RESPONSE OF LITTLE BLUESTEM TO BRUSH MANAGEMENT PRACTICES IN THE CROSS TIMBERS OF NORTHCENTRAL OKLAHOMA

By

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PREFACE

With the increasing population of the world comes increasing pressures on our forests and rangelands. Areas which had once been considered useless are pressed into service for the benefit of man. Many of these marginal areas are very fragile and at best should be left alone. The management of these lands as sustainable natural areas or for the continued benefit of man must be considered fully, for once they are turned by the plow or reduced by the saw, they will never be the same.

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CHAPTER I

ABSTRACT

Little bluestem (*Schizachyrium scoparium* (Michx.) Nash) is a dominant grass and often a key management species in tallgrass prairie islands throughout the Cross Timbers. The vigor and regrowth potential of little bluestem on prairie sites was measured in response to brush treatments within the Cross Timbers of Oklahoma. Herbicide treatments included tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol- 2-yl]-N,N'-dimethylurea) and triclopyr ([(3,5,6-trichloro-2-pyridyl) oxy] acetic acid) aerially applied at 2.2 kg/ha to 32.3 ha pastures in March 1983 and June 1983, respectively. Burning treatments were applied in the spring of 1984. In 1983, little bluestem plants in the control treatment showed a normal total nonstructural carbohydrate (TNC) storage curve. Little bluestem plants in the triclopyr treatment exhibited more regrowth ability than plants in either the control or tebuthiuron treatments. The phenological development of little bluestem in 1983 was not significantly different amoung treatments. In 1984, TNC concentrations were not significantly different amoung the five treatments except in early spring. No herbicide treatment, either with or without spring burning the

following year, resulted in any consistant regrowth superiority over any other treatment in 1984. Results suggest that triclopyr applications may result in improved little bluestem vigor and regrowth potential the year of treatment. Tebuthiuron applications may be inappropriate for undesirable forb control in the Cross Timbers on tallgrass prairie islands, because of a lack of improvement in vigor and regrowth potential of little bluestem. However, if tebuthiuron or triclopyr treated tallgrass prairie islands are burned the year following herbicide application, the regrowth and competitive ability of little bluestem would not be adversely affected.

CHAPTER II

INTRODUCTION

The Cross Timbers of Oklahoma and adjacent states covers three to four million ha of low quality savannahs and woody rangeland. In Oklahoma alone, the Cross Timbers make up about one million ha of potentially productive rangeland currently infested with oak (Quercus spp.) and juniper (Juniperus spp.). According to the Soil Conservation Service (1982), 66% of Oklahoma Cross Timbers rangelands are in fair or poor condition, with stocking rates as much as three times lower than good condition prairies in the same precipitation zone.

Land managers have for years controlled the undesireable vegetation on these lands with herbicides with the objective of increasing forage production and grazable land area. Some herbicides have been very useful in managing brush in the Cross Timbers and similar vegetation types (Scifres and Mutz 1978, Stritzke 1980, Boyd et al. 1983, Duncan and Scifres 1983, Jacoby et al. 1983). By reducing competition from brush, herbicide use has resulted in increased forage production (Baur and Bovey 1975, Stritzke et al. 1975, Scifres et al. 1977, Steinart and Stritzke 1977, Meyer et al. 1978, Scifres and Mutz 1978, Foster and Jacoby, Jr. 1979, Meyer and Bovey 1980, Scifres et al. 1981, Boyd et al. 1983, Duncan and Scifres 1983, Jacoby and Meadors 1983, Scifres et al. 1983, Jones and Pettit 1984). However, numerous studies have indicated detrimental effects, i.e., lower forage production, of several commonly used herbicides to forage grasses (Baur et al. 1977, Young and Evans 1978, Bovey and Meyer 1981, Britton and Sneva 1981, Britton and Sneva 1983, Crowder et al. 1983, Hamilton and Scifres 1983, Jacoby et al. 1983, Huffman and Jacoby, Jr. 1984, Clary et al. 1985).

Little bluestem (Schizachyrium scoparium (Michx.) Nash) is a dominant grass and often a key management species on droughty, tallgrass prairie sites that occur as islands within the Cross Timbers. Herbicides are usually broadcast applied to prairie and wooded sites alike in the vegetation mosaic because of the relatively smaller size of the tallgrass prairie islands and for additional weed control in the prairies. At application rates necessary for brush control on wooded sites, the herbicide application cost might better be eliminated on prairie sites if either the herbicide or a follow up burning treatment are not beneficial or are detrimental to the forage grasses.

This study was conducted to measure the effects of herbicide treatments, tebuthiuron and triclopyr, the year of application, and the effects of herbicide treatments alone and with a spring burn the following year on little bluestem vigor and regrowth potential in tallgrass prairie sites within the Cross Timbers.

CHAPTER III

METHODS AND MATERIALS

The study was conducted on the Cross Timbers Experimental Range (CTER) which is located 11 kilometers southwest of Stillwater in Payne County, Oklahoma. This area is dominated by the post oak (Quercus stellata (Wang.)) and blackjack oak (Q. marilandica (Muenchh.)) community type typical of the Cross Timbers (Bruner 1931, Rice and Penfound 1959, Penfound 1963, Dwyer and Santelmann 1964, Powell and Lowry 1980). Ewing et al. (1984) described the vegetation of the CTER in detail. Numerous tallgrass prairie islands, dominated by little bluestem, occur on shallow, fine textured soils within the study area. Annual precipitation averages 83 cm and occurs as a bi-model mid-spring and late fall pattern. Temperature highs are reached in late summer and average 39°C while lows are reached in mid-winter and average -16°C.

Data for this study were collected within the pasture units in proximity of permanant transects located in tallgrass prairie islands. The tallgrass prairie study areas are on shallow prairie range sites of the Grainola-Lucien soil complex (fine, mixed, thermic vertic Haplustalfs and loamy, mixed, thermic, shallow typic

Haplustolls). The CTER is composed of 20 fenced pastures each approximately 32.3 ha in size, which serve as the experimental treatment units. The experimental design was a randomized complete block with four replications. In 1983, the treatments consisted of: (1) aerial application of 2.2 kg/ha of tebuthiuron {N-[5-(1,1-dimethylethyl)--1,3,4-thiadiazol- 2-yl]-N,N'-dimethylurea} applied on 18 March 1983 (TEB), (2) aerial application of 2.2 kg/ha of triclopyr {[3,5,6-trichloro-2-pyridyloxy] acetic acid} applied on 21 June 1983 (TRI) and, (3) an untreated control (CNTL). In 1984, the treatments were: (1) TEB applied in 1983, (2) tebuthiuron applied in 1983 and then burned on 12 April 1984 (TEB+BURN), (3) TRI applied in 1983, (4) triclopyr applied in 1983 and then burned on 12 April 1984 (TRI+BURN) and, (5) an untreated control (CNTL). Weather conditions during the 12 April 1984 burn were: relative humidity of 25 to 30%, temperature of 16 to 21 $^{\circ}C$, and wind speeds of 15 with gusts to 25 kph.

Plant vigor and regrowth potential in this study was estimated by the amount of total nonstructural carbohydrate (TNC) concentrations in storage organs and by determining the amount of etiolated regrowth of clipped little bluestem plants under etiolation baskets (McKendrick and Sharp 1970, Ogden and Loomis 1972, Christiansen et al. 1981). Plant cores for determining TNC concentrations in storage organs (McIlroy 1967, White 1973, Perry et al. 1974) of little bluestem were collected biweekly from May through August and monthly from September through November in 1983. In 1984, TNC samples were collected biweekly from May through September and monthly in April, October and November. Plant cores (2.5 cm in diameter), consisting of the basal stems to a 2.5 cm height, crowns, and roots to a 15 cm depth, were collected from five randomly located plants which were in the characteristic phenological stage for the collection date and treatment. The five cores were composited and placed on ice in the field and then frozen for until processing. Processing consisted of cleaning with cold water, oven-drying at 65^{o}C for at least 48 hours, and grinding in a Wiley mill to pass a 20 mesh screen. TNC concentration was determined by the modified anthrone method outlined by Shroyer et al. (1979) to use standard values of 0, 50, 100, 150 and 200 µg glucose/ml water for comparison with the unknown sample values. Plants of approximately 78 cm^2 basal diameter were selected for etiolation measurements. Analysis of variance revealed no significant difference in basal diameter of plants between treatments. Etiolation baskets, constructed of 31 cm diameter half-sphere wire frames covered with 100% shade nursery cloth, were staked to the ground over little bluestem plants that were clipped to a stubble height of 2.5 cm and allowed to regrow until the next collection date. Etiolated regrowth was clipped to the original 2.5 cm stubble height and the oven dry weight reported for the original clipping date. After clipping the etiolated regrowth, a core was taken from the etiolated plant to measure residual TNC concentrations. The plant core was processed and analyzed as described above and TNC concentrations reported for the original clipping date.

Phenological measurements were collected throughout 1983 and 1984. Phenology was based on a numerical scale for dormancy (0), vegetative (1.00-1.99), reproductive (2.00-2.99) and plant maturity (3.00-3.66) stages (Table 1).

Data were analyzed with analysis of variance for a completely randomized block design. In the presence of a significant F value, least significant differences (LSD) were used to separate treatment means by individual collection dates in 1983 and 1984. Unless otherwise stated, all differences in treatment means were significant at the 0.10 level of probability.

Table 1. Numerical scale used for describing little bluestem phenological development on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

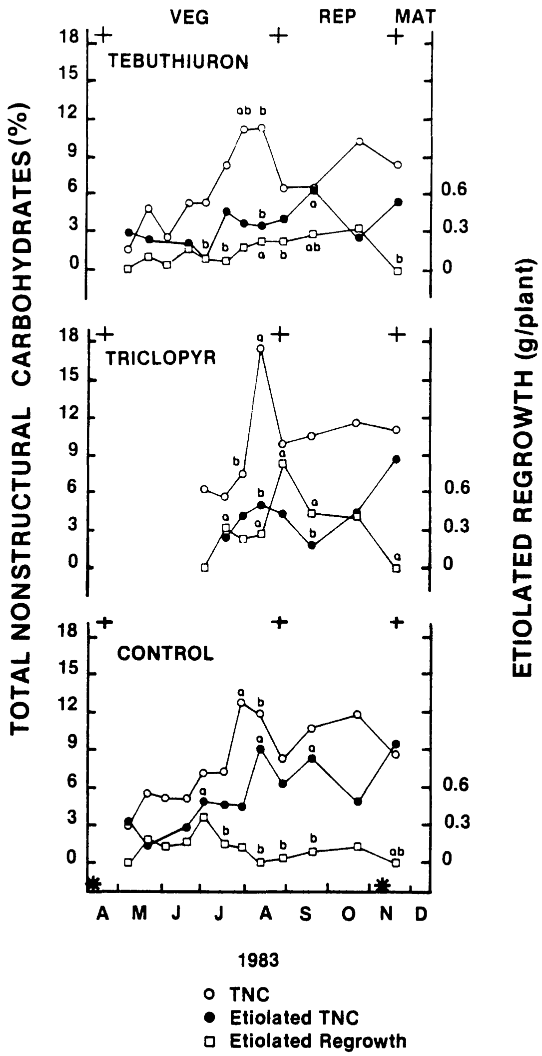
Phenological stages	Numerical scale
Dormant:	0= no new spring growth
Vegetative:	1.00= 1-3 leaves
	1.25- 4-6 leaves
	1.50= 7-8 leaves
	1.75= >8 leaves
Reproductive:	2.00= boot
	2.25= infloresence
	2.50= anthesis (pollen)
	2.75= anthesis (complete)
Maturity:	3.00= <50% of leaves yellow
	3.33= >50% of leaves yellow
	3.66= top growth all dead

CHAPTER IV

RESULTS AND DISCUSSION

Throughout 1983, TNC concentrations in storage organs of little bluestem on the CNTL followed the TNC storage curve typical for perennial warm season grasses (Fig. 1). As has been previously described for grasses, TNC concentrations decline rapidly with spring greenup, increase before and after flowering but decline again during flowering and gradually throughout the winter (Aldous 1930, Weinmann 1952, Kinsinger and Hopkins 1961, Davidson and Milthorpe 1966b, Owensby et al. 1970, Smith and Leinweber 1971, McKendrick et al. 1975, Smith 1975, Dewald and Sims 1981, Menke and Trlica 1981). TNC concentrations of plants in the CNTL were significantly greater than those in the TRI treatment in late July. Untreated plants may have diverted carbohydrates to storage rather than to growth. TNC concentrations have been reported to increase during water stress or drought situations (Brown and Blaser 1965, Blaser et al. 1966, Baker and Jung 1968, Brown and Blaser 1970, Pettit and Fagan 1974, Bokhari 1978, Chung and Trlica 1980). Conditions which inhibit growth more than photosynthesis will result in a carbohydrate storage increase (Blaser et al. 1966). No precipitation was recorded

Fig. 1. Total nonstructural carbohydrate concentrations in little bluestem storage organs (TNC), and in little bluestem storage organs after an etiolation period (Etiolated TNC), and dry weight of etiolated regrowth of little bluestem (Etiolated Regrowth) in 1983 on three treatments on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma. Means with the same letter on the same date for the same response variable are not significantly different at the .10 level of probability. Last and first $0^{o}C$ dates are marked by astericks (*). Phenological stages are separated in each treatment by plus signs (+).


VEG
REP
MAT
TEBUTHIURON
TRICLOPYR
CONTROL
TOTAL NONSTRUCTURAL CARBOHYDRATES (%)
ETIOLATED REGROWTH (g/plant)
18
15
12
9
6
3
0
0.6
0.3
0
A M J J A S O N D
1983
o TNC
● Etiolated TNC
□ Etiolated Regrowth

in July of 1983 (Table 2), creating an environmental condition where there would by plant competition for soil moisture. However, by the first sampling date in August, TNC concentrations of plants in the TRI treatment were significantly greater than either the CNTL or TEB treatment plants. This was an indication that the rapid growth phase of plants in the TRI treatment was ending and storage levels were being increased rather than depleted, as in the TEB and CNTL treatment plants which were going into the carbohydrate demand period of reproduction.

Etiolated regrowth of plants in the CNTL peaked in the spring and early summer with significantly lower amounts of regrowth than from plants in either TEB or TRI treatments in late summer and fall (Fig. 1). In contrast, plants in the TRI and TEB treatments produced maximum regrowth in late summer and early fall. Etiolated regrowth was significantly greater by plants in the TRI than regrowth from the TEB treatment on two dates within this late growing season period, and was almost three times greater than the regrowth from the CNTL treatment on the late August sampling date. The large amount of etiolated regrowth in TRI treatment plants was generally reflected in lower TNC concentrations after etiolation. In contrast, TNC concentrations after etiolation were high for treatments and on dates following low levels of etiolated regrowth. TNC concentrations after etiolation were significantly greater in the CNTL plants than in the TEB plants on two dates in early and late summer

Table 2. Monthly precipitation (cm) in Stillwater, Oklahoma for 1983, 1984 and Normal (1893 to 1980) (Meyers 1982).

	Precipitation (cm)		
Month	1983	1984	Normal
Jan	.98	.51	2.79
Feb	7.65	1.79	3.23
Mar	7.77	12.98	5.56
Apr	4.14	7.29	8.53
May	18.87	6.83	12.27
June	9.27	13.51	10.21
July	0.00	1.60	7.72
Aug	2.24	2.59	7.65
Sep	5.21	3.02	9.45
Oct	19.33	12.32	7.11
Nov	5.49	5.61	5.21
Dec	1.02	10.08	3.35
Total	81.81	78.13	63.08

and significantly greater than plants in the TRI treatment in September. It appears that regrowth took place at the expense of stored carbohydrates. Numerous studies have shown that regrowth rates are proportional to concentrations of TNC reserves (McCarty 1935, Sullivan and Sprague 1943, Jameson and Huss 1959, Brown and Blaser 1965, Adegbola 1966, Davidson and Milthorpe 1966a, McIlroy 1967, Baker and Jung 1968, Donart and Cook 1970, Booysen and Nelson 1975, Bokhari 1977) although rates of regrowth will also depend on other factors such as levels of nutrient uptake and leaf area present (Blaser et al. 1966, White 1973). Other studies (Brown and Blaser 1965, Menke and Trlica 1981) have shown that with conditions which promote greater amounts of growth, TNC concentrations were reduced or remained low throughout the growing season. Owensby et al. (1970) working on water stress studies in Kansas, found that moisture alone would not increase herbage production if soil nutrients were limiting. It appears that the little bluestem plants in the CNTL and TEB treatment have the same potential to grow as plants in the TRI treatment based on TNC concentrations throughout the growing season. However, under stress conditions of drought or declining nutrient availability plants in the CNTL and TEB treatments were less able to utilize stored carbohydrates, as evidenced by significantly less etiolated regrowth by the CNTL plants in July and by both CNTL and TEB treatments throughout late summer. Moreover, there were no significant differences between any treatments in phenological development during the 1983 season (Table 3), indicating that differences in TNC concentrations and regrowth at any date were not associated with delayed or more advanced phenology of plants from a particular treatment.

In 1984, TNC concentrations in storage organs of plants from all treatments were very similar to TNC concentrations of plants from the CNTL (Fig. 2). Significant differences were detected only on the first collection date before spring growth had begun. For the remainder of the year there were no differences in TNC concentrations amoung any of the five treatments.

Peak etiolated regrowth was in June in all treatments in 1984, quite different from 1983 when peak etiolated regrowth occurred later for the herbicide treatments. The only differences in etiolated regrowth occurred in July when plants in the TEB treatment produced significantly more regrowth than all other treatments. However, the magnitude of this difference was small compared to regrowth amounts earlier in the year and the differences detected between treatments in 1983.

The TNC concentrations in storage organs after etiolation were significantly different in July and again in October. Etiolated TNC concentrations were lowest in June and highest in October on the TRI treatment. These differences can not be explained on the basis of etiolation regrowth since regrowth was similar. As compared to

Table 3. Phenological development of little bluestem in 1983 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

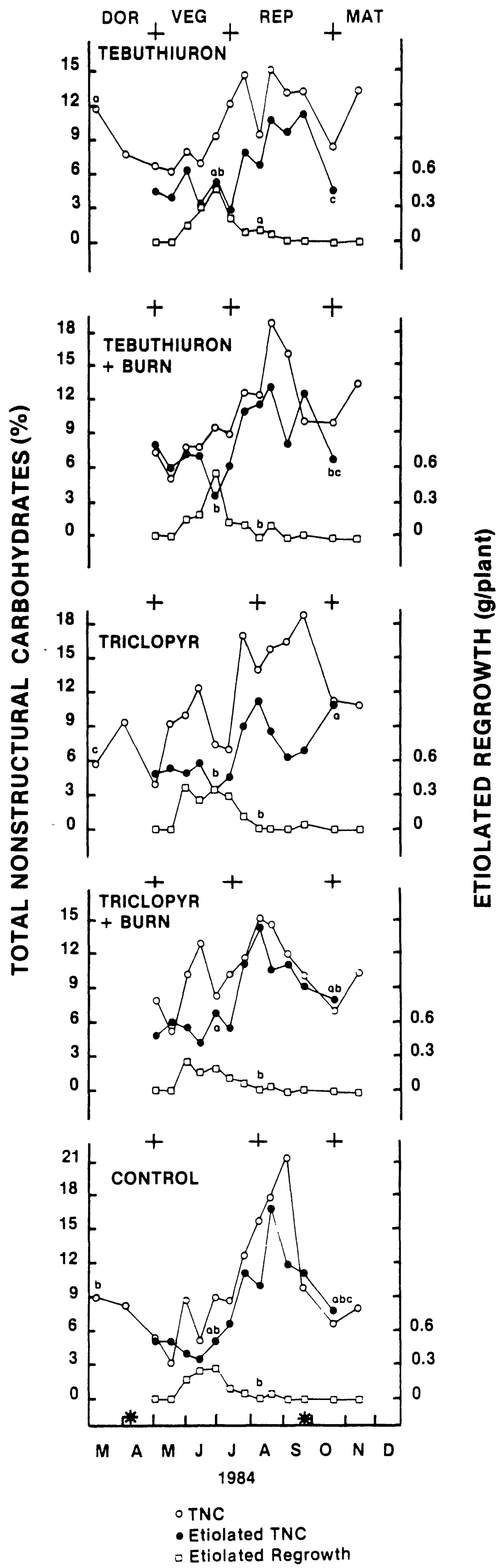
	1983												
	Apr	May		June		July		Aug			Sept	Oct	Nov
Trt[1]	21	10	25	7	20	5	20	2	15	31	21	24	21
Teb	0[2]	0	1.25	1.25	1.44	1.69	1.75	1.81	1.94	2.31	2.56	2.89	3.41
Tri	*[3]	*	*	*	*	1.50	1.50	1.69	1.81	2.06	2.69	2.81	3.33
Cntl	0	0	1.25	1.25	1.44	1.50	1.50	1.56	1.56	1.63	1.75	[illegible]	3.25

[1] Treatment: Teb= tebuthuiron, Teb+burn= tebuthiuron + spring burn.
Tri= triclopyr, Tri+burn= triclopyr + spring burn, Cntl= control.

[2] Refer to table 1 for scale of phenological development.

[3] Triclopyr was applied on 21 June 1983.

Fig. 2. Total nonstructural carbohydrate concentrations in little bluestem storage organs (TNC), and in little bluestem storage organs after an etiolation period (Etiolated TNC), and dry weight of etiolated regrowth of little bluestem (Etiolated Regrowth) in 1984 on five treatments on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma. Means with the same letter on the same date for the same response variable are not significantly different at the .10 level of probability. Last and first 0°C dates are marked by astericks (*). Phenological stages are separated by plus signs (+).


DOR VEG REP MAT
TEBUTHIURON
TEBUTHIURON + BURN
TRICLOPYR
TRICLOPYR + BURN
CONTROL
TOTAL NONSTRUCTURAL CARBOHYDRATES (%)
ETIOLATED REGROWTH (g/plant)
M A M J J A S O N D
1984
○ TNC
● Etiolated TNC
□ Etiolated Regrowth

etiolated regrowth, our data for TNC concentrations after etiolation were far less variable and therefore significant differences were more easily detected. But, amoung treatments differences in etiolated regrowth and the differences between treatments in TNC concentrations after etiolation appear to be of minor magnitude in 1984. Futhermore, there were no apparent consistant differences in the vigor measurements of TNC concentrations and etiolated regrowth between any treatments.

Burning resulted in brief differences in phenological development in 1984. Little bluestem plants in the CNTL and TRI treatments remained vegetative for no more than two weeks longer than plants in the other treatments (Table 4). Plants in the TEB+BURN and TRI+BURN treatment became reproductive (boot stage) several weeks earlier than either the CNTL or the TRI without a burn, a response to fire reported in earlier studies (Ehrenreich 1959, Owensby and Anderson 1967, Old 1969, Owensby et al. 1970, Adams and Anderson 1978). However, the reproductive stage was reached in all treatments by the mid-summer sampling date and all other significant differences in phenology occurred late in the growing season, in particular with entry into maturity. When compared to plants on the TEB and TRI treatments, plants in the CNTL, TEB+BURN, and TRI+BURN treatments advanced through reproductive stages more slowly and therefore reached maturity later. In contrast to the previously mentioned studies, burning did not hasten

Table 4. Phenological development of little bluestem in 1984 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	1984														
	Mar	Apr	May		June			July		Aug		Sept		Oct	Nov
Trt[1]	8	5	4	18	4	14	30	13	28	10	21	7	22	20	15
Teb	0[2]	0	1.00	1.25	1.25	1.25	1.25	2.00a[3]	2.00	2.00	2.12	2.44a	2.75	3.33a	3.58a
Teb + burn	*[4]	*	1.00	1.25	1.25	1.25	1.25	2.00a	2.00	2.00	2.06	2.06b	2.33	3.16ab	3.33b
Tri	0	0	1.00	1.25	1.25	1.25	1.25	1.62b	1.87	2.00	2.06	2.50a	2.50	3.33a	3.49ab
Tri + burn	*	*	1.00	1.25	1.25	1.25	1.25	2.00a	2.00	2.00	2.06	2.12b	2.37	3.08b	3.33b
Cntl	0	0	1.00	1.25	1.25	1.25	1.25	1.25c	1.87	2.00	2.00	2.00b	2.00	3.16ab	3.49ab
LSD (.10)								.24				.20		.17	.17

[1] Treatment: Teb= tebuthiuron. Teb+burn= tebuthiuron + spring burn, Tri= triclopyr, Tri+burn= triclopyr + spring burn. Cntl= control.
[2] Refer to table 1 for scale of phenological development.
[3] Means in a column followed by the same letter are not significantly different at the .10 level of probability.
[4] Burn treatments were applied on 12 April 1984.

maturity after reproduction in the burn treatments. In general, these differences in phenology did not appear to result in significant differences in either etiolated regrowth or carbohydrate storage patterns.

CHAPTER V

MANAGEMENT IMPLICATIONS

Different brush management techniques may result in varying plant vigor responses of grasses on tallgrass prairie sites within the Cross Timbers. For example, in this study the application of 2.2 kg/ha triclopyr resulted in enhanced etiolated regrowth of little bluestem growing in prairie openings. However, this increase in regrowth potential did not appear to carry-over into the second year of growth. Treatment with 2.2 kg/ha of tebuthiuron did not appear to result in as great an increase in etiolated regrowth of little bluestem as compared to the control either the year of application or the year after application. While the application of triclopyr to tallgrass prairie sites may be expected to result in an increase in little bluestem production and improve species composition, i.e., increase the little bluestem component, this would not appear to be the case for tebuthiuron. This would indicate an advantage of triclopyr over tebuthiuron in the Cross Timbers with significant proportions of tallgrass prairie sites, especially if a release from undesirable forb competition for grass production is a management objective. Burning the year after application of either tebuthiuron or triclopyr had neither a harmful or beneficial effect on little bluestem in the tallgrass prairie islands within the Cross Timbers.

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APPENDIX

Table 5. Total nonstructural carbohydrate concentrations in little bluestem storage organs in 1983 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	May		June		July		Aug			Sept	Oct	Nov
	10	25	7	20	5	20	2	15	31	21	24	21
Treatment	Total nonstructural carbohydrates (%)											
Tebuthiuron	1.6	4.9	2.6	5.4	5.4	8.4	11.2ab[1]	11.4b	6.5	6.4	10.3	8.5
Triclopyr	*[2]	*	*	*	6.3	5.7	7.6b	17.5a	9.9	10.6	11.6	11.1
Control	2.9	5.5	5.2	5.2	7.2	7.3	12.8a	11.9b	8.3	10.6	11.8	8.7
LSD (.10)							3.5	3.5				

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

[2] Triclopyr was applied on 21 June 1983.

Table 6. Total nonstructural carbohydrate concentrations in little bluestem storage organs after etiolated regrowth in 1983 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	May		June		July		Aug			Sept	Oct	Nov
	10	25	7	20	5	20	2	15	31	21	24	21
Treatment	Total nonstructural carbohydrates (%)											
Tebuthiuron	3.0	2.4	-[1]	2.2	1.0b[2]	4.7	3.7	3.6b	4.1	6.3a	2.6	5.5
Triclopyr	*[3]	*	-	*	*	2.4	4.2	5.1b	4.4	1.9b	4.6	8.8
Control	3.3	1.4	-	2.8	4.9a	4.6	4.6	9.6a	6.3	8.3a	4.9	9.5
LSD (.10)					2.0			3.8		2.1		

[1] Missing data on 7 June 1983.
[2] Means in a column followed by the same letter are not significantly different at the .10 level of probability.
[3] Triclopyr was applied on 21 June 1983.

Table 7. Dry weight (g/plant) of etiolated regrowth of little bluestem in 1983 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	May	June		July		Aug			Sept	Oct	Nov
	25	7	20	5	20	2	15	31	21	24	21
Treatment	Dry weight (g/plant)										
Tebuthiuron	.11	.05	.17	.09	.07b[1]	.19	.22a	.24b	.29ab	.34	.00b
Triclopyr	*[2]	*	*	*	.32a	.23	.27a	.84a	.45a	.41	.00a
Control	.18	.13	.17	.36	.15b	.13	.01b	.03b	.08b	.13	.00ab
LSD (.10)					.13		.17	.47	.18		.00

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

[2] Triclopyr was applied on 21 June 1983.

Table 8. Maximum leaf length (cm) of etiolated regrowth of little bluestem in 1983 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	May	June		July		Aug			Sept	Oct	Nov
	25	7	20	5	20	2	15	31	21	24	21
Treatment	Maximum leaf length (cm)										
Tebuthiuron	16.2	11.0	11.0	12.9	10.5	12.5ab[1]	13.1a	17.2a	16.9a	19.9	.0
Triclopyr	*[2]	*	*	*	15.8	14.4a	14.5a	18.7a	19.4a	22.9	.0
Control	11.0	13.1	15.3	18.5	18.0	7.6b	.9b	6.5b	8.9b	15.1	.0
LSD (.10)						5.3	4.8	5.5	3.4		

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

[2] Triclopyr was applied on 21 June 1983.

Table 9. Dry weight (g/plant) of live standing crop of little bluestem in 1983 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	May		June		July		Aug			Sept	Oct
	10	25	7	20	5	20	2	15	31	21	24
Treatment	Dry weight (g/plant)										
Tebuthiuron	.97	1.82	3.93b[1]	2.94	5.51	5.55	5.04	5.59	2.07	7.83a	5.98
Triclopyr	*[2]	*	*	*	4.75	7.02	4.51	6.30	5.37	1.82b	7.26
Control	1.12	2.13	6.66a	5.03	3.75	2.61	4.82	6.39	5.65	6.33a	4.23
LSD (.10)			2.30							1.75	

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.
[2] Triclopyr was applied on 21 June 1983.

Table 10. Maximum live leaf length (cm) of little bluestem in 1983 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	May		June		July		Aug			Sept	Oct
	10	25	7	20	5	20	2	15	31	21	24
Treatment	Maximum leaf length (cm)										
Tebuthiuron	22.1	33.1	39.1	39.9	51.4	51.4	44.0	46.4	41.1	43.1	46.6
Triclopyr	*[1]	*	*	*	45.1	49.3	43.7	51.1	49.0	51.0	41.5
CONTROL	25.9	31.4	41.8	45.1	41.2	42.6	49.9	44.1	44.9	45.2	49.0

[1] Triclopyr was applied on 21 June 1983.

Table 11. Phenological development of big bluestem, little bluestem, switchgrass and indiangrass in 1983 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	April	May		June		July		Aug			Sept	Oct	Nov
Trt[1]	21	10	25	7	20	5	20	2	15	31	21	24	21
						Big bluestem (*Andropogon gerardii*)							
Teb	0	0	1.25	1.25	1.44	1.69	1.75	1.81	1.94	2.31	2.56	3.08	3.58
Tri	*[2]	*	*	*	*	1.50	1.50	1.69	1.81	2.06	2.69	2.75	3.49
Cntl	0	0	1.25	1.25	1.44	1.50	1.50	1.56	1.56	1.63	1.75	2.31	3.58
						Little bluestem (*Schizachyrium scoparium*)							
Teb	1.00	1.00	1.19	1.25	1.25	1.25	1.50	1.75	1.88	2.00	2.63	2.89	3.41
Tri	*[2]	*	*	*	*	1.25	1.50	1.75	1.88	2.00	2.63	2.81	3.33
Cntl	1.00	1.00	1.13	1.25	1.25	1.25	1.50	1.50	1.50	1.75	2.13	2.69	3.25
						Switchgrass (*Panicum virgatum*)							
Teb	.50	.75	.94	.94	.94	1.13	1.19	1.57	1.63	1.69	2.07	2.33	2.75
Tri	*[2]	*	*	*	*	1.25	1.63	1.88	2.13	2.38	2.69	3.00	3.66
Cntl	1.00	1.00	1.25	1.25	1.25	1.25	1.75	1.94	2.06	2.06	2.63	3.17	3.66
						Indiangrass (*Sorgastrum nutans*)							
Teb	0	.25	1.00	1.25	1.25	1.25	1.31	1.56	1.56	2.00	2.56	2.81	3.50
Tri	*[2]	*	*	*	*	1.25	1.25	1.31	1.56	1.75	2.38	2.81	3.50
Cntl	.50	1.00	1.00	1.25	1.25	1.25	1.25	1.31	1.44	1.44	2.00	2.69	3.41

DORMANT:	VEGETATIVE:	REPRODUCTIVE:	MATURITY:
0	1.00= 1-3 leaves	2.00= boot	3.00= <50% of leaves yellow
	1.25= 4-6 leaves	2.25= inflorescence	3.33= >50% of leaves yellow
	1.50= 7-8 leaves	2.50= anthesis(pollen)	3.66= top growth all dead
	1.75= >8 leaves	2.75= anthesis complete	

[1] Treatments: Teb= tebuthiuron, Tri= triclopyr, Cntl= control.
[2] Triclopyr was applied on 21 June 1983.

Table 12. Total nonstructural carbohydrate concentrations in little bluestem storage organs in 1984 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	Mar	Apr	May		June			July		Aug		Sept		Oct	Nov
	8	5	4	18	4	14	30	13	28	10	21	7	22	20	15
Treatment	Total nonstructural carbohydrates (%)														
Tebuthiuron	11.8a[1]	7.7	6.7	6.2	8.0	6.9	9.4	12.2	14.8	9.5	15.1	13.2	13.2	8.4	13.3
Tebuthiuron + burn	*[2]	*	7.4	5.1	7.8	7.8	9.6	9.0	12.7	12.4	18.8	16.2	10.3	10.2	13.6
Triclopyr	5.7c	9.4	4.0	9.3	10.0	12.4	7.5	7.0	17.0	14.0	15.8	16.4	18.7	11.3	10.9
Triclopyr + burn	*	*	7.9	5.3	10.3	13.0	8.4	10.3	11.8	15.3	14.7	12.2	10.3	7.1	10.4
Control	9.0b	8.2	5.4	3.2	8.8	5.2	9.0	8.7	12.8	15.8	17.9	21.5	9.9	6.8	8.0
LSD (.10)	4.2														

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

[2] Burn treatments were applied on 12 April 1984

Table 13. Total nonstructural carbohydrate concentrations in little bluestem storage organs after etiolated regrowth in 1984 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	May		June			July		Aug		Sept		Oct
	4	18	4	14	30	13	28	10	21	7	22	20
Treatment	Total nonstructural carbohydrates (%)											
Tebuthiuron	4.5	3.9	6.3	3.4	5.3ab[1]	2.8	7.9	6.8	10.7	9.7	11.3	4.6c
Tebuthiuron + burn	8.1	6.0	7.3	7.1	3.6b	6.2	11.0	11.7	13.1	8.2	12.7	6.9bc
Triclopyr	4.9	5.4	5.0	5.9	3.8b	4.6	9.0	11.2	8.5	6.4	6.9	11.0a
Triclopyr + burn	4.8	6.0	5.6	4.3	6.9a	5.5	11.2	14.5	10.8	11.2	9.2	8.0ab
Control	5.1	5.1	4.0	3.5	5.1ab	6.6	11.3	10.1	16.9	12.0	11.2	7.8abc
LSD (.10)					2.1							3.3

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

Table 14. Dry weight (g/plant) of etiolated regrowth of little bluestem in 1984 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	June			July		Aug		Sept		Oct	Nov
	4	14	30	13	28	10	21	7	22	20	15
Treatment	Dry weight (g/plant)										
Tebuthiuron	.15	.31	.47	.21	.09	.11a[1]	.07	.01	.02	.00	.00
Tebuthiuron + burn	.15	.19	.55	.13	.11	.00b	.10	.00	.02	.00	.00
Triclopyr	.37	.26	.34	.29	.11	.00b	.00	.00	.04	.00	.00
Triclopyr + burn	.26	.16	.20	.12	.08	.01b	.05	.00	.02	.01	.00
Control	.17	.25	.27	.10	.05	.00b	.05	.00	.00	.00	.00
LSD (.10)						.01					

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

Table 15. Maximum leaf length (cm) of etiolated regrowth of little bluestem in 1984 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	June			July		Aug		Sept		Oct	Nov
	4	14	30	13	28	10	21	7	22	20	15
Treatment	Maximum leaf length (cm)										
Tebuthiuron	24.8	11.1c[1]	17.5	13.1	10.5	5.1	11.4	5.6	6.0	1.1	.0
Tebuthiuron + burn	18.2	13.6bc	17.8	10.6	5.7	1.9	4.1	2.4	3.2	.0	.0
Triclopyr	20.5	20.3ab	11.5	14.6	8.9	1.3	4.1	.0	7.6	.0	.0
Triclopyr + burn	14.8	15.1abc	15.5	9.5	4.3	4.8	3.8	.0	3.4	1.6	.0
Control	15.3	20.9a	17.3	11.0	3.0	2.5	5.7	1.9	2.4	.0	.0
LSD (.10)		7.0									

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

Table 16. Dry weight (g/plant) of live standing crop of little bluestem in 1984 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	June			July		Aug		Sept		Oct	Nov
	4	14	30	13	28	10	21	7	22	20	15
Treatment	Dry weight (g/plant)										
Tebuthiuron	3.81	6.40	13.23	13.68a[1]	22.85	12.63	13.36a	5.88	10.45a	6.45	3.24bc
Tebuthiuron + burn	2.68	3.50	7.02	8.71a	13.19	7.69	6.26b	6.81	3.80c	4.78	4.49b
Triclopyr	2.47	4.48	6.36	11.47a	8.28	8.57	8.88ab	11.16	9.07ab	4.95	3.86b
Triclopyr + burn	3.05	4.63	7.48	11.82a	6.19	6.21	9.08ab	8.46	7.94abc	6.48	10.18a
Control	2.46	4.42	5.03	5.06b	6.30	5.93	3.69b	4.15	4.16c	1.97	1.50c
LSD (.10)				5.36			5.72		4.03		1.94

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

Table 17. Maximum live leaf length (cm) of little bluestem in 1984 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	June			July		Aug		Sept		Oct	Nov
	4	14	30	13	28	10	21	7	22	20	15
Treatment	Maximum leaf length (cm)										
Tebuthiuron	33.9a[1]	42.6	41.8	47.0a	47.3	48.6a	49.0a	41.0	37.1	31.4	29.5
Tebuthiuron + burn	22.9b	30.6	36.8	36.9b	39.0	35.2b	33.3b	32.8	28.8	30.8	26.7
Triclopyr	36.7a	38.7	43.4	46.3a	44.1	42.3a	43.3ab	37.8	43.2	32.5	23.4
Triclopyr + burn	29.8ab	32.1	34.7	36.5b	33.3	32.3b	32.8b	36.3	28.3	26.1	23.4
Control	34.7a	39.6	44.3	39.5ab	41.1	34.7b	42.7ab	37.0	36.5	28.1	23.2
LSD (.10)	8.3			8.4		6.2	9.9				

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

Table 18. Dry weight (g/plant) of non-etiolated regrowth of little bluestem in 1984 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	June			July		Aug		Sept		Oct	Nov
	4	14	30	13	28	10	21	7	22	20	15
Treatment	Dry weight (g/plant)										
Tebuthiuron	.71	1.00ab[1]	.66	.34	.08	.23	.17	.01a	.04	.01ab	.00
Tebuthiuron + burn	.98	.73abc	.37	.60	.03	.00	.04	.00b	.01	.00b	.00
Triclopyr	.37	.46bc	.15	.04	.16	.00	.05	.00b	.03	.00b	.00
Triclopyr + burn	.63	1.17a	.43	.06	1.11	.01	.03	.00b	.01	.01a	.00
Control	.70	.39c	.22	1.13	.02	.00	.46	.00b	.02	.00b	.00
LSD (.10)		.55						.00		.01	

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

Table 19. Maximum leaf length (cm) of nonetiolated regrowth of little bluestem in 1984 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

	June			July		Aug		Sept		Oct	Nov
	4	14	30	13	28	10	21	7	22	20	15
Treatment	Maximum leaf length (g/plant)										
Tebuthiuron	31.4	26.7a[1]	20.3a	13.5a	6.9ab	3.8	4.6	2.4	3.7	.3	.0
Tebuthiuron + burn	26.7	15.1c	15.6ab	9.0ab	3.0bc	.4	3.5	.0	3.7	.6	.0
Triclopyr	17.7	16.7c	11.2b	6.0b	8.3a	.6	4.1	.0	5.8	.3	.0
Triclopyr + burn	17.8	22.7ab	14.1b	6.5b	3.2bc	.4	2.5	.0	4.1	1.0	.0
Control	21.2	12.6c	12.2b	5.1b	2.3c	.0	4.8	1.3	7.0	.6	.0
LSD (.10)		5.9	4.9	5.2	4.1						

[1] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

Table 20. Phenological development of big bluestem and little bluestem in 1984 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

Trt[1]	Mar 8	Apr 5	May 4	May 18	June 4	June 14	June 30	July 13	July 28	Aug 10	Aug 21	Sept 7	Sept 22	Oct 20	Nov 15
Big bluestem, (*Andropogon gerardii*)															
Teb	0	0	1.00	1.25	1.25	1.31	1.37	1.62ab[2]	1.5ab	1.87	2.44a	2.62	2.50	3.25	3.66
Teb + burn	‡[3]	‡	.50	1.17	1.25	1.25	1.33	1.75a	1.75a	2.00	2.08ab	2.33	2.12	3.22	3.55
Tri	0	0	.25	1.25	1.18	1.25	1.25	1.31c	1.31b	1.75	2.44a	2.69	2.75	3.33	3.66
Tri + burn	‡	‡	.75	1.25	1.25	1.31	1.31	1.62ab	1.50ab	2.00	2.08ab	2.67	3.00	3.14	3.58
Cntl	0	0	.25	1.25	1.25	1.25	1.25	1.37b	1.25b	1.50	1.81b	2.50	2.56	3.25	3.66
LSD (.10)								.29	.31		.44				
Little bluestem (*Schizachyrium scoparium*)															
Teb	0	0	1.00	1.25	1.25	1.25	1.25	2.00a	2.00	2.00	2.12	2.44a	2.75	3.33a	3.58a
Teb + burn	‡	‡	1.00	1.25	1.25	1.25	1.25	2.00a	2.00	2.00	2.06	2.06a	2.33	3.16ab	3.33b
Tri	0	0	1.00	1.25	1.25	1.25	1.25	1.62b	1.87	2.00	2.06	2.50a	2.50	3.33a	3.49ab
Tri + burn	‡	‡	1.00	1.25	1.25	1.25	1.25	2.00a	2.00	2.00	2.06	2.12b	2.37	3.08b	3.33b
Cntl	0	0	1.00	1.25	1.25	1.25	1.25	1.25c	1.87	2.00	2.00	2.00b	2.00	3.16ab	3.49ab
LSD (.10)								.24				.20		.17	.17

Dormant:	Vegetative:	Reproductive:	Maturity:
0	1.00= 1-3 leaves	2.00= boot	3.00= <50% of leaves yellow
	1.25= 4-6 leaves	2.25= infloresence	3.33= >50% of leaves yellow
	1.50= 7-8 leaves	2.50= anthesis (pollen)	3.66= top growth all dead
	1.75= >8 leaves	2.75= anthesis (complete)	

[1] Treatment: Teb= tebuthiuron, Teb+burn= tebuthiuron + spring burn, Tri= triclopyr, Tri+burn= triclopyr + spring burn, Cntl= control.

[2] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

[3] Burn treatments were applied on 12 April 1984.

Table 21. Phenological development of switchgrass and indiangrass in 1984 on a shallow prairie range site at the Cross Timbers Experimental Range in Payne County, Oklahoma.

Trt[1]	Mar 8	Apr 5	May 4	May 18	June 4	June 14	June 30	July 13	July 28	Aug 10	Aug 21	Sept 7	Sept 22	Oct 20	Nov 15
							Switchgrass (*Panicum virgatum*)								
Teb	0	0	1.00	1.25	1.25	1.25	1.25c[2]	1.83	2.25	2.25	2.50a	2.50	3.00	3.33	3.66a
Teb + burn	*[3]	*	1.00	1.19	1.25	1.25	1.31bc	2.25	2.31	2.44	2.44a	2.44	2.83	3.16	3.49b
Tri	0	0	.50	1.19	1.19	1.25	1.69a	2.19	2.25	2.31	2.42a	2.69	3.00	3.33	3.66a
Tri + burn	*	*	1.00	1.25	1.25	1.25	1.25c	2.00	2.03	2.44	2.50a	2.69	3.00	3.33	3.66a
Cntl	0	0	.75	1.19	1.25	1.25	1.62ab	2.19	2.25	2.37	2.25b	2.50	3.08	3.25	3.66a
LSD (.10)							.32				.12				.11
							Indiangrass (*Sorgastrum nutans*)								
Teb	0	0	1.00	1.00b	1.12	1.06ab	1.12a	1.25	1.37a	1.31	1.62	2.19	2.50	3.25	3.66a
Teb + burn	*	*	1.00	1.19a	1.19	1.19a	1.19a	1.25	1.25b	1.25	1.69	1.75	2.25	3.11	3.41b
Tri	0	0	1.00	1.00b	1.00	1.00b	1.06a	1.25	1.25b	1.25	1.25	2.25	2.62	3.25	3.58a
Tri + burn	*	*	1.00	1.19a	1.19	1.19a	1.28a	1.25	1.25b	1.25	1.25	2.12	2.50	3.08	3.49ab
Cntl	0	0	1.00	1.06ab	1.12	1.00b	1.00b	1.25	1.25b	1.25	1.25	1.81	1.94	3.00	3.66a
LSD (.10)				.12		.12	.13		.08						.12

Dormant:	Vegetative:	Reproductive	Maturity:
0	1.00= 1-3 leaves	2.00= boot	3.00= <50% of leaves yellow
	1.25= 4-6 leaves	2.25= infloresence	3.33= >50% of leaves yellow
	1.50= 7-8 leaves	2.50= anthesis (pollen)	3.66= top growth all dead
	1.75= >8 leaves	2.75= anthesis (complete)	

[1] Treatments: Teb= tebuthiuron, Teb+burn= tebuthiuron + spring burn, Tri= triclopyr, Tri+burn= triclopyr + spring burn, Cntl= control.

[2] Means in a column followed by the same letter are not significantly different at the .10 level of probability.

[3] Burn treatments were applied on 12 April 1984.

Table 22. Monthly temperatures (°C, maximum & minimum) in Stillwater, Oklahoma for 1983, 1984 and Normal (1893 to 1980) (Meyers 1982).

	Temperature (°C)					
	Maximum			Minimum		
Month	1983	1984	Normal	1983	1984	Normal
Jan	23	22	9	-8	-24	-4
Feb	19	25	12	-12	-5	-2
Mar	28	27	17	-7	-4	2
Apr	28	29	22	-3	-1	9
May	32	32	26	4	3	14
June	34	36	31	8	16	18
July	40	41	34	14	16	21
Aug	41	43	34	13	16	21
Sep	38	38	30	2	-1	16
Oct	31	29	24	2	1	9
Nov	26	26	16	-6	-4	3
Dec	16	22	10	-23	-12	-2

VITA

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Candidate for the Degree of

Master of Science

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