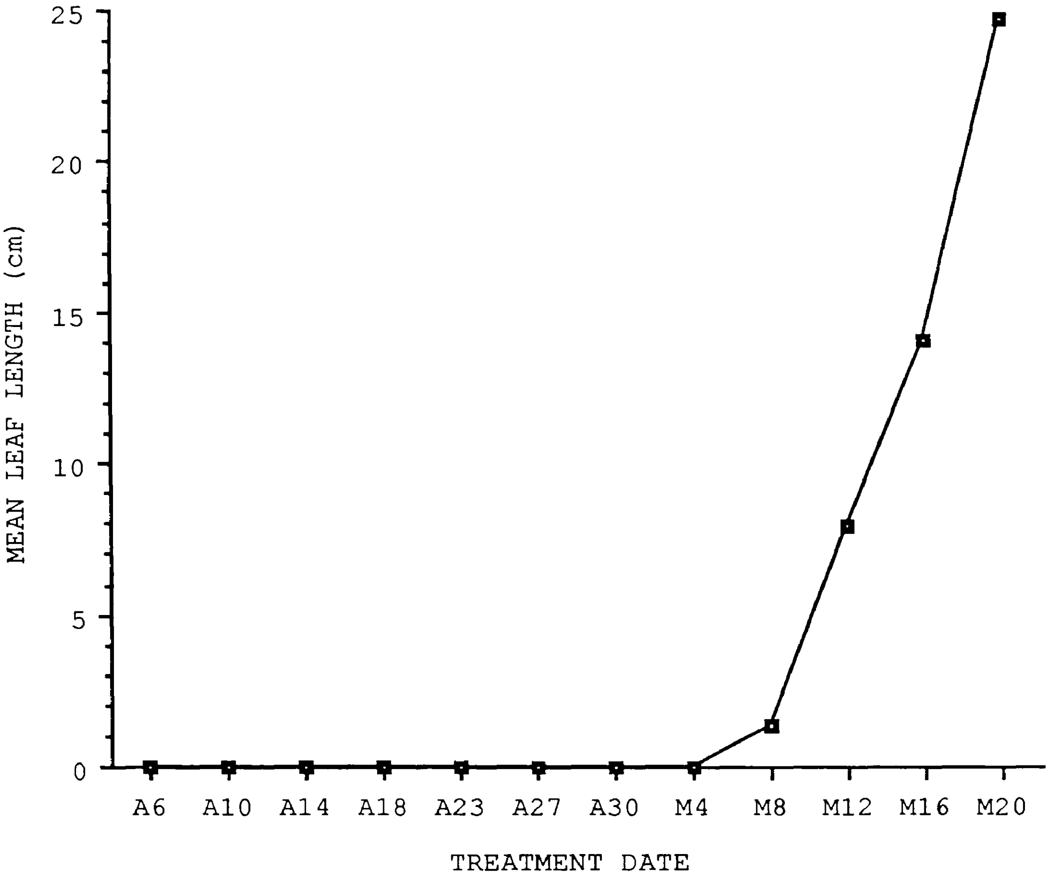
The results of this portion of the study show that the response of big bluestem to spring burning is variable and clearly dependent on the specific date. Some of the variability in plant response reported in the literature, therefore, may reflect this differential response. This study substantiates previous observations that late spring burning causes a shift to warm-season species thus further emphasizing the need to time burns carefully.

Effect of Plant Status at Time of Burn

The closer the time of burning was to the onset of spring growth, the greater was the resulting density and height of flowering stems (Figs. 1-3). These findings are consistent with those of Towne and Owensby (1984), although the trait they measured was total net production of big bluestem. The present study extends evaluation of the effects of burning several weeks beyond the initiation of spring growth. Burning at this time produced the highest mean densities and greatest mean heights.

This aspect of the study provides a means by which

Fig. 3. Mean length of leaves prior to burning. A=April, M=May, numbers following A/M indcate treatment date.


MEAN LEAF LENGTH (cm)
0
5
10
15
20
25
A6
A10
A14
A18
A23
A27
A30
M4
M8
M12
M16
M20
TREATMENT DATE

managers can obtain some suggestion about the likely response of burning at a particular time. As a manager, being able to predict the response of a species and, to a certain extent, the response of a community, will allow for more appropriate management of the tallgrass prairie ecosystem.

Effect of Soil Moisture at Time of Burn

The cause of the flowering responses to date of burning remains to be tested. Increased flowering has been considered a response to improved conditions resulting from litter removal and timely microclimate changes that permit warm season plants to begin growth early (Knapp 1984). It has been suggested that this early growth allows plants to build up favorable carbohydrate reserves before the normal period of flower initiation and thus produce taller and more abundant flowering stalks (Curtis and Partch 1950, Ehrenreich and Aikman 1963, Hulbert 1969). An additional explanation is related to injury of a plant's terminal apices, such as by clipping or burning. This type of injury stimulates growth from axillary buds and results in increased tillering (Leopold 1949, Jameson and Huss 1959). Such an explanation could account for the increased number of flowering stems, although it does not account for the increase in height.

Stress may be another important factor in explaining differential plant response to the time of burning (Risser et al. 1981, Bragg 1988). Stress, as used in the present study, refers to conditions that result in an atypical response to an environment for which the species is not well adapted. Production of above- and below-ground biomass, number of flowers, and seed production are all mediated by soil water (Risser et al. 1981, Knapp 1985). Pre-burn soil moisture recorded in this study showed a 16% decline from 6 April through 23 April and a 32% decline after 8 May (Fig. 4). Burning on a date when soil moisture was low combined with low soil moisture throughout the growing season may have differentially stressed the plants. Regressions of flowering stem height and density versus soil moisture were significant (Figs. 5-6). Thus soil moisture on the date of the burn was an indicator of plant response accounting for 59% of the variation in flowering stem height and 67% in flowering stem density.

Details of the relationship between flowering response and soil moisture are instructive. On 27 April the soil moisture was less than 25%. A significant increase in both the number and height of flowering stems occurred on this date, perhaps as a response to stress. Precipitation at this time may also account for some, but not all of the increase. Above 25% soil moisture, from 6-23 April, no significant differences in flowering response were observed. The increase in flowering observed on 27 April occurred when no above-

Fig. 4. Percent soil moisture prior to burning. A=April, M=May, numbers following A/M indicate treatment date.

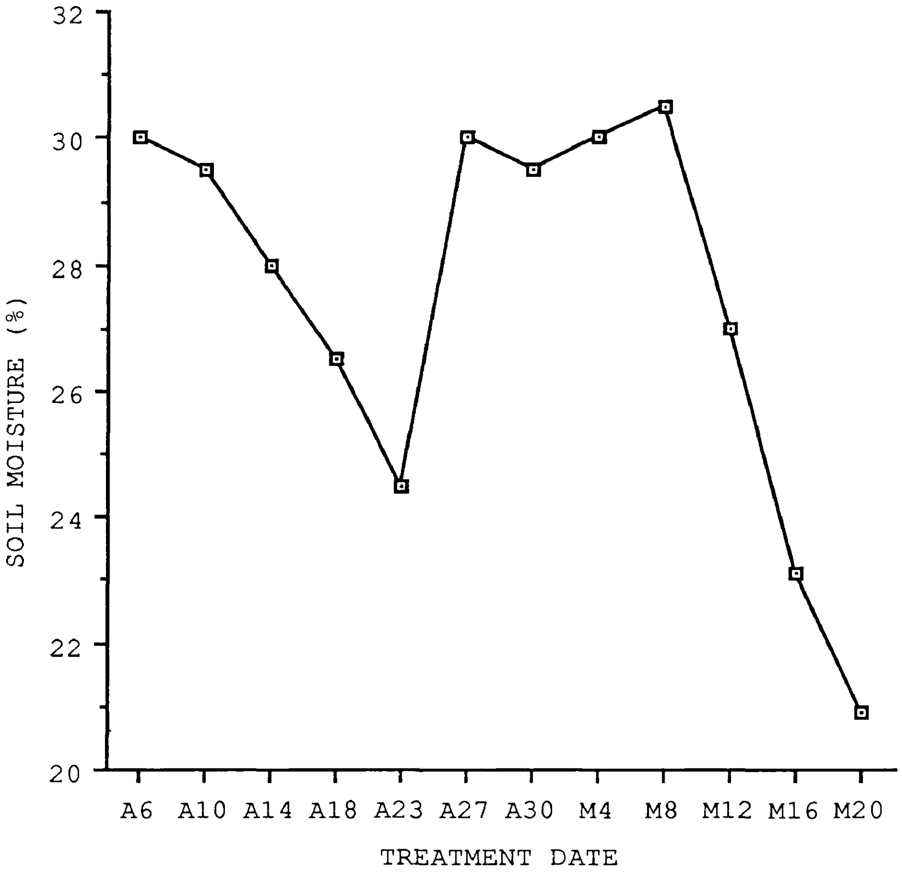

32
30
28
26
24
22
20
SOIL MOISTURE (%)
A6
A10
A14
A18
A23
A27
A30
M4
M8
M12
M16
M20
TREATMENT DATE

Fig. 5. Regression of flowering stem height versus soil moisture ($p < 0.05$; $r^2 = 0.59$).

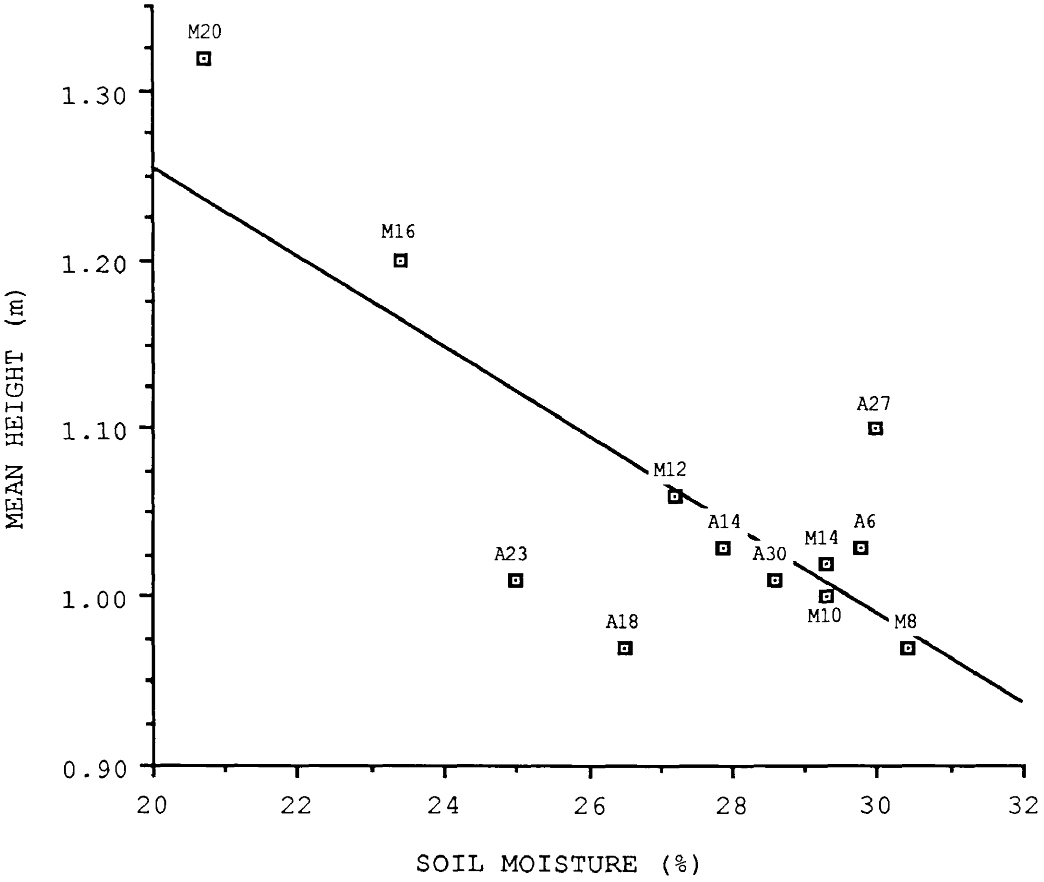

M20
M16
A27
M12
A14
A6
M14
A23
A30
M10
A18
M8
1.30
1.20
1.10
1.00
0.90
MEAN HEIGHT (m)
20
22
24
26
28
30
32
SOIL MOISTURE (%)

Fig. 6. Regression of flowering stem density versus soil moisture ($p < 0.05$; $r^2 = 0.67$).

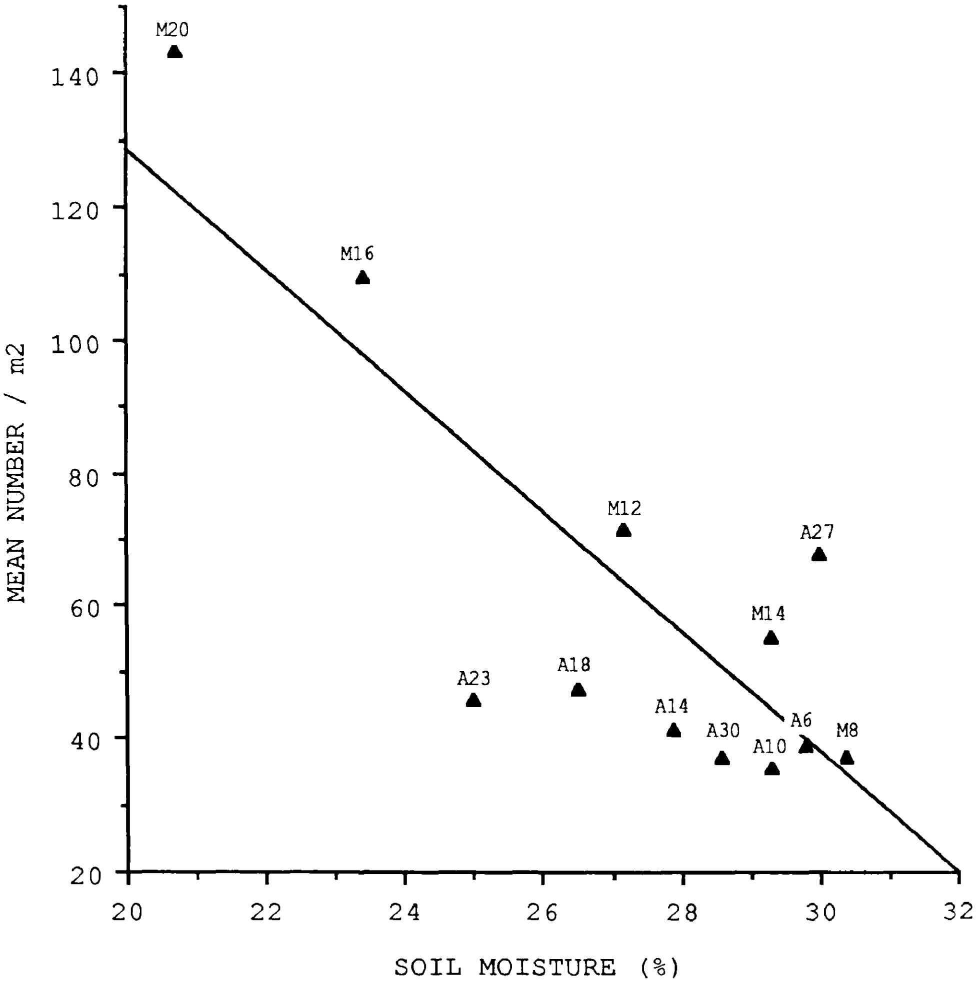
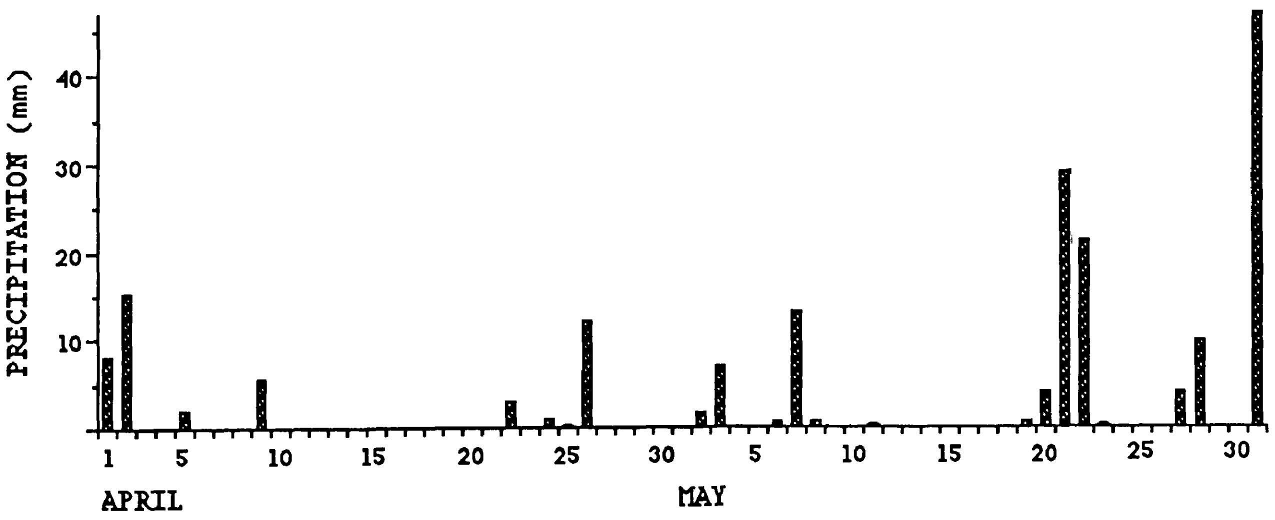

MEAN NUMBER / m2
SOIL MOISTURE (%)
140
120
100
80
60
40
20
20
22
24
26
28
30
32
M20
M16
M12
A27
M14
A23
A18
A14
A30
A10
A6
M8

Fig. 7. Daily precipitation during the treatment period (April-May).

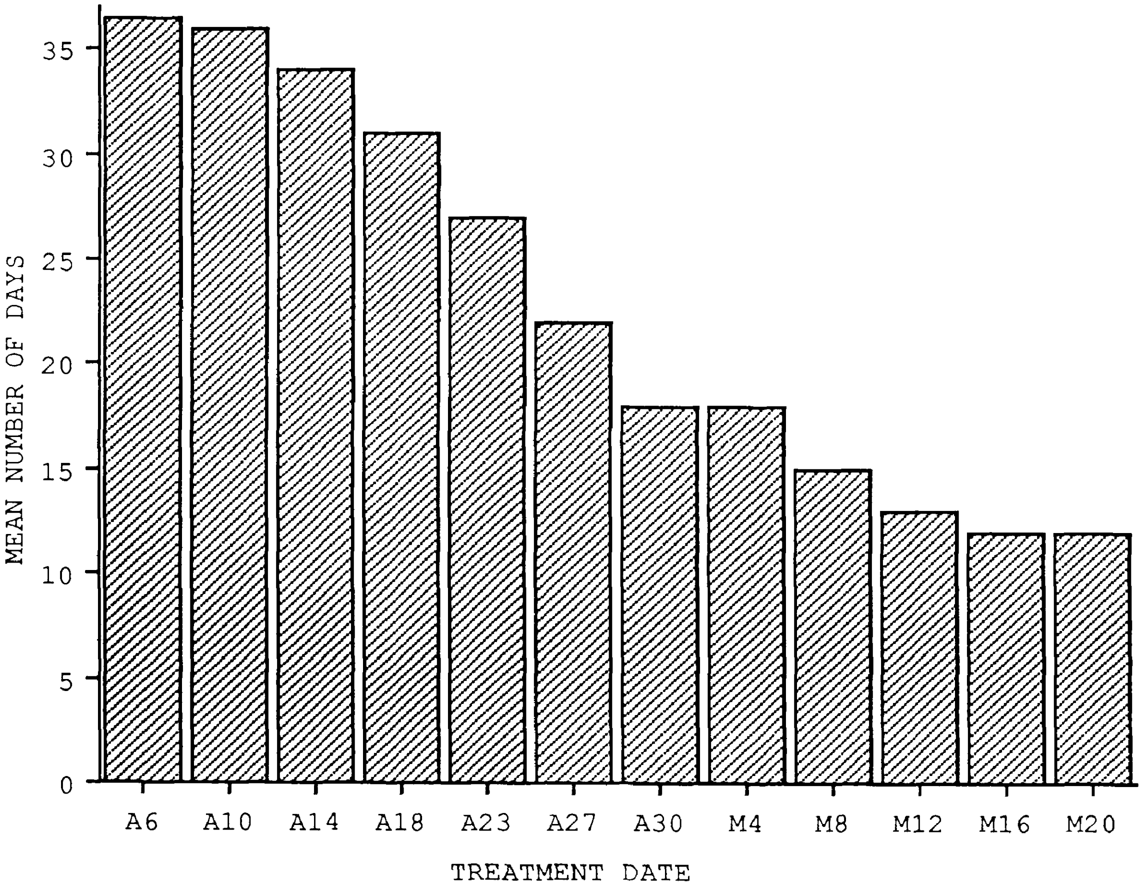

PRECIPITATION (mm)
40
30
20
10
1
5
10
15
20
25
30
5
10
15
20
25
30
APRIL
MAY

ground growth was apparent (Fig. 3). This showed that the conditons at the time, stressful or otherwise, affected the plant even prior to leaf emergence.

No significant differences in plant response to burning occurred from 27 April to 12 May during which time soil moisture remained above 25%. The second decline in soil moisture occurred after 12 May, with soil moisture again less than 25%, significant increases in flowering were observed. In combination, these observations suggest that flowering response is inversely related to soil moisture (Figs. 1-2 and 4). In contrast to 27 April responses, the May responses occurred when plants were increasing above-ground production and when rainfall and soil moisture was minimal (Fig. 7). After 8 May, decreasing soil moisture and lack of precipitation resulted in higher evapotranspiration. This soil moisture stress in May, may partly explain the greater flowering response in these plots. At this time, soil moisture dropped substantially below the 25% level, just as for 27 April.

In addition to improved environmental conditions, plant morphological development, and stress, some of the observed differences in flowering response may originate from climatic variation. Significant differences in plant response were observed for the 16 and 20 May treatments. Soil temperature and the rate of growth, measured as the number of days for plants to reach 20 cm in height after burning (Fig. 8.), were essentially identical on these two dates. The significant differences in flowering response may be due, in part, to precipitation following the treatments. Substantial precipitation occurred 5 days after the 16 May treatment while the 20 May treatment received substantial rainfall the following day (Fig. 7). These results serve to emphasize the complexity of flowering response, especially that of a perennial species.

Fig. 8. Mean number of days for plants to reach 20 cm in height after burning. A=April, M=May, numbers following A/M indicate treatment date.



MEAN NUMBER OF DAYS
0
5
10
15
20
25
30
35
A6
A10
A14
A18
A23
A27
A30
M4
M8
M12
M16
M20
TREATMENT DATE

Conclusion

Compared to the unburned plots, burning increased flowering stem density and height (ANOVA, $P < 0.05$). Comparisons among burned plots showed that increases occurred only during apparently stressful times, such as when soil moisture on the date of the burn declined below 25%. Thus, water stress may contribute to the variable flowering response and should be considered in further investigations on the effects of burning on reproduction and vegetative growth of mature prairie plants. Clearly the specific time of spring burning has an effect on big bluestem and, therefore, may have similar effects on other species. Soil moisture and plant growth status may be useful indicators of specific times during which to burn.

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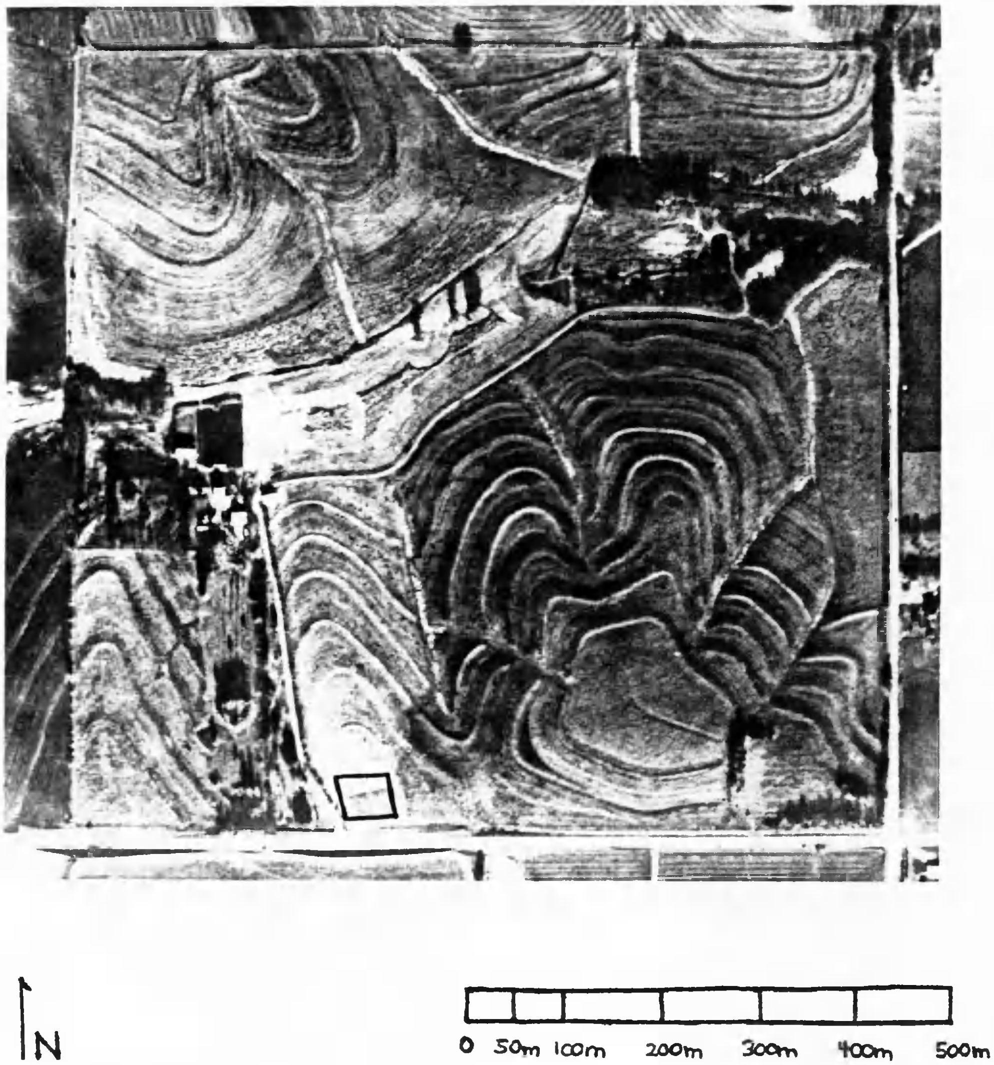
APPENDIX

Appendix Fig. 1. Allwine Prairie Preserve: SE 1/4 Sect. 23 T16N R11E (1965 photo) The study site is indicated by black border.


N
0
50m
100m
200m
300m
400m
500m

Appendix Table 1. Mean flowering stem height for burned and unburned samples for each treatment date.

DATE	**TREATMENT**	**NO. OF SAMPLES**	**MEAN**	**STD. DEV.**
APRIL 6	BURNED	80	1.03	0.16
	UNBURNED	22	0.82	0.34
APRIL 10	BURNED	80	1.02	0.14
	UNBURNED	20	0.83	0.50
APRIL 14	BURNED	80	1.03	0.14
	UNBURNED	29	0.85	0.52
APRIL 18	BURNED	80	0.97	0.13
	UNBURNED	27	0.81	0.42
APRIL 23	BURNED	80	1.01	0.13
	UNBURNED	26	0.86	0.52
APRIL 27	BURNED	80	1.10	0.13
	UNBURNED	23	0.82	0.47
APRIL 30	BURNED	80	1.01	0.13
	UNBURNED	27	0.88	0.61
MAY 4	BURNED	80	1.00	0.15
	UNBURNED	25	0.84	0.48
MAY 8	BURNED	80	0.97	0.13
	UNBURNED	26	0.87	0.59
MAY 12	BURNED	80	1.06	0.14
	UNBURNED	27	0.89	0.62

Appendix Table 1. Mean flowering stem height (continued).

DATE	**TREATMENT**	**NO. OF SAMPLES**	**MEAN**	**STD. DEV.**
MAY 16	BURNED	80	1.20	0.13
	UNBURNED	30	0.91	0.44
MAY20	BURNED	80	1.32	0.13
	UNBURNED	23	0.86	0.52

Appendix Table 2. Mean density of flowering stems per square meter for burned and unburned samples for each treatment date.

DATE	**TREATMENT**	**NO. OF SAMPLES**	**MEAN**	**STD. DEV.**
APRIL 6	BURNED	20	39.0	4.09
	UNBURNED	20	4.67	0.80
APRIL 10	BURNED	20	35.67	3.05
	UNBURNED	20	3.67	0.60
APRIL 14	BURNED	20	41.33	2.31
	UNBURNED	20	2.67	0.60
APRIL 18	BURNED	20	47.33	4.06
	UNBURNED	20	3.67	0.69
APRIL 23	BURNED	20	45.67	3.28
	UNBURNED	20	4.00	0.60
APRIL 27	BURNED	20	68.0	3.27
	UNBURNED	20	3.67	0.51
APRIL 30	BURNED	20	37.33	2.39
	UNBURNED	20	6.33	1.15
MAY 4	BURNED	20	55.33	4.81
	UNBURNED	20	4.67	0.98
MAY 8	BURNED	20	37.33	2.37
	UNBURNED	20	3.00	0.69
MAY 12	BURNED	20	71.67	5.73
	UNBURNED	20	5.67	1.04

Appendix Table 2. Mean flowering stem density (continued).

DATE	TREATMENT	NO. OF SAMPLES	MEAN	STD. DEV.
MAY 16	BURNED	20	109.33	5.89
	UNBURNED	20	6.33	0.83
MAY 20	BURNED	20	143.33	8.30
	UNBURNED	20	3.33	0.51