EFFECTS OF BRUSH MANAGEMENT ON WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) IN THE CROSS TIMBERS REGION OF OKLAHOMA

By

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1987

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1992

EFFECTS OF BRUSH MANAGEMENT ON WHITE-TAILED DEER (ODOCOILEUS VIRGINIANUS) IN THE CROSS TIMBERS REGION OF OKLAHOMA

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ACKNOWLEDGMENTS

I would like to extend my sincere appreciation to my major advisor Dr. Robert L. Lochmiller for his guidance throughout this research project. Thanks also go to my committee members Drs. David M. Leslie and David M. Engle for their patience and support for the duration of this study. A special word of thanks is extended to Dr. S. L. "Bud" Burks for his assistance with the telemetry analysis and computer work. I would also like to thank Scott McMurry, Jon Jenks, Alan Peoples, Michelle Vesty, Bill Dinkines, Jon Boren, Jim Boggs, Cindy Schultz and all other graduate and undergraduate students for their unselfish assistance with the field work and data collection. Thanks are also expressed to James Kulbeth and all other agronomy research assistants for their assistance with browse identification and collection.

I would also like to thank my creator and his son who gave me more endurance, courage, and ability then I thought possible. A special thank you for the support given to me by my mother Joann Soper who made me believe in myself and my abilities. A thank you also goes to Derald and Linda Suffridge for keeping my wife sane while I was driving her crazy.

A special word of thanks goes Craig Ferris and Louise Mango. Thank you for the time and understanding that I needed to complete this degree.

Most importantly, my deepest love and appreciation go to my dearest wife Dessa. There is no way to describe the amount of patience, love, and support you gave to me. Thank you Dessa, there would have been no reason to endure if not for you and our wonderful children, Kalyin Elizabeth and Kableb Abaliene.

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CHAPTER I

INTRODUCTION

This thesis is composed of 3 manuscripts formatted for submission to scientific journals. Each manuscript is complete as written and does not require additional support material. The order of arrangement for each manuscript is text, literature cited, tables, and figures. Chapter II, "Condition and diet quality of white-tailed deer in response to vegetation management in central Oklahoma," is written in the format of the Proceedings of the Oklahoma Academy of Science. Chapter III, "Nutritional quality of browse in response to brush management on the cross timbers rangeland," is written in the format of the Journal of Range Management. Chapter IV, "Habitat use by white-tailed deer on managed cross timbers rangeland," is written in the format of the Journal of Wildlife Management.

CHAPTER II

CONDITION AND DIET QUALITY OF WHITE-TAILED DEER IN RESPONSE TO VEGETATION MANAGEMENT IN CENTRAL OKLAHOMA

ABSTRACT.-- We examined the effects of woody vegetation management using herbicide and fire on condition and diet quality of white-tailed deer (Odocoileus virginianus) in the cross timbers of central Oklahoma. Condition of deer was assessed seasonally (1987-1989) on an area containing a mosaic of habitat types created by various brush removal treatments and on a control area that was not exposed to any brush treatments. Five brush removal treatments were used to create a mosaic of habitat types on the Cross Timbers Experimental Range (CTER) and included tebuthiuron, tebuthiuron with an annual spring burn, triclopyr, triclopyr with an annual spring burn, and untreated habitat. Deer carcass weights were significantly higher on the CTER than untreated areas; no differences were detected in any morphological or reproductive parameters examined. Concentrations of nitrogen in postmortem feces and rumen digesta of animals collected in spring were higher on the

untreated control than CTER study areas. Concentrations of nitrogen and acid detergent fiber in feces differed significantly among seasons and study areas, reflecting higher quality diets on the CTER than untreated control areas. Differences among study areas were also noted for concentrations of insoluble and soluble nitrogen in feces. Variable herbicide patterning positively influenced the quality of diets available to white-tailed deer, but had only minimal influence on physical condition.

INTRODUCTION

The cross timbers land resource area is a western extension of the Ozark plateau, oak-hickory ecosystem and accounts for approximately 19 million ha of land in the central United States (1, 2). Livestock production on these oak-dominated rangelands is relatively low because of low herbaceous forage production (3). Brush management programs that selectively remove unwanted woody species and increase herbaceous forage production can often benefit both white-tailed deer (Odocoileus virginianus) and livestock (3, 4). Improved cattle and deer production after removing woody vegetation has promoted the use of herbicides and fire on rangeland in the cross timbers area (5, 6, 7, 8).

Effects of a variety of brush management strategies using herbicides and fire on white-tailed deer have been examined in a variety of habitat types. Initial improvements in browse and forb production have been demonstrated following applications of 2,4,5-T, picloram, 2,4,-D, tebuthiuron, triclopyr, and glyphosate (9, 10). However, white-tailed deer behavioral and population responses to herbicide-induced vegetation changes varies considerably and appears to be dependent on habitat type (11, 12, 13, 14). Little has been reported on the nutritional and physiological responses of deer to brush management.

We initiated studies in 1987 to evaluate the impact of a brush management strategy utilizing variable herbicide patterning and prescribed burning on diet quality and condition of white-tailed deer on cross timbers rangeland in Oklahoma. Variable herbicide patterning (VHP) is a modification of the "variable rate patterning" (15) approach to brush management, where two or more dosages of a single herbicide are applied to alternating strips or blocks of vegetation to create a diversity of vegetation types. With VHP two or more herbicides may be used on alternating strips or blocks of vegetation to create a diverse mosaic of habitat types because herbicides vary considerably with respect to efficacy and selectivity (16). In this study we examined seasonal changes in diet quality and physical condition of white-tailed deer exposed to variable herbicide patterning with tebuthiuron and triclopyr used in combination with annual prescribed burning.

METHODS

Study area: Our study was conducted on the Cross Timbers Experimental Range (CTER) Payne County, Oklahoma

(36°2' to 36°4'N, 97°9' to 97°11'W) The CTER is a 648 ha research area which was established in 1983 to compare vegetation, livestock, and wildlife responses to brush management. Two control sites, Hamns Lake Research Area (HLRA) and Zoological Research Area (ZRA), are located 13 and 9 km west of Stillwater, respectively. All three research areas were located in the western cross timbers forest and on a rugged landscape dissected by stream drainages with steep slopes. Soils of the region were described by Gray and Stahnke (17), and a pre-treatment vegetation inventory of the area was completed in 1982 (18).

Upland hardwood forest, dominated by blackjack (Quercus marilanda) and post oak (Quercus stellata) is the primary vegetation type in the area on course-textured soils, although tallgrass prairie is interspersed on fine-textured soils (18). The upland forest, prior to treatment, varied from an open hardwood overstory with a productive herbaceous understory to a completely closed overstory with negligible understory production. Bottomland forest occupies a rather restricted position along drainages. Understory species were dominated by coralberry (Symphoricarpos orbiculatus), eastern redcedar (Juniperus virginia), poison ivy (Rhus radicans), rough-leaf dogwood (Cornus drummondii), redbud (Cercis canadensis), and American elm (Ulmus americana). Dominant herbaceous vegetation included little bluestem (Schizachyrium scoparium), indiangrass (Sorghastrum nutans), western ragweed (Ambrosia psilostachya), and rosette panicgrass (Panicum oligosanthes) (18).

Variable herbicide patterning: A mosaic of five habitat types was created on the CTER by using two-hebicide patterning, in combination with or without annual prescribed burning, and interspersed with untreated habitats. The CTER was divided into 20 adjacent, fenced 32.4 ha pastures, and 4 replications each of 5 different brush treatments were randomly applied to differing pastures on the study area (Fig. 1). The 5 brush treatments included: (1) tebuthiuron (N-[-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N +N'-dimethlurea); (2) tebuthiuron in conjunction with an annual spring burn; (3) triclopyr ([(3,5,6-tricloro-2-pyridinyl)oxy] acetic acid); (4) tyiclopyr application with an annual prescribed burn; (5) untreated control. Each herbicide was applied aerially at a rate of 2.2 kg/ha (tebuthiuron in March and triclopyr in June 1983) and annual prescribed burning in April 1985-87.

Vegetation responses to tebuthiuron and triclopyr applications, with and without prescribed burning, on the CTER have been reported previously (10, 19). Tebuthiuron habitats had little overstory, dense herbaceous cover, and very little woody understory; triclopyr habitats contained little overstory with moderate amounts of herbaceous cover and a dense understory of resprouting woody species; and untreated habitats were characterized by a dense woody canopy with little herbaceous cover and moderate amounts of woody understory (10, 19). Annual prescribed burning was effective at suppressing cover of eastern redcedar and improving nutritional quality of selected herbaceous forages (20).

<u>Evaluation of animal condition</u>: Fecundity and general condition of white-tailed deer on CTER were compared to those on ZRA in March from 1987 to 1989. Five adult does (3 collected on ZRA in 1987) were collected from each study area using a spotlight and a high powered rifle. Blood samples for hematologies were obtained within 5-min of death by cardiac puncture into 3-ml Vacutainer tubes containing EDTA-K_2 as an anticoagulant and placed on ice. Rumens were injected with a 10% solution of mercuric chloride ($HgCl_2$) to cease microbial fermentation. Deer were transported to the laboratory for postmortem evaluation.

Hematocrit and hemoglobin concentration were determined within 6 hours as described by Lochmiller et al. (21). Body weight was recorded to the nearest 0.5 kg using a standard spring scale and age determined by tooth eruption and wear (22). Spleen, paired adrenal glands, thymus, kidneys, kidney fat, and uterus were removed, trimmed of excess fat and connective tissue, and weighed to the nearest 0.01 g. Kidney fat index was calculated as described by Rinney (23). Femur marrow fat was estimated by the oven-dry method at 50 °C (24). Fetuses were enumerated, aged (25, 26), and conception date calculated by back dating (27).

Postmortem subsamples of digesta from the rumen (mixed prior to sampling) and feces from the rectum were obtained from each animal to assess recent dietary quality. Subsamples of rumen digesta and feces were oven dried (50 °C) and ground with a Wiley-Micro mill to pass through a 1 mm mesh screen. Subsamples were analyzed for concentrations of neutral detergent fiber (NDF) and acid detergent fiber (ADF) using the procedures of Goering and Van Soest (28). Concentration of total nitrogen was determined by the Kjeldahl procedure (29). Concentration of insoluble nitrogen (fiber-bound, indigestible nitrogen) was determined by analyzing the residual nitrogen after removal of acid detergent solubles (30). Concentration of soluble nitrogen was calculated as the difference between total and insoluble nitrogen concentrations.

Seasonal evaluation of dietary quality: We indirectly monitored seasonal changes in the nutritional quality of diets of white-tailed deer on each of the three study areas using fecal indices (31, 32). Fecal pellet groups were collected in winter (January), spring (April), summer (July), and fall (October) from winter 1988 to summer 1989. Because deer could not be observed defecating, we collected feces that appeared fresh (33). A minimum of 15 fecal groups were collected from each study area and composited for analysis (34). Five composites (1 composite of 15 fecal groups per habitat type on the CTER) were compared to 5 composites each from the ZRA and HLRA for each season.

Composited fecal samples were analyzed for concentrations of total nitrogen, soluble nitrogen, insoluble nitrogen, and ADF concentrations as previously described for postmortem samples.

Statistical analysis: Differences in morphological indices of condition between study areas (CTER, ZRA) were examined using a one-way analysis of covariance with body weight as the covariate; differences in body and carcass weight were examined using age as a covariate. Differences in indices of dietary quality (total nitrogen, soluble nitrogen, insoluble nitrogen, NDF, ADF) of postmortem rumen and fecal samples were analyzed using a two-way analysis of variance with year and study area (CTER, ZRA) as the independent variables. If significant interactions were indicated, differences between study areas were analyzed by year for that variable. Indices of diet quality (total nitrogen, soluble nitrogen, insoluble nitrogen, ADF) from seasonal fecal collections were analyzed for differences among study areas (CTER, ZRA, HLRA) within each season using a one-way analysis of variance. Hartley's F-Max test was used to test for homogeneity of variances among study areas (35). Variables with heterogeneous variances (kidney fat index, ruminal nitrogen, and fecal insoluble nitrogen) were rank-transformed prior to analysis (36). Protected multiple comparisons (LSD) were used when analysis of variance suggested that we reject the null hypothesis that study areas were similar. The Statistical Analysis System (SAS) was used for all data analyses (37).

RESULTS

Animal collection: Twenty-six adult female deer were collected from 1987-89 from the ZRA (n = 13) and the CTER (n = 13). Brush management on the CTER had a significant (P < 0.05) influence on carcass weight of adult does which averaged about 2 kg heavier on the CTER than the ZRA (Table 1). Body weight and weights of uterus, adrenal glands, thymus gland, and spleen did not differ (P > 0.05) between CTER and ZRA. Femur fat and kidney fat indices were higher in deer collected on the CTER than ZRA, but differences were not significant (P > 0.05).

Measurements of fecundity indicated that variable herbicide patterning had no influence on reproduction of adult does (Table 1). Mean conception date, proportion of does pregnant, and number of fetuses/doe were similar between study areas.

Packed cell volume and hemoglobin concentrations averaged 43.96% and 16.12%, respectively, and were not influenced (P > 0.05) by brush management (Table 1). Postmortem concentrations of total nitrogen and NDF in rumen digesta showed significant (P < 0.05) annual fluctuations, and a significant (P < 0.05) interaction between year and habitat type was indicated. Total nitrogen was lower and NDF was higher (P < 0.005) in rumen digesta of deer collected from the CTER ($\underline{x}$ = 2.52 ± 0.23 SE %, and 60.67 ± 2.87%) compared to ZRA (3.81 ± 0.17%, and 48.24 ± 1.50%, respectively) in 1988, but not in other years. Concentrations of insoluble nitrogen in rumen digesta was significantly ($\underline{P}$ < 0.05) lower on the CTER than the ZRA. Concentrations of soluble nitrogen did not differ ($\underline{P}$ > 0.05) between study areas (Table 2).

Differences among years were not significant ($\underline{P}$ > 0.05) for mean concentrations of total nitrogen, ADF, or soluble nitrogen in postmortem feces (Table 2). Concentrations of total nitrogen in feces of collected deer tended to be lower ($\underline{P}$ = 0.055) on the CTER than the ZRA. Mean concentration of ADF was significantly ($\underline{P}$ < 0.001) higher on CTER than the ZRA. Brush management had no significant influence ($\underline{P}$ > 0.05) on soluble and insoluble nitrogen concentrations of feces (Table 2).

Seasonal monitoring of diet quality: Concentrations of total nitrogen, soluble nitrogen, insoluble nitrogen, and ADF in feces were different ($\underline{P}$ < 0.05) among seasons (Fig. 2). All nitrogen parameters measured were highest in concentration in spring and lowest in winter. Concentrations of ADF were highest in winter and lowest in summer.

Differences in fecal indices of diet quality were indicated between brush-treated and untreated control study areas (Fig. 2) Concentrations of total and soluble nitrogen in feces were significantly greater ($\underline{P}$ < 0.05) on the CTER than both untreated control areas in fall and ZRA in winter. There were no significant differences ($P > 0.05$) in concentrations of insoluble nitrogen between the CTER and untreated areas for any season, but levels were higher ($P < 0.05$) on the HLRA than ZRA in spring. Concentrations of ADF in feces of deer collected from the CTER were significantly lower ($P < 0.05$) than both untreated areas in fall, but were significantly higher ($P < 0.001$) than HLRA in winter. All other seasonal comparisons between study areas were not significant ($P > 0.05$).

DISCUSSION

Variable patterning of the herbicide applications created a series of different habitat types on the CTER. Herbicides were applied to reduce overstory dominance of post oak and blackjack oak. As a result of these treatments and their respective herbaceous responses, the mosaic that was created on the CTER was comprised of open areas containing grasses and forbs, areas with high cover and browse production, and patches of typical cross timbers habitat.

Morphometric parameters such as body weight, carcass weight, kidney fat index, femur marrow fat, and metabolically active organ weights have been used to assess body condition in white-tailed deer populations (38). Kie (39) demonstrated that eviscerated carcass weight, and other morphological and physical parameters were useful indices for comparing the relative condition of white-tailed deer between high and low density populations in Texas. Similar morphometric parameters of condition were used by Hesselton and Sauer (40) to asses the relative condition of 4 deer herds in New York. Eviscerated carcass weight is a less variable indicator of condition than body weight and may reflect long term protein intake (41, 42, 43).

Greater carcass weights of white-tailed deer collected on the CTER suggests that variable herbicide patterning provides long-term improvements in nutrition in comparison to untreated study areas. Increased forage production was observed during the first 2 years post-treatment but declined over time (44) (Fig. 3). Tanner et al. (45) observed that white-tailed deer were often attracted to new succulent woody growth following application of herbicides in Texas. McCollum et al. (20) noted that the burn treatments used on the CTER increased weight gain in cattle. Deer density was not determined in our study.

Nutritional quality of the habitat and diets of white-tailed deer are frequently assessed indirectly by determining concentrations of selected nutrients in feces and rumen digesta. Leslie and Starky (31) found a strong correlation between dietary nitrogen and fecal nitrogen concentrations. High concentrations of nitrogen in feces (31) and ruminal nitrogen (45) are associated with a high quality diet whereas high concentrations of fiber components are indicative of poor quality forage (46). Kie (47) effectively used ruminal concentration of crude protein to make relative comparisons of diet quality between two populations of white-tailed deer in Texas. Ruminal concentrations of nitrogen have also been used to index range quality for sitka black-tailed deer (Odocoileus hemionus sitkensis) in southwest Alaska (48). Fecal soluble nitrogen is thought to reflect dietary quality because it indexes soluble nitrogen from dietary and other endogenous sources (49).

Indices of diet quality fluctuated greatly across seasons on both brush-treated and untreated study areas. Differences among seasons undoubtedly reflected changes in food habits of white-tailed deer, as demonstrated by Van Vreede (49) on cross timbers rangeland in south central Oklahoma. Diets in the cross timbers are typically dominated by woody browse and mast in fall and winter, and forbs in the spring and summer. Comparisons of fecal indices (total nitrogen, soluble nitrogen, and ADF) of diet quality indicated that nutritional conditions were improved on the CTER than untreated study areas in fall and winter. Digestibility and concentrations of crude protein in coralberry (Syphoricarpus orbiculatus), greenbriar (Smilax spp.), hackberry (Celtis spp.), blackberry (Rubus spp.), and elm (Ulmus spp.) were found to be greater on herbicide-treated habitats than untreated areas on the CTER (50) in fall and winter. Similar improvements in the quality of browse were documented by Bogle et al. (51) following applications of tebuthiuron and fire. Improvements in the nutritional quality of diets from fall to winter may account for greater eviscerated carcass weights of white-tailed deer on the CTER compared to untreated areas. Fecal indices indicated that the higher quality diets on the CTER in fall and winter did not persist into spring and summer when diets of deer typically shift to succulent forbs (49). This observation was largely supported by postmortem fecal and rumen digesta analyses as well.

Variable herbicide patterning increased the nutritional quality of white-tailed deer diets. Although these advantages may only be manifested in long-term benefits (i.e. carcass weight), alterations to habitat by variable herbicide patterning can be used to positively influence white-tailed deer habitat. Topography, soil type, and geology of an area relative to type of patterning should be considered before herbicide application.

ACKNOWLEDGEMENTS

This is journal article J-_____ of the Oklahoma Agricultural Experiment Station. This study was funded in part by the National Science Foundation (BSR-8657043), Oklahoma Agricultural Experiment Station, Kerr Foundation, Oklahoma Cooperative Fish and Wildlife Research Unit (Fish and Wildlife Service, Oklahoma Department of Wildlife Conservation, Oklahoma State University, and Wildlife

Management Institute, cooperating), and the Department of Zoology, Oklahoma State University.

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Table 1. Comparisons of morphological, physiological, and reproductive indices of condition in adult female white-tailed deer collected on the Cross Timbers Experimental Range (CTER) and Zoological Research Area (ZRA) in March of 1987-1989.

	Study area					
	CTER			ZRA		
Variable	n	x	SE	n	x	SE
Packed cell volume (%)	13	45.22	1.50	13	42.63	2.16
Hemoglobin (g/)	8	15.16	1.92	8	17.09	0.06
Femur marrow fat (%)	13	72.31	6.11	13	69.98	4.71
Kidney fat (%)	13	27.22	7.49	13	17.33	2.77
Fetuses/doe	13	1.93	0.18	13	2.00	0.25
Does pregnant (%)	13	100.00	--	13	92.00	--
Body weight (kg)	13	49.78	1.83	13	48.83	2.23
Carcass weight (kg)	13	37.53	1.94	13	35.45	1.40
Uterus (kg)	13	413.81	43.47	13	489.14	87.50
Ovaries (kg)	13	1.84	0.36	13	1.54	0.16
Adrenal glands (g)	13	4.11	0.41	13	4.23	0.39
Thymus gland (g)	11	16.12	3.45	11	18.58	3.45
Spleen (g)	13	221.79	20.51	11	254.33	17.77

Table 2. Nutritional indexes of rumen and fecal samples taken from adult white-tailed deer on the Cross Timbers Experimental Range (CTER) and the Zoological Experimental Area (ZRA) in the spring of 1987-89.

	Study area					
	CTER			ZRA		
Variable	n	x	SE	n	x	SE
Rumen content						
Nitrogen (%)	12	3.35	0.24	12	4.10	0.20
NDF (%)	12	53.00	2.38	13	47.18	0.94
ADF (%)	12	35.62	1.68	13	31.52	1.23
Insoluble nitrogen	11	0.46	0.04	13	0.64	0.06
Soluble nitrogen	11	3.00	0.23	13	3.46	0.19
Feces						
Nitrogen (%)	12	2.55	0.18	13	2.94	0.21
ADF (%)	13	48.12	1.77	13	39.02	1.58
Insoluble nitrogen	13	0.54	0.02	13	0.55	0.04
Soluble nitrogen	13	2.02	0.11	13	2.39	0.18

Fig. 1. Distribution of experimental brush-control treatments used to create a mosaic of habitat types using variable herbicide patterning on the Cross Timbers Experimental Range.

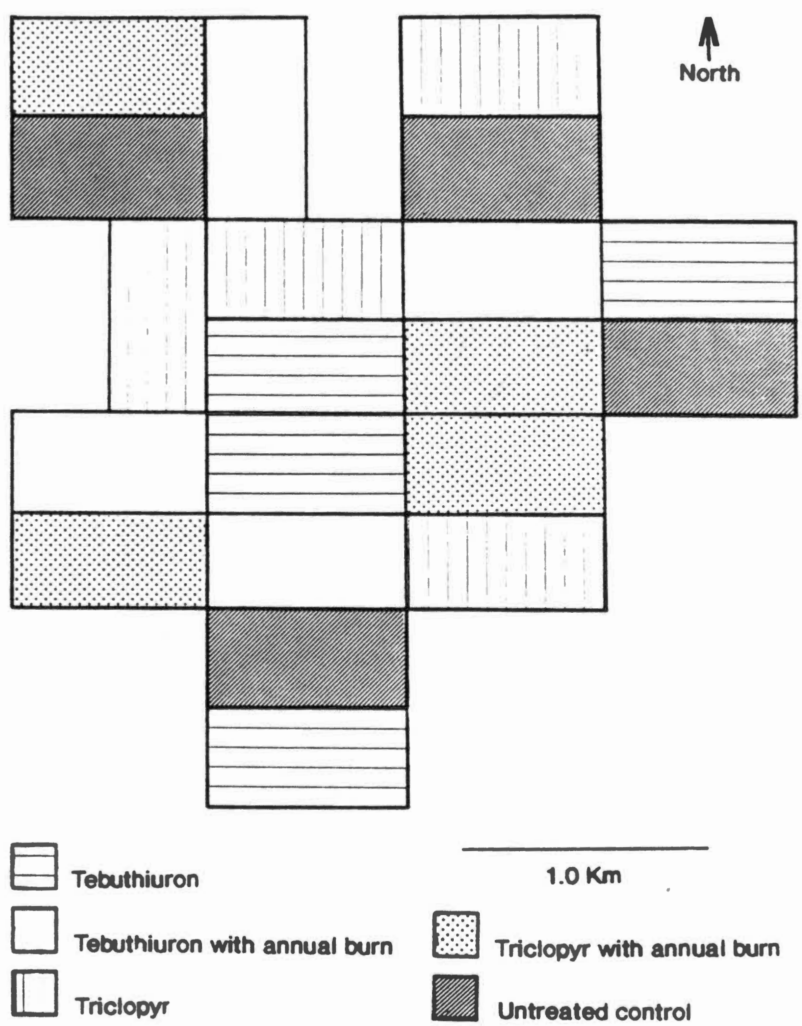
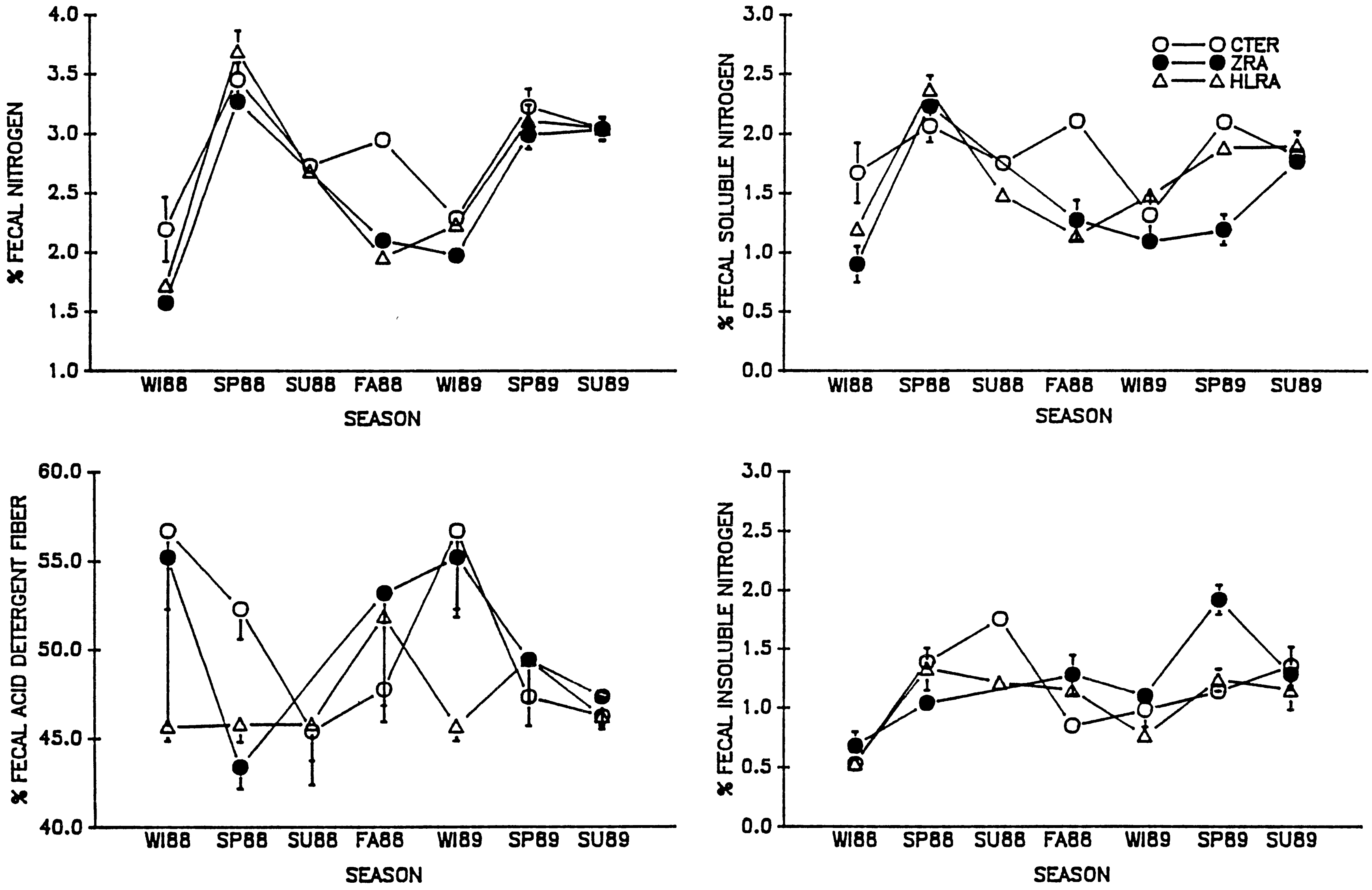
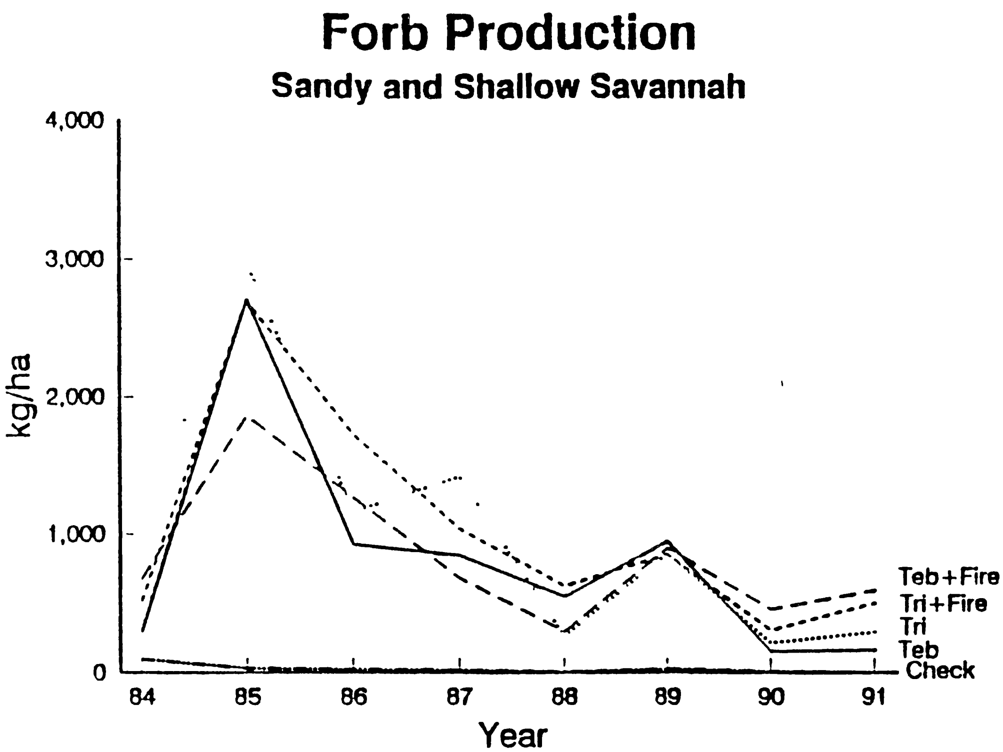

North
1.0 Km
Tebuthiuron
Tebuthiuron with annual burn
Triclopyr
Triclopyr with annual burn
Untreated control

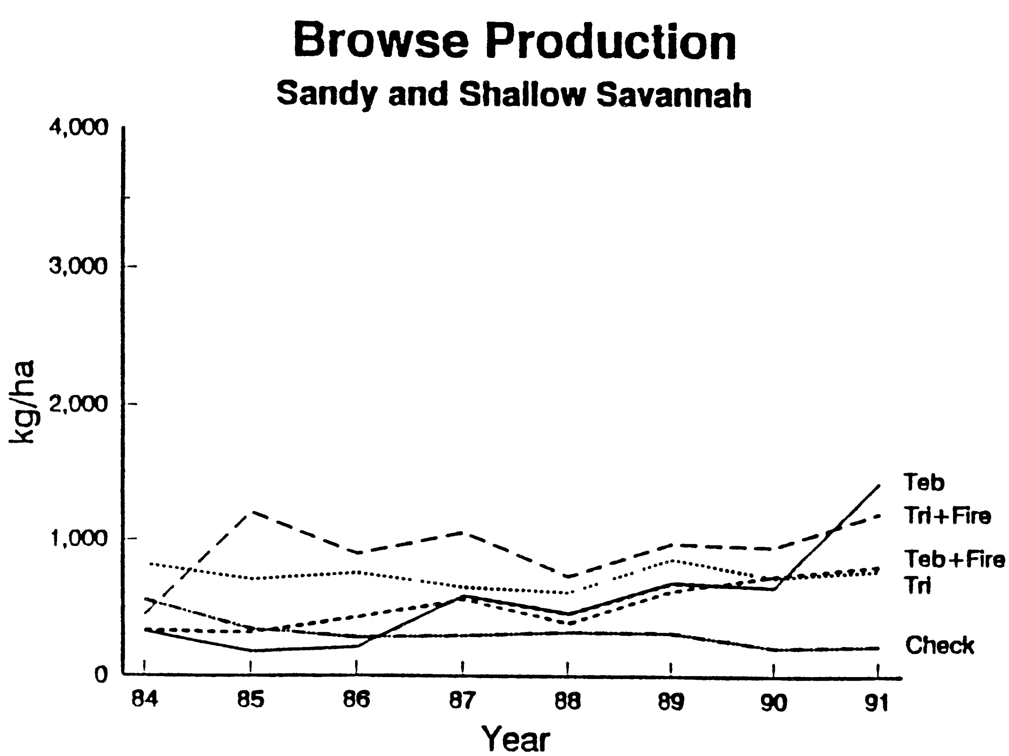
Fig. 2. Concentrations of selected nutritional parameters (± SE) of feces collected seasonally from the Cross Timbers Experimental Range (CTER), Zoological Research Area (ZRA), and Hamns Lake Research Area (HLRA) from winter 1988 to summer 1989.



4.0
3.5
3.0
2.5
2.0
1.5
1.0
% FECAL NITROGEN
WI88 SP88 SU88 FA88 WI89 SP89 SU89
SEASON
3.0
2.5
2.0
1.5
1.0
0.5
0.0
% FECAL SOLUBLE NITROGEN
CTER
ZRA
HLRA
WI88 SP88 SU88 FA88 WI89 SP89 SU89
SEASON
60.0
55.0
50.0
45.0
40.0
% FECAL ACID DETERGENT FIBER
WI88 SP88 SU88 FA88 WI89 SP89 SU89
SEASON
3.0
2.5
2.0
1.5
1.0
0.5
0.0
% FECAL INSOLUBLE NITROGEN
WI88 SP88 SU88 FA88 WI89 SP89 SU89
SEASON

Fig. 3. Annual standing crop (kg/ha) of browse and forb biomass on the two most dominant soil types within each experimental brush treatment on the Cross Timbers Experimental Range.


Forb Production
Sandy and Shallow Savannah
4,000
3,000
2,000
1,000
0
kg/ha
84
85
86
87
88
89
90
91
Year
Teb+Fire
Tri+Fire
Tri
Teb
Check


Browse Production
Sandy and Shallow Savannah
4,000
3,000
2,000
1,000
0
kg/ha
84
85
86
87
88
89
90
91
Year
Teb
Tri+Fire
Teb+Fire
Tri
Check

CHAPTER III

NUTRITIONAL QUALITY OF BROWSE IN RESPONSE TO BRUSH MANAGEMENT ON CROSS TIMBERS RANGELAND

ABSTRACT.-- Seasonal changes in browse quality in response to experimental manipulations to control unwanted woody vegetation using selected combinations of herbicide and fire were evaluated on cross timbers rangeland in central Oklahoma 5-6 years post-treatment. The study area consisted of 32-ha replications of 4 brush treatments: tebuthiuron herbicide, tebuthiuron with prescribed burning, triclopyr herbicide, and triclopyr prescribed burning. Control areas with no herbicide or fire applications also were evaluated. Herbicides were applied in 1983 and fires initiated in 1985. Nutritional responses of blackberry (Rubus spp), coralberry, (Symphoricarpos orbiculatus), roughleaf dogwood (Cornus drummondi), elm (Ulmus spp), greenbrier (Smilax spp), hackberry (Celtis spp), and smooth sumac (Rhus glabra) were assessed by measuring crude protein, in vitro dry matter digestibility (IVDMD), neutral detergent fiber (NDF), acid detergent fiber (ADF),

hemicellulose and moisture content. Crude protein was consistently higher on herbicide-treated areas compared to untreated controls. Triclopyr treatments were consistently higher in crude protein than tebuthiuron treatments. In vitro dry matter digestibility was higher on herbicide-treated areas compared to untreated controls. Fiber constituents (NDF, ADF, hemicellulose) and moisture content were not influenced by brush treatments. Prescribed burning in combination with herbicide applications did not improve the quality of browse. Our results indicate that browse quality can be improved for white-tailed deer by applications of tebuthiuron or triclopyr and improvements persist for up to 6 years post treatment.
Key Words: white-tailed deer, Odocoileus virginianus, browse quality, tebuthiuron, triclopyr, burning, herbicide, Oklahoma,

Woody browse comprises a significant proportion of the diet of many species of wildlife, including white-tailed deer (Odocoileus virginianus). In addition to phenology, the nutritional quality of browse is influenced by species (Cowan et al. 1970), soil type (Hundley 1959), rainfall (Laycock and Price 1970), fire (Dewitt and Derby 1955), amount of canopy cover (Halls and Epps 1969), and a variety of other environmental factors (Robbins and Moen 1975, Van Soest 1982). Woody vegetation is also frequently managed using mechanical, chemical, and burning techniques on rangeland to increase herbaceous forage production for both livestock and wildlife (Scifres 1980). Management techniques that alter environmental factors can frequently be used to alter the nutritional quality of woody and herbaceous vegetation (Evertt 1983, Rasmussen et al. 1983, Masters and Scifres 1984).

The cross timbers land resource area is a western extension of the Ozark plateau oak-hickory ecosystem and accounts for approximately 19 million ha of rangeland in Oklahoma (SCS 1981, Garrison et al. 1977). Livestock production is relatively low in the cross timbers region due to low herbaceous forage production. As a result, mechanical and chemical (with and without fire) treatments are routinely used to remove unwanted brush species and increase forage production for livestock in this land resource area (Scifres and Mutz 1978, Scifres et al. 1979, Scifres 1980, Scifres et al. 1981, Scifres et al. 1983, Ivey and Causey 1984, Wood 1988).

Many landowners are interested in managing white-tailed deer in conjunction with livestock operations in the cross timbers. Little is known about the effects of many range improvement practices used in the cross timbers on the nutritional quality of important forages of deer. The objective of our study was to evaluate seasonally nutritional quality of 7 woody browse species as influenced by applications of a systemic herbicide, tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-

dimethylurea), and a contact herbicide, triclopyr ([(3,5,6,-trichlor-2-pyridinyl)oxy]acetic acid), used in conjunction with and without an annual spring burn 5-6 years post treatment. Prescribed fire was used to control secondary regrowth on herbicide-treated areas.

This is journal article J-_____ of the Oklahoma Agricultural Experiment Station. This study was funded in part by the Departments of Agronomy and Zoology, Oklahoma State University, Oklahoma Cooperative Fish and Wildlife Research Unit (U.S. Fish and Wildlife Service, Oklahoma Department of Wildlife Conservation, Oklahoma State University, and Wildlife Management Institute, cooperating), National Science Foundation (BSR-8567043), and Oklahoma Agricultural Experiment Station.

METHODS

Study area.--The Cross Timbers Experimental Range (CTER), located 13 km southwest of Stillwater, Oklahoma, is a 640-ha research area that was established in 1983 to compare responses of vegetation, livestock, and wildlife to management of woody vegetation. The CTER was divided into 20 adjacent and fenced 32-ha pastures of 4 replications of 4 randomly applied brush treatments and untreated control. The 4 brush treatments included: (1) tebuthiuron; (2) tebuthiuron with annual spring burn; (3) triclopyr; (4) triclopyr with an annual spring burn; and an untreated control. A more detailed description of treatments and study area lay out was given in Lochmiller et al. (1991).

Each herbicide was applied aerially at a rate of 2.2 kg/ha (tebuthiuron, March 1983; triclopyr, June 1983) and annual prescribed burning was applied in April 1985-1987. Description of pre-treatment vegetation (Ewing et al. 1984) and soils (Gray and Stanke 1970) have been published for the CTER.

Upland hardwood forest, dominated by blackjack oak (Quercus marilandica) and post oak (Q. stellata), is the primary vegetation type in the area on course-textured soils; tallgrass prairie is interspersed on fine-textured soils (Ewing et al. 1984). The upland forest, prior to treatment, varied from open hardwood overstory with a productive herbaceous understory to completely closed overstory canopy with negligible understory production. Bottomland forest occupies a rather restricted position along drainages. Understory species were dominated by coralberry (Symphoricarpos orbiculatus), eastern redcedar (Juniperus virginiana), poison ivy (Rhus radicans), roughleaf dogwood (Cornus drummondi), redbud (Cercis canadensis), and American elm (Ulmus americana). Dominant herbaceous species include little bluestem (Schizarium scoparium), indiangrass (Sorghastrum nutans), western ragweed (Ambrosia psilostachya), and rosette panicgrass (Panicum oligosanthes) (Ewing et al. 1984).

Changes in the botanical composition of vegetation following tebuthiuron and triclopyr applications, with and without prescribed burning on the CTER have been reported previously (Engle et al. 1991, Stritzke et al. 1991). Briefly, tebuthiuron greatly reduced the hardwood understory and overstory, and increased herbaceous forage production. Triclopyr also reduced the hardwood overstory and moderately increased herbaceous forage production, but a dense understory of resprouting woody species resulted. Untreated habitats were characterized by a dense woody canopy with little herbaceous cover and moderate amounts of woody understory (Engle et al. 1991, Stritzke et al. 1991). Prescribed burning did not greatly alter the woody vegetation except that it reduced the cover of eastern redcedar (Stritzke et al. 1991), improved gains of stocker cattle (McCollum et al. 1987), and improved the nutritional quality of selected herbaceous forages (Bogle et al. 1989).

Browse collection.--We sampled 7 species of browse commonly consumed by white-tailed deer in Oklahoma (Deliberto 1987, Van Vreede 1987, Jenks 1991, Gee et al. 1991): blackberry (*Rubus* spp.), coralberry (*Symphorcarpus orbiculatus*), roughleaf dogwood (*Cornus drummondi*), elm (*Ulmus* spp.), greenbrier (*Smilax* spp.), hackberry (*Celtis* spp.), and smooth sumac (*Rhus glabra*). Browse was sampled from 2 replications of each experimental treatment in winter (Jan), spring (Apr), summer (Jul), and fall (Oct) from winter 1988 to spring 1989. Within each treatment replication, browse was sampled on upland (shallow savannah soils) and bottomland (deep sandy hardwood soils) habitat sites. Five cm of current annual growth of both leaf and stem were collected from 10 locations on 10 individual plants within each habitat site. Samples were placed in sample bags and dried at 52°C to a constant weight. Dried samples were ground in a Wiley Mill through a 1-mm mesh screen prior to chemical analyses.

Nutrient analysis.--Browse samples were analyzed for percentage of crude protein, neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose, in vitro dry matter digestibility (IVDMD), and moisture content. Crude protein was calculated by determining nitrogen concentration of 0.25 g samples on a rapid Kjeldhal system and multiplying by the correction factor 6.25 (Williams 1984). Concentrations of NDF and ADF were estimated as described by Goering and Van Soest (1970). Concentration of hemicellulose was calculated as the difference between ADF and NDF. Percent IVDMD was determined using the acid-pepsin enzymatic digestion procedure as described by Choo et al. (1981). Percent moisture was determined as the proportion of weight lost after oven-drying (52°C). All values are expressed on a percent dry matter basis with the exception of moisture which we expressed on a live tissue basis.

Statistical analysis.--Main and interaction effects of treatment and season were examined with a 2-way analysis of variance (ANOVA) for the nutritional constituents of each browse species. Protected multiple comparisons (LSD) were used to separate treatment differences when analysis of variance rejected the null hypothesis that treatments were similar. Specific contrasts were used to compare variation in nutritional quality of browse within brush treatment categories (treated vs. untreated, burned herbicide-treated vs. unburned herbicide-treated, tebuthiuron-treated vs. triclopyr-treated). A 1-way ANOVA was used to examine significant season x treatment interactions for treatment main effects. The Statistical Analysis System (SAS 1985) was used for all statistical procedures. Means were considered statistically different at $\underline{P} < 0.05$.

RESULTS

Indices of browse quality showed significant seasonal fluctuations for all species across the entire study. Crude protein, IVDMD, and moisture were highest in spring and lowest in winter (Figs. 1, 2, and 3) Appendices A, B, and C). Conversely, NDF (Fig. 4), ADF (Fig. 5), and hemicellulose (Fig. 6) were lowest in spring and highest in winter (Appendixes D-F). Among species, all forage quality indices except IVDMD were highest for greenbrier; coralberry was highest in IVDMD.

Throughout the study, treatment differences were most apparent for crude protein (Fig. 1). Crude protein showed significant variation among the 5 treatments for 5 (blackberry, coralberry, elm, greenbrier, and hackberry) of 7 browse species examined. Season x treatment interactions were significant for crude protein concentrations in coralberry, blackberry, elm, and hackberry. One-way ANOVA and multiple comparisons indicated that crude protein concentrations were significantly higher on the 2 triclopyr-treated areas compared to untreated controls for blackberry (winter and spring 1989), elm (spring 1988, 1989), and hackberry (spring 1988, 1989, and fall 1988); other comparisons were not significant.

Specific contrasts indicated that crude protein was significantly higher on herbicide-treated areas compared to untreated controls for 5 (coralberry, blackberry, dogwood, elm, and hackberry) of 7 browse species (Table 1). On average, browse species contained 14% more crude protein on herbicide-treated areas than controls; differences were most pronounced for elm which contained 25% more crude protein on treated areas. Specific contrasts also indicated that crude protein concentrations were significantly higher on areas treated with triclopyr compared to tebuthiuron for 6 (coralberry, blackberry, dogwood, elm hackberry, and greenbrier) of 7 browse species (Table 1). Browse from triclopyr-treated areas contained an average of 11% more crude protein than tebuthiuron-treated areas; differences were most pronounced for greenbrier which contained about 18% more protein. Burning influences were limited to crude protein concentrations for elm which were significantly higher (6%) on burned than unburned areas.

Percent IVDMD mirrored seasonal and treatment differences for crude protein; however, the main effect of treatment was only significant for blackberry and there was a significant season x treatment interaction. One-way ANOVA and multiple comparisons indicated that IVDMD of blackberry was significantly higher on the 2 triclopyr-treated areas than the 2 tebuthiuron treatments in winter 1988 and spring 1989.

Specific contrasts showed that IVDMD was significantly higher for 5 (blackberry, dogwood, hackberry, greenbrier, and smooth sumac) of 7 species on herbicide-treated areas compared to untreated controls. In vitro dry matter digestibility was 9% higher on average for browse from treated areas compared to untreated controls; differences were most pronounced for blackberry which contained about 15% more protein. Although not significant, IVDMD values for 4 (coralberry, blackberry, greenbrier, and smooth sumac) of the 7 browse species were higher on triclopyr-treated areas compared to those treated with tebuthiuron. Burning had no influence on IVDMD.

Experimental treatments had only minimal impacts on other measures of browse quality. Differences in fiber constituents (NDF, ADF) of blackberry were significant among treatments. Specific contrasts showed both NDF (on average 16% lower) and ADF (17% lower) levels were significantly lower on herbicide-treated areas than untreated controls (Table 1). Fiber concentrations of browse were not influenced by type of herbicide applied or prescribed burning; hemicellulose was not influenced by any treatment. Treatment differences in moisture content were confined to greenbrier where levels were significantly higher on untreated controls compared to herbicide-treated areas.

DISCUSSION AND CONCLUSIONS

Alterations in the nutritional quality of white-tailed deer browse were apparent 5-6 years after experimental herbicide and fire applications to control woody vegetation on the CTER. Crude protein, with concomitant changes in IVDMD, were the attributes of browse quality most sensitive to brush management. Although season modified the amplitude of differences among treatments, browse quality was consistently better on herbicide-treated and triclopyr-treated areas compared to untreated controls and tebuthiuron treatments, respectively. Several studies have indicated that forage quality increases shortly after initial application of herbicide (Powell and Box 1966, Kirby and Stuth 1982, Masters and Scifres 1984). However, information on long-term effects (see Sears et al. 1986) of herbicide treatments on nutritional attributes of browse and other forages used by white-tailed deer are extremely limited and nonexistent for the cross timbers land resource area.

Elucidation of the mechanisms responsible for the observed nutritional benefits of brush management on the CTER are hampered by this information void. However, several factors such as removal of canopy cover (Blair et al. 1983), changes in soil moisture (Laycock and Price 1970), and nutrient release (Sears et al. 1986) could be acting singly or in concert to maintain post-treatment differences in nutritional quality of browse. Sears et al. (1986) noted that soil nitrogen concentrations and soil organic matter increased on tebuthiuron treated areas 6 years post-treatment in the sand shinnery oak communities of northern Texas. They attributed the nitrogen increase to the increase in forb production, decaying litter, and oak death/decompostion. Similarly, persistent elevations of crude protein in browse on the CTER may reflect a slow release of nitrogen into the soil from decaying overstory biomass on treated areas. We can not rule out the possibility that differences in nutritional attributes among treatments reflected plant phenological differences at the time of collection.

In vitro dry matter digestibility mirrored changes in crude protein on the CTER in response to herbicide applications. Although not as evident, a similar trend was apparent for browse collected from triclopyr-treated areas compared to tebuthiuron-treated areas. Van Soest (1982) indicated that protein is positively associated with digestibility. Although not as sensitive to treatment, fiber constituents (NDF, ADF) of a limited number of browse species were lower on herbicide-treated areas as one would expect with an increase of crude protein and IVDMD (Van Soest 1982).

Burning had little impact on browse quality on the CTER, limited to improvements in crude protein for elm. Insufficient fuel loads on the CTER made burning of limited use for secondary brush control on triclopyr treatments, but was more effective on tebuthiuron treatments (Engle et al. 1991). Previous studies have shown that nutritional responses of browse to periodic burning are variable and dependent upon fire intensity, ranging from relatively minor and short lived increases (Wood 1988) to more substantial and persistent improvements in quality following high-intensity burns (Dewitt and Derby 1955).

Seasonal fluctuations in crude protein values have been well documented on undisturbed sites (Short et al. 1975, Blair et al. 1980). Seasonal crude protein, IVDMD, and moisture content values were highest in spring and summer, but declined as plants matured in fall and winter. Conversely, fiber constituents increased as plants matured. Everitt (1983) documented that seasonal nutrient rhythms associated with plant development did not differ between shredded (mechanical brush control) and nonshredded woody browse in south Texas. Our results, as evidenced by a small number of significant season x treatment statistical interactions, indicated that seasonal cycles of browse quality were also not affected appreciably by brush management practices on the CTER. When significant interactions were present, treatment differences appeared to be more prevalent in winter and spring during the early phenological stages of development. All treated areas on the CTER had seasonal crude protein values above the estimated 6 to 7% maintenance levels required for white-tailed deer (French et al. 1965).

Thill and Morris (1980) noted that deer in southern upland forests generally are limited by forage quality and not forage quantity. Our results indicate that nutritional quality of common white-tailed deer browse in the cross timbers of central Oklahoma can benefit over the long-term (6 years post-treatment) from range improvement practices incorporating the use of triclopyr or tebuthiuron. Overall crude protein values (data pooled across species, seasons, and years) averaged 5% greater on tebuthiuron and 10% greater on triclopyr treatments compared to untreated controls.

Although triclopyr provided better long-term nutritional benefits than tebuthiuron, resulting improvements in herbaceous forage production following triclopyr application (Engle et al. 1991) would make this a less attractive alternative than tebuthiuron for most livestock producers. Economic models incorporating lease hunting of deer and multiple livestock enterprises indicate tebuthiuron, triclopyr, and prescribed burning in combination will optimize returns in the cross timbers (Bernardo et al. 1992). Landowners wishing to improve quality of rangeland for both livestock and deer may wish to consider the application of both herbicides (variable herbicide patterning) to create a mosaic of habitat types

(Bernardo et al. 1992, Soper et al. 1992; Scifres and Koerth 1986).

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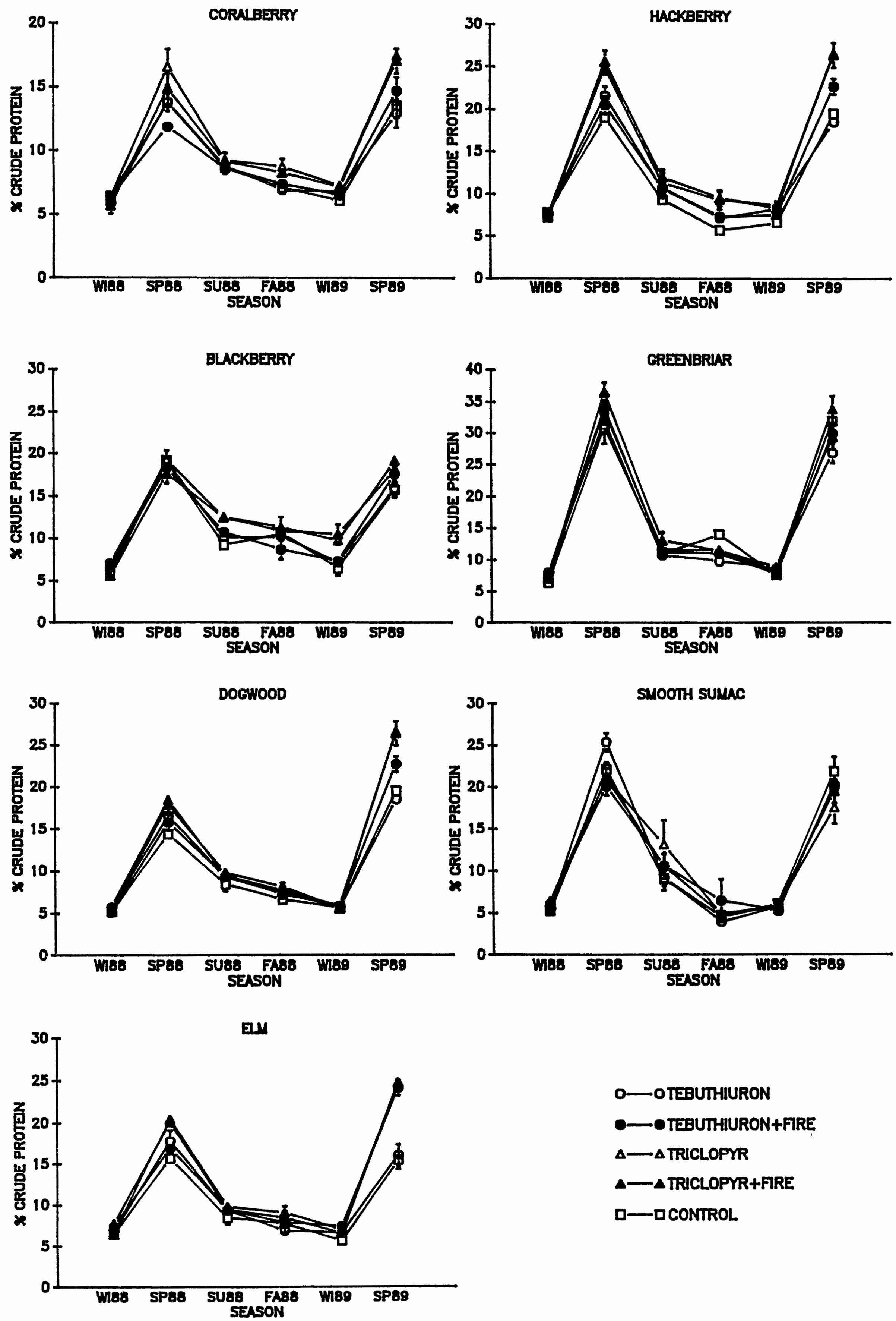
Table 1. Nutrient quality indices for 7 common browse species on the Cross Timbers Experimental Range in 1988-89. Contrasts made from 4 brush treatments (tebuthiuron and triclopyr with and with out fire) and an untreated control. Data are means from 6 sampling periods (all seasons in 1988, spring and winter 1989).

Species	Nutrient[2]	Treatment contrasts[1]			
		Treated vs Untreated		Tebuthiuron vs Triclopyr	
		X (SE)	X (SE)	X (SE)	X (SE)
Coralberry	Crude protein	9.9±0.41	9.2±0.69	9.1±0.47	10.6±0.65
Blackberry	Crude protein	12.1±0.49	11.4±1.08	11.6±0.67	12.8±0.70
	IVDMD[3]	42.4±1.04	36.9±2.45		
	Neutral detergent fiber	38.6±1.17	44.7±3.62		
	Acid detergent fiber	22.2±1.10	28.4±3.39		
	Moisture content			58.8±2.12	63.4±2.13
Dogwood	Crude protein	10.2±0.50	9.0±0.82	9.9±0.66	10.6±0.75
	IVDMD	43.8±1.29	40.8±2.67		
Elm	Crude protein	12.4±0.68	9.9±0.88	11.6±0.86	13.1±1.04
Hackberry	Crude protein	13.6±0.75	11.3±1.21	12.5±0.90	14.8±1.19
	IVDMD	38.4±1.48	35.8±2.68		
Greenbriar	Crude protein			16.5±1.51	17.7±1.67
	IVDMD	36.6±1.43	33.7±2.54		
	Hemicellulose			17.1±0.59	16.1±0.55
	Moisture content	67.1±1.84	70.1±3.60		
Smooth sumac	IVDMD	44.0±1.58	40.9±3.41		

[1]Signifcant at the 0.05 level.
[2]Nutrient values expressed as % dry matter; moisture content expressed as % fresh tissue.
[3]In vitro dry matter digestibility.

Figure 1. Mean seasonal (±SE) crude protein content for 7 southern browse species collected from experimental treatments from the Cross Timbers Experimental Range in all seasons in 1988 and winter and spring of 1989.


CORALBERRY
% CRUDE PROTEIN
0
5
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20
WI88 SP88 SU88 FA88 WI89 SP89
SEASON
HACKBERRY
% CRUDE PROTEIN
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30
WI88 SP88 SU88 FA88 WI89 SP89
SEASON
BLACKBERRY
% CRUDE PROTEIN
0
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15
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WI88 SP88 SU88 FA88 WI89 SP89
SEASON
GREENBRIAR
% CRUDE PROTEIN
0
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40
WI88 SP88 SU88 FA88 WI89 SP89
SEASON
DOGWOOD
% CRUDE PROTEIN
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WI88 SP88 SU88 FA88 WI89 SP89
SEASON
SMOOTH SUMAC
% CRUDE PROTEIN
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SEASON
ELM
% CRUDE PROTEIN
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WI88 SP88 SU88 FA88 WI89 SP89
SEASON
TEBUTHIURON
TEBUTHIURON+FIRE
TRICLOPYR
TRICLOPYR+FIRE
CONTROL

Figure 2. Mean seasonal (±SE) in vitro dry matter digestibility of 7 southern deer browse species collected from experimental brush treatments on the Cross Timbers Experimental Range throughout all seasons in 1988 and winter and spring in 1989.

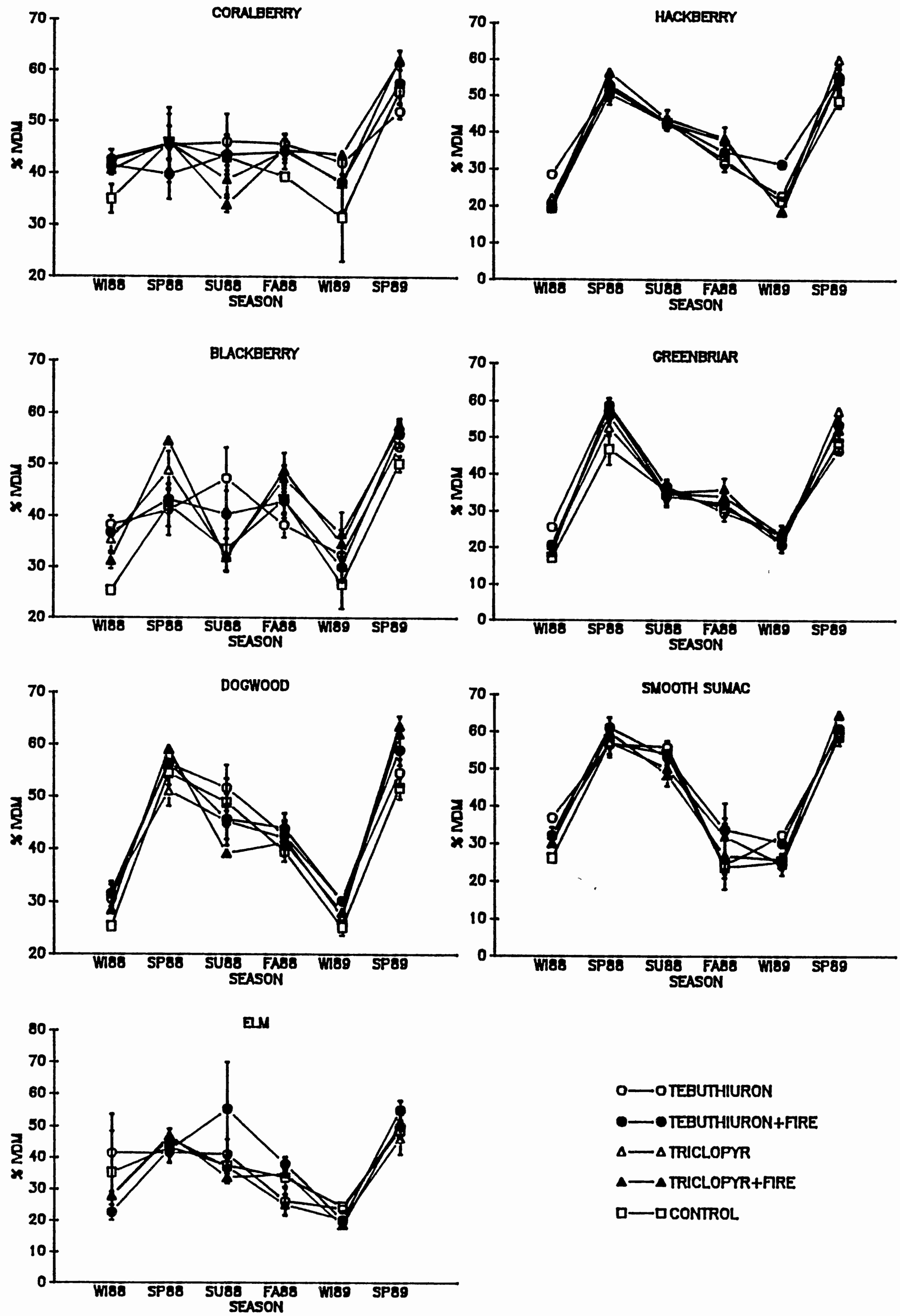

CORALBERRY
HACKBERRY
BLACKBERRY
GREENBRIAR
DOGWOOD
SMOOTH SUMAC
ELM
% IVDM
WI88 SP88 SU88 FA88 WI89 SP89
SEASON
TEBUTHIURON
TEBUTHIURON+FIRE
TRICLOPYR
TRICLOPYR+FIRE
CONTROL

Figure 3. Means seasonal (±SE) moisture content of 7 southern deer browse species collected from experimental brush treatments on the Cross Timbers Experimental Range throughout all seasons in 1988 and winter and spring 1989.

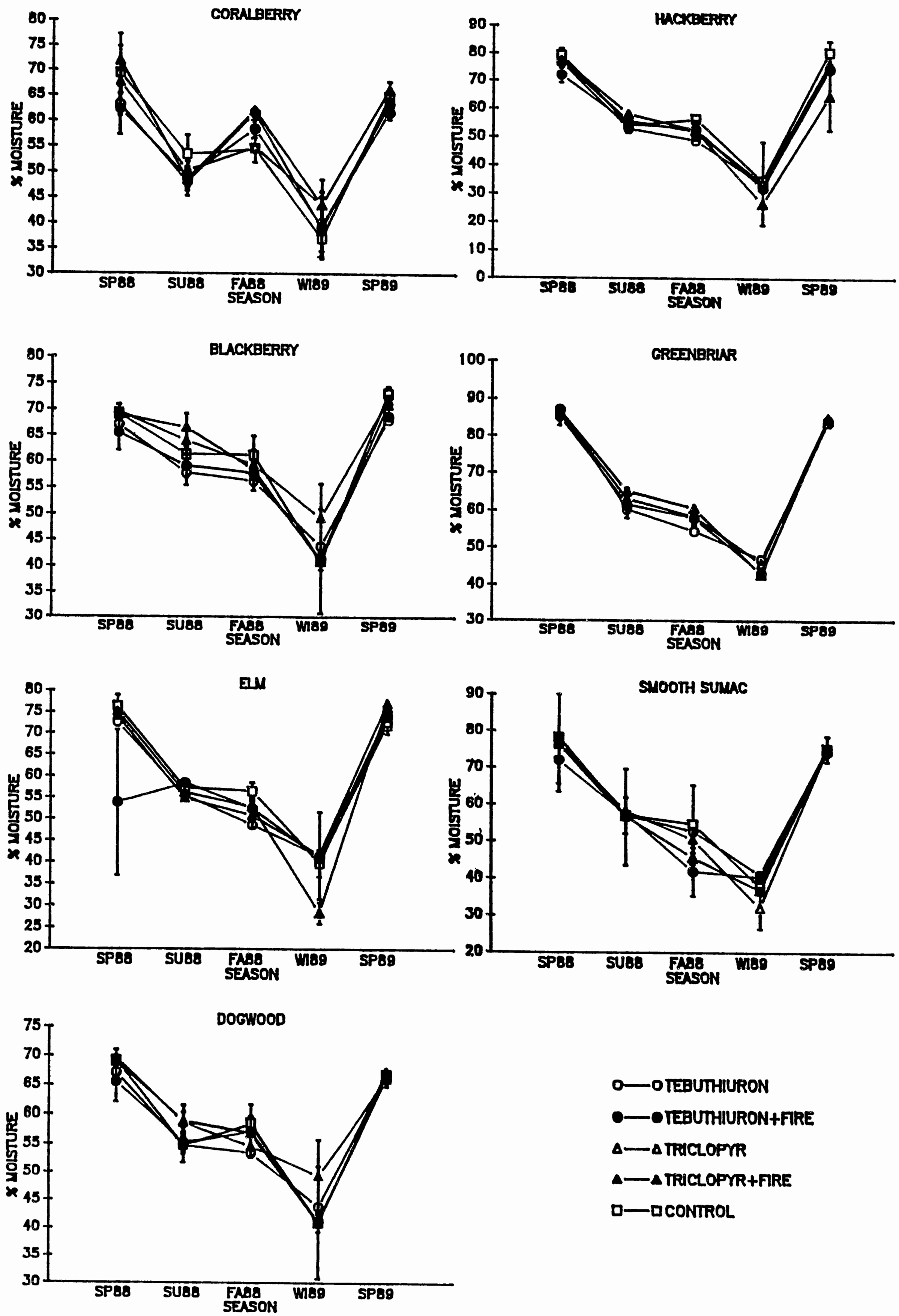

CORALBERRY
HACKBERRY
BLACKBERRY
GREENBRIAR
ELM
SMOOTH SUMAC
DOGWOOD
% MOISTURE
SP88
SU88
FA88
WI89
SP89
SEASON
TEBUTHIURON
TEBUTHIURON+FIRE
TRICLOPYR
TRICLOPYR+FIRE
CONTROL

Figure 4. Mean seasonal (±SE) neutral detergent fiber content for 7 southern deer browse species collected from experimental brush treatments from the Cross Timbers Experimental Range throughout all seasons in 1988 and winter and spring in 1989.

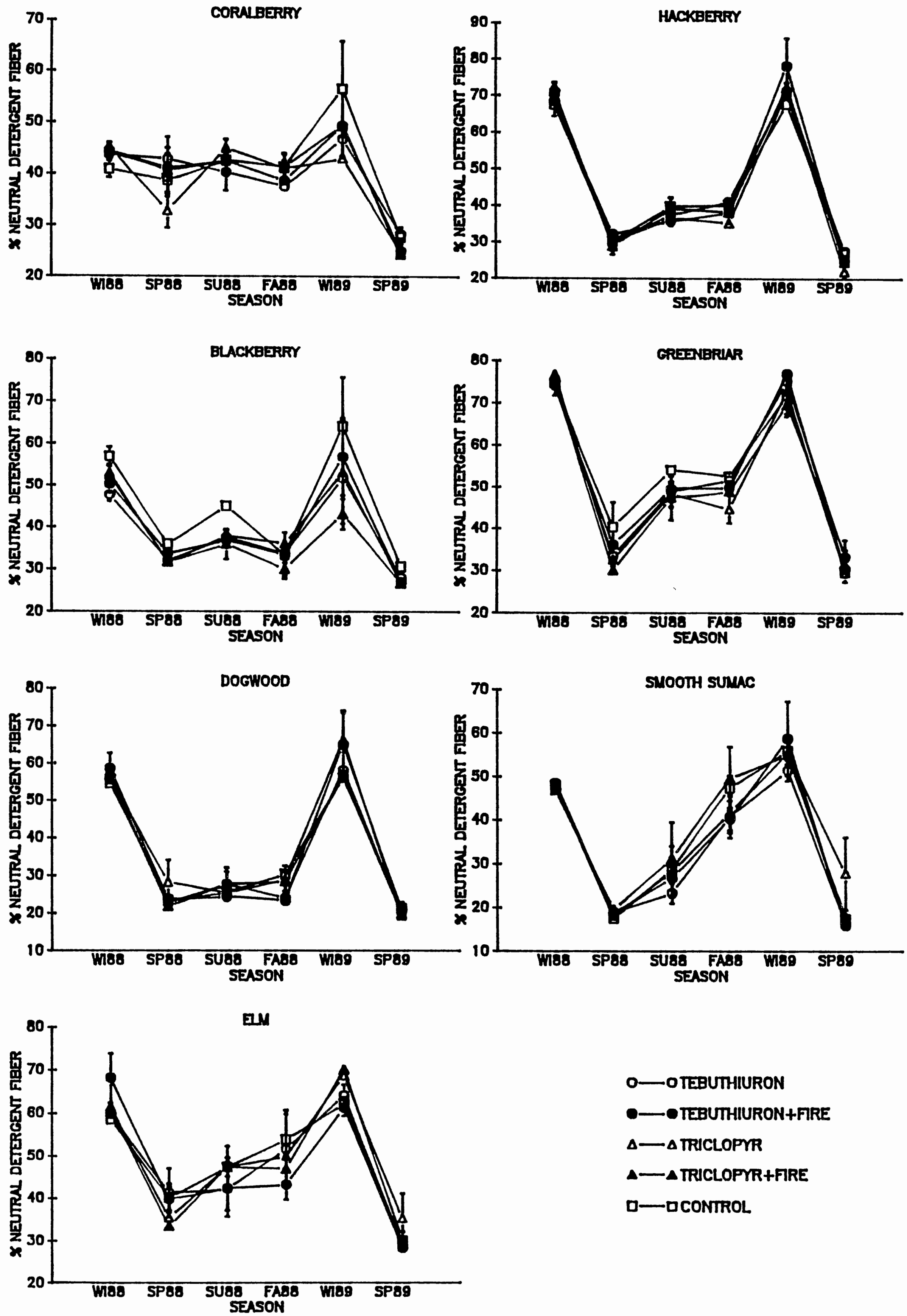

CORALBERRY
HACKBERRY
BLACKBERRY
GREENBRIAR
DOGWOOD
SMOOTH SUMAC
ELM
% NEUTRAL DETERGENT FIBER
SEASON
WI88
SP88
SU88
FA88
WI89
SP89
TEBUTHIURON
TEBUTHIURON+FIRE
TRICLOPYR
TRICLOPYR+FIRE
CONTROL

Figure 5. Mean seasonal (±SE) acid detergent fiber content for 7 southern deer browse species collected from experimental brush treatments from the Cross Timbers Experimental Range throughout all seasons in 1988 winter and spring 1989.

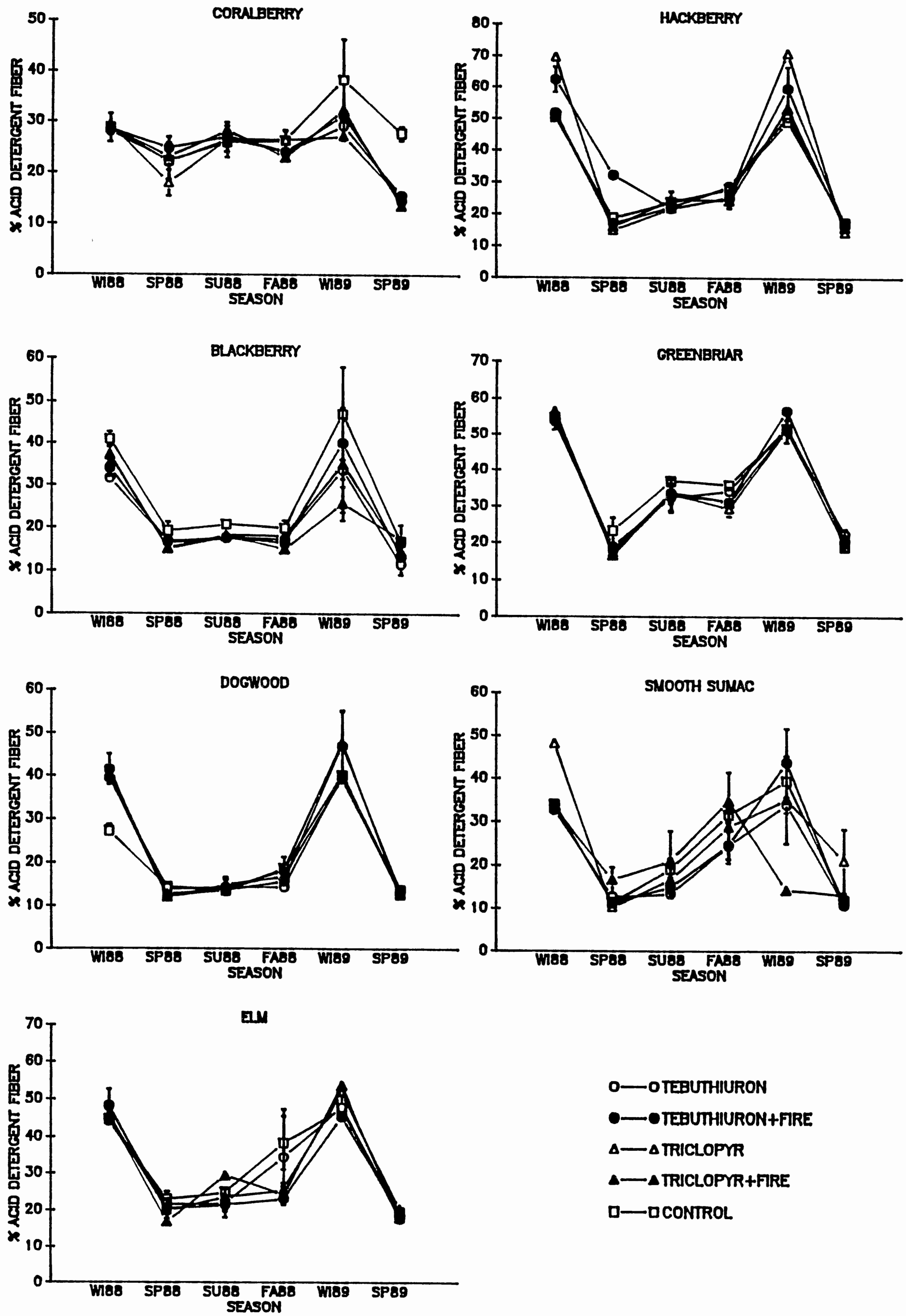
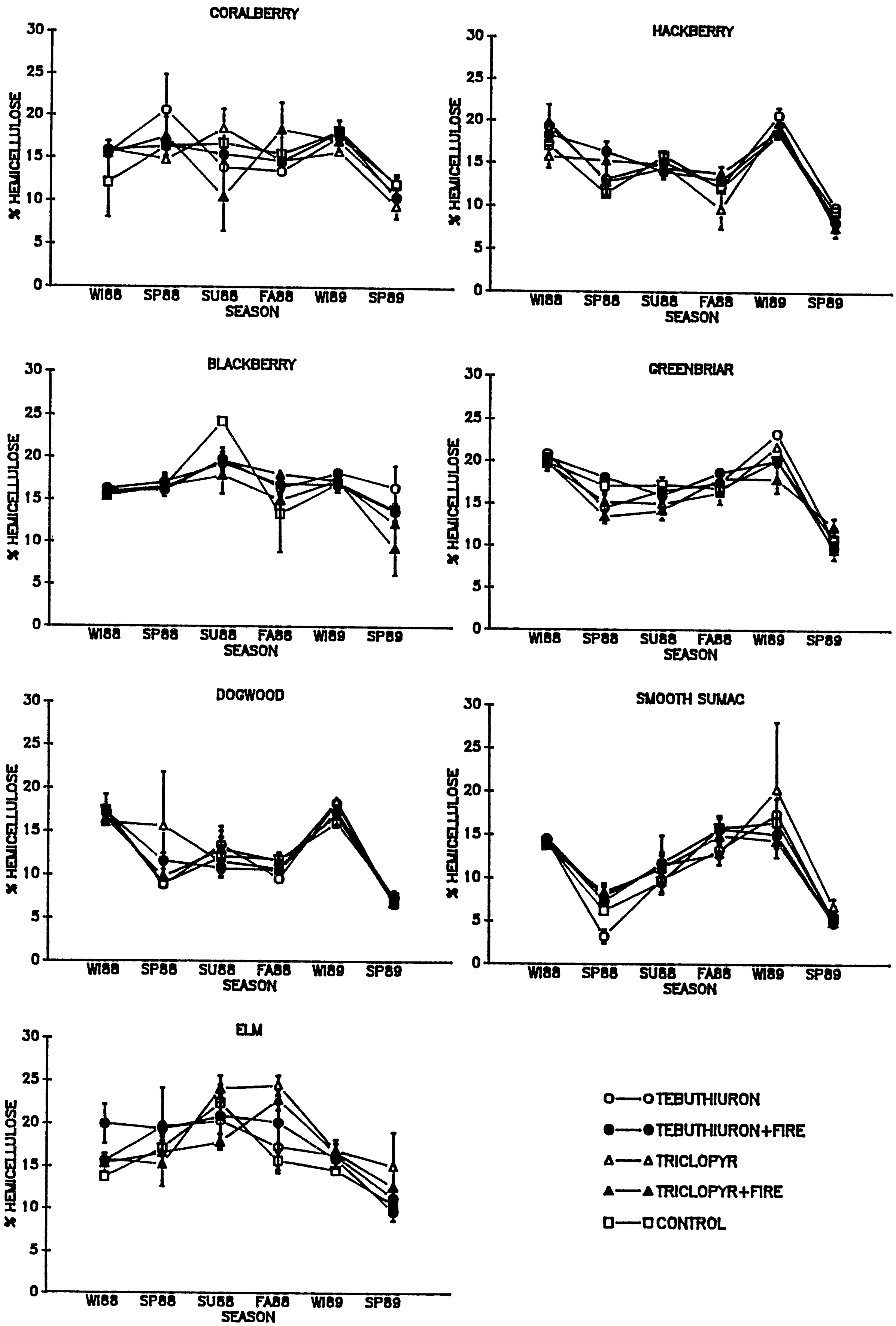

CORALBERRY
HACKBERRY
BLACKBERRY
GREENBRIAR
DOGWOOD
SMOOTH SUMAC
ELM
% ACID DETERGENT FIBER
WI88 SP88 SU88 FA88 WI89 SP89
SEASON
TEBUTHIURON
TEBUTHIURON+FIRE
TRICLOPYR
TRICLOPYR+FIRE
CONTROL

Figure 6. Mean seasonal (±SE) hemicellulose concentrations for 7 southern deer browse species collected from the Cross Timbers Experimental Range throughout all seasons in 1988 and winter and spring in 1989.


CORALBERRY
HACKBERRY
BLACKBERRY
GREENBRIAR
DOGWOOD
SMOOTH SUMAC
ELM
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SEASON
TEBUTHIURON
TEBUTHIURON+FIRE
TRICLOPYR
TRICLOPYR+FIRE
CONTROL

CHAPTER IV

HABITAT USE BY WHITE-TAILED DEER ON MANAGED CROSS TIMBERS RANGELAND

Abstract: Seasonal habitat use by white-tailed deer (*Odocoileus virginianus*) was monitored with radio telemetry in 1988-89 to determine responses to experimental brush treatments, 5-6 years post treatment, in the cross timbers region of central Oklahoma. The study area was a mosaic of 32-ha replications of 5 brush treatments: tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiazol-2-y-1]-N,N'-dimethylurea) herbicide, tebuthiuron with an annual spring burn, triclopyr ([(3,5,6,-trichlor-2-pyridinyl)oxy]acetic acid) herbicide, triclopyr with an annual spring burn, and no herbicide with an annual spring burn. Control areas with no burning or herbicide applications also were evaluated. Herbicides were applied in 1983 and fires were initiated in 1985. Home range averaged 99.9 ha. Second-order habitat selection indicated that deer preferred triclopyr treatments in 1988 and tebuthiuron treatments in 1989; they selected treated areas over control areas throughout our study. Third-order selection was similar with greater than expected use of triclopyr treatments in winter (1989) and spring (1988 and 1989) and tebuthiuron treatments in winter (1989). Both second- and third-order selection indicated that deer preferred unburned habitats in winter and burned habitats in summer and fall. Overall, herbicide-treated areas (with and without fire) were used more than untreated controls which was probably due to increased cover, browse, and forb production.

J. WILDL. MANAGE. 00(0):000-000

Key words: burning, cross timbers, habitat, habitat use, behavior, herbicide, *Odocoileus virginianus*, Oklahoma, radio telemetry, second-order selection, third-order selection, white-tailed deer.

The cross timbers is a western extension of the Ozark plateau, oak-hickory ecosystem and contains about 19 million ha in the central United States (Garrison et al. 1977, Soil Conser. Serv. 1981). Livestock production in these oak-dominated rangelands is relatively low due to poor production of herbaceous forage (Scifres 1980). Brush management programs (e.g., herbicides and fire) that selectively remove unwanted woody species and increase herbaceous forage production can benefit both white-tailed deer and livestock (Darr and Klebenow 1975, Scifres 1980, Rollins 1987).

Responses of white-tailed deer to removal of woody vegetation with herbicides and fire have not been examined in cross timbers rangeland. In other habitat types, initial improvements in browse and forb production have been demonstrated following applications of 2,4,5-T, picloram, 2,4,-D, tebuthiuron, triclopyr, and glyphosate (Scifres and Mutz 1978, Scifres 1980). Behavioral and population responses of white-tailed deer to herbicide-induced vegetation changes vary considerably and appear to be partly dependent on habitat type (Davis and Winkler 1968, Beasom and Scifres 1977, Quinton et al. 1979, Beasom et al. 1982, Inglis 1983).

Our objective was to determine if deer preferred areas treated with herbicides and prescribed fire in the cross timbers. White-tailed deer prefer edge habitat and are generally attracted to areas that have been set back successionally (Crawford 1984). Chemical and mechanical brush control techniques are used primarily to set back successional stages to increase primary production (Scifres 1980). As a result, our hypothesis was that deer would be attracted to herbicide-treated and burned cross timbers rangeland.

This is journal article J-_____ of the Oklahoma Agricultural Experiment Station. This study was funded in part by the Departments of Agronomy and Zoology, Oklahoma State University, Oklahoma Cooperative Fish and Wildlife Research Unit (U.S. Fish and Wildlife Service, Oklahoma Department of Wildlife Conservation, Oklahoma State University, and Wildlife Management Institute, cooperating), National Science Foundation (BSR-8567043), and Oklahoma Agricultural Experiment Station.

STUDY AREA

The Cross Timbers Experimental Range (CTER), located 13 km southwest of Stillwater, Oklahoma, is a 640-ha research area that was established in 1983 to compare responses of vegetation, livestock, and wildlife to management of woody vegetation. The CTER was divided into 22 fenced 32-ha pastures of 4 replications of 5 randomly applied brush treatments (Fig. 1). The 5 brush treatments included: (1) tebuthiuron; (2) tebuthiuron with annual spring burn; (3) triclopyr; (4) triclopyr with annual spring burn; and (5) and no herbicide with annual spring burn (2 replications). Control areas with no burning or herbicide applications also were evaluated. Each herbicide was applied aerially at a rate of 2.2 kg/ha (tebuthiuron, Mar 1983; triclopyr, Jun 1983), and prescribed burning was done in April 1985-1987.

Upland hardwood forests were dominated by blackjack (*Quercus marilandica*) and post oak (*Q. stellata*) on coarse-textured soils; tallgrass prairie was interspersed throughout CTER on fine-textured soils (Ewing et al. 1984, Gray and Stanke 1970). Bottomland forests were restricted to intermittent stream bottoms. Understory woody species were dominated by coralberry (*Symphoricarpos orbiculatus*), eastern redcedar (*Juniperus virginiana*), poison ivy (*Rhus radicans*), roughleaf dogwood (*Cornus drummondi*), redbud (*Cercis canadensis*), and American elm (*Ulmus americana*).

Dominant herbaceous vegetation included little bluestem (Schizachrium scoparium), indiangrass (Sorghastrum nutans), western ragweed (Ambrosia psilostachya), and rosette panicgrass (Panicnum oligosanthes) (Ewing et al. 1984).

Prior to treatment, upland forests varied from open hardwood overstories with productive herbaceous forage to closed overstories with negligible understory production. Tebuthiuron greatly reduced hardwood understory and overstory and increased herbaceous production (Engle et al. 1991, Stritzke et al. 1991). Triclopyr reduced hardwood overstory, moderately increased herbaceous production, and produced a dense understory of resprouting woody species. Tebuthiuron had a more consistent tree kill (52-99%) than triclopyr (8-100%) herbicides (Stritzke et al. 1987). Untreated habitats had a dense woody canopy, little herbaceous cover, and moderate amounts of woody understory (Engle et al. 1991, Stritzke et al. 1991). Prescribed burning did not greatly alter woody vegetation, but it reduced cover of eastern redcedar (Stritzke et al. 1991), improved gains of stocker cattle (McCollum et al. 1987), and increased nutritional quality of selected herbaceous forages (Bogle et al. 1989).

METHODS

Habitat

Deer were captured with a drop net (Ramsey 1968) or Stephenson box trap (Masters 1978); both were baited with whole kernel corn. Deer were ear tagged with numbered cattle tags and fitted with radio transmitters. Each animal was located during 4 activity periods/day (0600-0900, 1200-1500, 1800-2100, and 2200-2400 hr) and 4 days/week during winter (Jan-Feb), spring (Apr-May), summer (Jul-Aug), and fall (Oct-Nov) 1988-89. Three-element Yagi antennae and portable receivers were used to collect a minimum of 3 compass bearings/location (Heezen and Tester 1967). Compass bearings were taken at treatment intersections throughout the CTER (Fig. 1). Locations were plotted in the field on enlarged 1:24,000 U.S.G.S. topographic maps with an overlay of the CTER to insure proper treatment assignment. If an observation was made near a treatment border, observers walked to the location to determine which treatment the animal was in.

Telemetry accuracy was determined with 13 stationary radio transmitters placed at locations on the CTER unknown to the observer. Bearing errors ranged from 0 to 17° and averaged 3°. Average distance from observer to radiocollared deer was <0.8 km from the observer. Given these criteria, our error polygon averaged 1.2 ha.

Seasonal and annual home ranges were calculated with the harmonic mean distance method (Dixon and Chapman 1980, Boluanger and White 1990) using McPAAL (M. Stuwe and C. E. Blohowiak, Conser. Res. Cent. Natl. Zool. Park, Smithsonian Inst., Front Royal Va.). We evaluated seasonal second- and third-order selection (Johnson 1980) of treatments 5-6 years post treatment. Second-order selection was determined seasonally by comparing the number of locations observed (use) within a treatment to the total amount of area for each treatment available to deer on the CTER (availability). Third-order selection was determined seasonally by comparing the number of locations observed within a treatment (use) to the amount of area for each treatment available (availability) within an individual home range. Use of control-type habitat off the CTER was included only in determining third-order selection.

Statistical Analyses

Chi-square goodness of fit tests (Steel and Torrie 1980) were used to evaluate treatments selected relative to availability. When differences were indicated, treatment preference or avoidance was determined using Bonferroni confidence intervals at the 0.05 level of significance (Neu et al. 1974, Byers et al. 1984). Locations of individual deer were pooled for all animals within seasons (Fleiss 1981).

Specific contrasts were used with chi-square analyses to compare main treatment groups (i.e., control vs. treated, tebuthiuron vs. triclopyr, and burned vs. unburned) within each season. A 2-way analysis of variance (SAS 1985) with year and season as main effects was used to determine if home range changed in size seasonally on the CTER.

RESULTS

Seventeen white-tailed deer were captured from December 1987 to February 1989 (10 females and 7 males). We obtained a total of 2,670 relocations with an average of 42 relocations per deer (range = 7-79). Annual home range averaged 99.9 ha and ranged seasonally from 82.4 ± 8.12(SE) ha in summer to 122.89 ± 21.61 ha in winter. Seasonal home range size did not vary significantly (P > 0.05) among seasons.

Second-order Selection

Specific contrasts indicated that deer selected triclopyr over tebuthiuron treatments in 1988 (X^2 = 55.50, 1 df, P < 0.005) except in fall 1988 (X^2 = 0.62, 1 df, P > 0.05) and tebuthiuron over triclopyr treatments in 1989 (X^2 = 11.91, 1 df, P < 0.005), except in spring (X^2 = 7.70, 1 df, P < 0.005) when triclopyr was selected. Burned treatments were selected over unburned treatments in summer 1988 (X^2 = 4.88, 1 df, P < 0.005) and fall 1989 (X^2 = 4.88, 1 df, P < 0.05); unburned treatments were selected over burned treatments in winter (X^2 = 29.97, 1df, P < 0.005) and spring (X^2 = 11.21, 1df, P < 0.005) 1989. Treated areas were selected over controls in all seasons for 1988 and 1989 (X^2 = 25.22, 1df, P < 0.005).

Chi-square goodness-of-fit analyses indicated significant differences between overall availability and treatment usage for all seasons in 1988 and 1989 (Table 1). Bonferroni intervals showed tebuthiuron treatments in winter, spring, and fall and tebuthiuron treatments with fire in winter 1988 were avoided. Conversely, deer usage in 1989 of tebuthiuron treatments in winter and fall and tebuthiuron with fire treatments in summer and fall was greater than expected. Triclopyr only treatments were selected in winter 1988 and spring 1989, but were avoided in fall 1989. Deer usage of burned triclopyr treatments did not differ from expected during the study. In 1988, burned treatments with no herbicide application were avoided in winter and untreated controls were avoided in spring and summer. Burned treatments with no herbicide application and untreated controls were avoided in all seasons in 1989.

Third-order Selection

Specific contrasts showed that deer used triclopyr treatments more than tebuthiuron treatments in winter ($\underline{X}^2$ = 18.60, 1 df, $\underline{P}$ < 0.005) and spring 1988 ($\underline{X}^2$ = 6.25, 1 df, $\underline{P}$ < 0.01) and spring 1989 ($\underline{X}^2$ = 15.86, 1 df, $\underline{P}$ < 0.005). Deer usage of tebuthiuron treatments was greater than triclopyr treatments in winter 1989 ($\underline{X}^2$ = 5.63, 1 df, $\underline{P}$ < 0.025). Burn vs. unburned comparisons indicated that burn treatments were selected in summer 1988 ($\underline{P}$ < 0.005); unburned treatments were selected throughout 1989 (winter $\underline{X}^2$ = 33.72, 1 df, $\underline{P}$ < 0.005, summer $\underline{X}^2$ = 129.41, 1 df, $\underline{P}$ < 0.005, fall $\underline{X}^2$ = 115.81, 1 df, $\underline{P}$ < 0.005), except in spring ($\underline{X}^2$ = 2.78, 1 df, $\underline{P}$ > 0.05). Deer selected brush-treated areas over untreated controls in winter ($\underline{X}^2$ = 6.01, 1 df, $\underline{X}$ = < 0.01) and fall ($\underline{X}^2$ = 7.71, 1 df, $\underline{P}$ < 0.005) 1988 and throughout 1989 (winter $\underline{X}^2$ = 42.72, 1 df, $\underline{P}$ < 0.005, spring $\underline{X}^2$ = 4.92, 1 df, $\underline{P}$ < 0.025, summer $\underline{X}^2$ = 104..04, 1 df, $\underline{P}$ < 0.005, fall $\underline{X}^2$ = 171.66, 1 df, $\underline{P}$ < 0.005).

Chi-square goodness-of-fit analyses indicated significant differences between overall availability and treatment usage for winter and spring 1988 and for all seasons in 1989 (Table 2). Bonferroni intervals showed tebuthiuron treatments were used by deer as expected throughout 1988 and 1989, except fall 1989 when usage was greater than expected. Tebuthiuron with fire treatments were avoided in winter and spring 1988, but were used as expected in all other seasons. Both triclopyr and triclopyr with fire were used greater than or as expected throughout the study except in winter 1989 when burned areas were avoided. Deer usage of burned treatments was proportional to availability in all seasons except winter 1988 when usage was less than expected. Untreated controls were used less than or as expected throughout the study except in winter 1989.

DISCUSSION

Habitat response to brush treatments varied with specific treatment applications creating remarkably disparate habitat types on the CTER (Engle et al. 1991, Stritzke et al. 1991). Tebuthiuron effectively controlled woody species and their resprouts which permitted the release of monocot-dominated herbaceous forage. Triclopyr was less effective at removing woody overstory species and was ineffective at controlling resprouting, resulting in abundant browse production in the understory with concomitant suppression of herbaceous forage production.

Burning did not completely control regrowth of woody species because of insufficient fuel loads.

Both second- and third-order selection analyses showed that deer used treated areas more than untreated controls. Deer habitat usage of triclopyr and tebuthiuron sprayed habitats, in combination with prescribed burning, has not been previously examined. Other studies examining demographic and nutritional responses of deer to various herbicide treatments (mostly 2,4,5-T) have been equivocal. Darr and Klebenow (1975) found that deer densities were 4-fold higher 1-3 years post-treatment on areas sprayed with 2,4,5-T herbicide on sandyland ecotone habitats in Texas and concluded that herbicide spraying can be beneficial to deer. Tanner et al. (1978) used fecal pellet counts and aerial censuses to ascertain that 2,4,5-T and picloram applications had a negative impact on deer use 1-year post-treatment of Rio Grande Plain mixed-brush habitat. A similar study by Beasom and Scifres (1977) found no differences in deer densities 2-years post-treatment between sprayed and control areas. Other studies examining nutritional effects of 2,4,5-T (Quinton et al. (1978) and tebuthiuron (Fulbright and Garza 1991) applications on south Texas rangelands suggested that such practices may have negative long-term impacts on diet quality, but may not influence carcass composition.

We suggest that deer were attracted on the CTER to herbicide-treated areas because of an 8-fold increase in forb and browse production (Engle et al. 1991, Stritzke et al. 1991). Similar observations of deer usage have been made on areas following mechanical removal (50-70% removal) of brush (Rollins et al. 1988). Herbaceous and woody understory forage on both herbicide treatments increased on the CTER after the herbicide-induced reduction of woody overstory (Engle et al. 1991).

Overall triclopyr-treated areas (with and without fire) were used more than tebuthiuron-treated areas (with and without fire). Third-order habitat selection analyses showed that deer usage of triclopyr treatments was greater than expected in one or both sampling periods (1988, 1989) for each of the 4 seasons during the 2-year study. In comparison, selection of tebuthiuron treatments was only greater than expected during one occasion (winter 1989). It was impossible to ascertain the relative importance of nutritional or cover attributes of each resulting habitat type in deer usage patterns. As previously described, both the 2 herbicides created remarkably disparate habitats with respect to vegetation structure and composition. Vegetation cover on triclopyr treatments was denser and browse production greater than tebuthiuron-treated areas (Engle et al. 1991, Stritzke et al. 1991); however, tebuthiuron sites consistently had greater forb production.

The long-term consequences to deer habitat usage of repeated prescribed burning as a follow-up to herbicide applications remains unclear. Deer showed some preference for burned treatments in summer 1988 but selected unburned habitats throughout 1989. Cattle body mass gains following seasonal grazing on herbicide-treated areas of the CTER showed burning (24% gain) had a positive nutritional influence compared to areas not burned (8% gain) (McCollum et al. 1987).

Second-order selection in this study considered only the CTER as being available for preference determinations, while third-order selection considered all of the area used by individual deer within their home ranges (i.e., off-area untreated habitat) (Johnson 1980). Both selection indices yielded basically similar results in our specific contrasts analyses, but they did differ with respect to Bonferroni intervals. Given that deer frequently used areas off the CTER, third-order selection was believed to be a better reflection of true treatment selection as suggested by Yeo and Peek (1992).

Traditionally, land managers have manipulated deer habitat populations by setting back succession which generally increases white-tailed deer populations (Crawford 1984). Economic projections in the cross timbers region indicate that land managers could use brush manipulation to increase primary production for cattle and wildlife (Bernado 1990, Bernado et al. 1992). Based on our results, this would have a positive influence on deer populations in this region as much as 6 years post-treatment. Although our data showed a slight preference for triclopyr treatments, tebuthiuron treatments were seasonally selected as well suggesting that deer could benefit from brush management schemes in the cross timbers region that incorporate the use of both herbicides to create a diversity of habitat responses.

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Table 1. Seasonal second-order treatment preference of radiocollared deer on the Cross Timbers Experimental Range (CTER) throughout 1988-89.

		Winter (n = 8,10)[a] (X^2 = 102.8, 5 df)		Spring (n = 9,9) (X^2 = 23.0, 5 df)		Summer (n = 6,6) (X^2 = 39.4, 5 df)		Fall (n = 8,7) (X^2 = 12.8, 5 df)	
Treatment	% Availability[b]	No. of locations	Preference[c]	No. of locations	Preference	No. of locations	Preference	No. of locations	Preference
1988									
Tebuthiuron	18.2	22	-	13	o	31	-	39	-
Tebuthiuron/ fire	18.2	21	-	20	o	54	o	46	o
Triclopyr	18.2	94	+	37	o	56	o	45	o
Triclopyr/ fire	18.2	60	o	23	o	65	o	30	o
No herbicide/ fire	9.0	8	-	10	o	36	o	30	o
Control	18.2	29	o	9	-	18	-	28	o

Table 1. Cont.

Treatment	% Availability[b]	Winter ($\underline{n}$ = 8,10)[a] ($\underline{X}^2$ = 99.9, 5 df)		Spring ($\underline{n}$ = 9,9) ($\underline{X}^2$ = 98.8, 5 df)		Summer ($\underline{n}$ = 6,6) ($\underline{X}^2$ = 65.9, 5 df)		Fall ($\underline{n}$ = 8,7) ($\underline{X}^2$ = 86.5, 5 df)	
		No. of locations	Preference[c]	No. of locations	Preference	No. of locations	Preference	No. of locations	Preference
1989									
Tebuthiuron	18.2	111	+	61	o	123	o	114	+
Tebuthiruon/ fire	18.2	40	o	59	o	148	+	114	+
Triclopyr	18.2	64	o	115	+	120	o	54	-
Triclopyr/ fire	18.2	39	o	52	o	84	o	86	o
No herbicide/ fire	9.0	6	-	11	-	13	-	11	-
Control	18.2	29	-	38	-	72	-	36	-

[a]Number of deer monitored in each season ($\underline{n}$ = 1988,1989).
[b]Availability determined from treatments and controls on CTER only.
[c]Chi-square analyses with Bonferroni confidence intervals (Neu et al. 1974; + = preferred, o = no preference, - = avoided ($\underline{P}$ < 0.05)

Table 2. Seasonal third-order treatment preference of radiocollared deer on the Cross Timbers Experimental Range (CTER) throughout 1988-89.

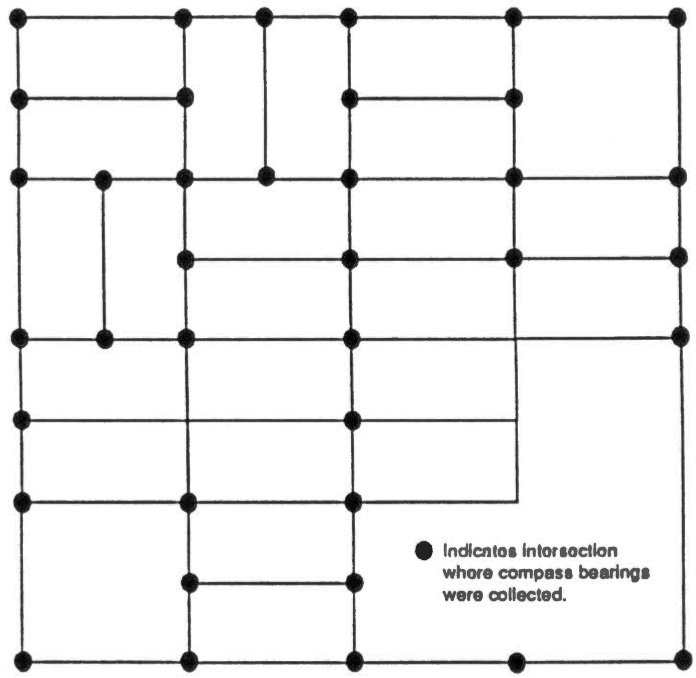
Treatment	Winter (n = 8,10)[a] (X^2 = 42.5, 5 df)			Spring (n = 9,9) (X^2 = 41.9, 5 df)			Summer (n = 6,6) (X^2 = 12.8, 5 df)			Fall (n = 8,7) (X^2 = 10.8, 5 df)		
	% Availability[b]	No. of locations.	Preference[c]	% Availability	No. of locations.	Preference	% Availability	No. of locations.	Preference	% Availability	No. of locations.	Preference
1988												
Tebuthiuron	13.4	27	o	7.9	17	o	14.6	31	o	12.3	39	o
Tebuthiuron/ fire	15.3	25	-	20.5	20	-	18.2	54	o	19.1	46	o
Triclopyr	29.4	95	+	26.5	43	o	22.8	56	o	14.3	45	o
Triclopyr/ fire	13.4	58	+	4.9	25	+	16.3	65	o	8.2	30	o
No herbicide/ fire	8.0	8	-	19.7	41	o	10.5	36	o	9.7	30	o
Control	20.4	35	-	20.5	28	o	17.6	46	o	36.4	77	o

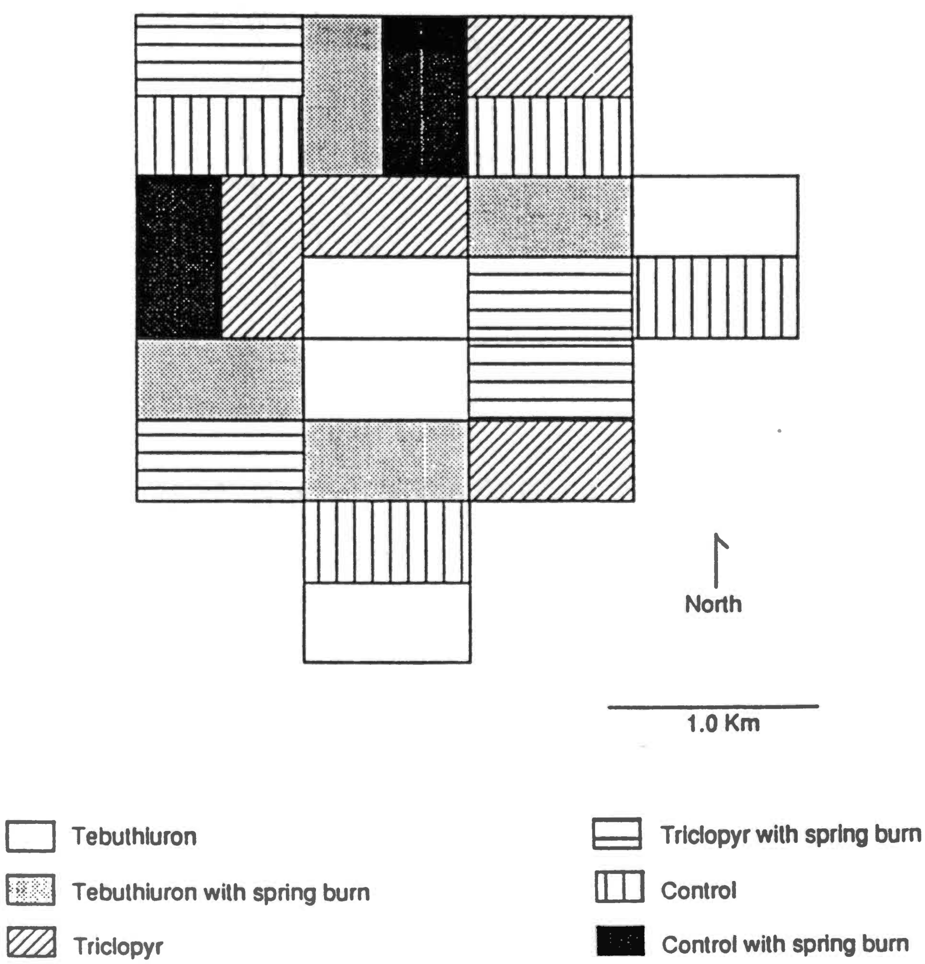
Table 2. Cont.

Treatment	Winter (n = 8,10)[a] ($\underline{X}^2$ = 59.7, 5 df)			Spring (n = 9,9) ($\underline{X}^2$ = 35.8, 5 df)			Summer (n = 6,6) ($\underline{X}^2$ = 177.7, 5 df)			Fall (n = 8,7) ($\underline{X}^2$ = 290.8, 5 df)		
	% Availability[b]	No. of locations.	Preference[c]	% Availability	No. of locations.	Preference	% Availability	No. of locations.	Preference	% Availability	No. of locations.	Preference
1989												
Tebuthiuron	28.3	111	o	18.5	61	o	18.5	123	o	10.0	114	+
Tebuthiruon/ fire	13.5	40	o	17.6	59	o	11.2	148	o	11.7	114	o
Triclopyr	17.1	64	o	18.4	115	+	13.4	120	+	11.2	54	o
Triclopyr/ fire	21.4	39	-	14.4	52	o	5.4	84	+	5.1	86	+
No herbicide/ fire	2.6	6	o	4.0	11	o	.1	13	o	3.1	11	o
Control	17.3	112	+	27.0	84	o	49.8	215	-	59.0	175	-

[a]Number of deer monitored in each season (n = 1988,1989).
[b]Overall availability of treatments and control from seasonal home ranges.
[b]Chi-square analyses with Bonferroni confidence intervals (Neu et al. 1974; + = preferred, o = no preference, - = avoided ($\underline{P}$ < 0.05)

Fig. 1. Intersection map delineating reference points used to collect telemetry locations on animals fitted with a radio transmitter on the Cross Timbers Experimental Range (CTER) in 1988-89 and a treatment map showing placement of experimental brush treatments on the CTER.


Indicates intersection where compass bearings were collected.


North
1.0 Km
Tebuthiuron
Tebuthiuron with spring burn
Triclopyr
Triclopyr with spring burn
Control
Control with spring burn

APPENDIX A

AVERAGE (±SE) CRUDE PROTEIN (DRY MATTER) CONTENT OF BROWSE SPECIES COLLECTED SEASONALLY FROM THE CROSS TIMBERS EXPERIMENTAL RANGE

APPENDIX A

CRUDE PROTEIN (% DRY MATTTER) CONTENT OF BROWSE SPECIES COLLECTED SEASONALLY FROM THE CROSS TIMBERS EXPERIMENTAL RANGE

Key to abbrevations:		Treatment:	
CB = CORALBERRY	HA = HACKBERRY	1 = TEBUTHIURON	5 = CONTROL
BL = BLACKBERRY	GB = GREENBRIAR	2 = TEBUTHIURON + FIRE	
DW = DOGWOOD	SM = SOOTH SUMAC	3 = TRICLOPYR	
EM = ELM		4 = TRICLOPYR + FIRE	

SPECIES	TRT	WI88	SP88	SU88	FA88	WI89	SP89
CB	1	5.82±0.14	13.76±0.72	8.77±0.61	6.89±0.28	6.76±0.16	12.89±1.11
	2	6.37±0.42	11.83±0.30	8.54±0.41	7.36±0.23	6.50±0.15	14.69±1.09
	3	6.28±0.21	16.52±1.43	9.20±0.61	8.69±0.66	7.23±0.17	17.41±0.47
	4	5.63±0.63	14.82±1.23	9.12±0.43	8.24±0.41	7.16±0.27	17.05±0.99
	5	6.35±0.24	13.73±0.17	8.62±0.19	7.08±0.19	6.08±0.42	13.54±1.01
BL	1	5.81±0.14	19.04±0.08	10.17±0.49	10.22±0.44	7.19±0.61	15.95±0.48
	2	6.37±0.42	18.34±0.75	10.70±0.37	8.68±1.18	7.31±0.19	17.60±0.95
	3	6.28±0.21	19.21±1.32	12.48±0.37	11.28±1.30	9.72±0.68	19.10±0.43
	4	5.63±0.63	17.61±1.13	12.46±0.74	10.88±0.78	10.48±0.78	18.11±0.98
	5	6.35±0.24	18.16±0.58	9.24±0.33	10.64±0.68	6.50±0.89	15.69±0.84
DW	1	7.57±0.08	16.53±1.11	9.36±0.19	7.44±0.29	5.63±0.18	14.94±0.83
	2	5.17±0.75	15.77±1.00	9.33±0.45	7.28±0.53	5.84±0.32	16.27±0.75
	3	5.72±0.11	18.39±0.77	9.39±0.33	7.71±0.95	5.81±0.06	16.38±0.09
	4	5.17±0.26	17.87±0.49	9.79±0.33	8.16±0.44	5.70±0.16	17.32±0.45
	5	5.27±0.21	14.42±0.65	8.46±0.83	6.63±0.46	5.62±0.10	14.07±0.96
EM	1	6.71±0.39	17.81±1.34	9.34±0.63	6.86±0.17	6.58±0.39	16.07±1.34
	2	7.38±0.09	16.91±0.73	10.40±0.79	7.86±0.62	7.38±0.59	24.11±0.94
	3	7.69±0.11	20.07±0.72	10.91±0.34	8.41±0.89	6.53±0.31	24.63±0.58
	4	6.40±0.60	20.47±0.54	9.72±0.49	9.07±0.84	6.98±0.38	24.79±0.53
	5	6.48±0.19	15.70±0.38	8.98±0.35	7.73±1.07	5.63±0.13	15.40±1.12
HA	1	7.68±0.28	21.55±1.16	10.64±1.16	7.18±0.35	8.36±0.83	18.51±0.59
	2	7.51±0.56	20.47±1.07	10.67±0.83	7.35±0.15	7.61±0.37	22.73±0.96
	3	7.15±0.69	24.84±0.83	11.30±1.12	9.27±1.09	8.66±0.20	26.60±0.46
	4	7.36±0.62	25.61±1.34	11.97±0.97	9.54±0.96	8.33±0.24	26.45±1.47
	5	7.37±8.04	19.03±0.60	9.34±0.65	5.72±0.12	6.70±0.39	19.52±0.68
GB	1	7.96±0.18	31.87±1.92	10.90±0.52	9.77±0.29	8.62±0.78	26.85±1.68
	2	7.79±0.11	33.93±0.90	11.29±0.61	10.99±0.10	7.76±0.29	29.94±1.62
	3	7.71±0.05	33.65±1.55	11.65±0.75	11.50±0.63	8.13±0.42	33.82±2.15
	4	7.03±0.19	36.52±1.37	13.06±1.37	11.42±0.63	8.89±0.92	29.41±1.92
	5	6.44±0.08	30.94±2.66	11.06±0.53	10.04±0.50	7.63±0.67	31.96±1.85
SU	1	5.47±0.15	25.36±1.13	9.10±0.94	3.96±0.16	5.75±0.49	19.94±0.86
	2	6.02±0.42	20.07±0.42	10.57±0.32	6.44±2.58	5.20±0.16	20.24±0.31
	3	6.33±0.47	20.90±1.35	13.08±2.97	4.80±0.47	5.99±0.15	17.47±1.89
	4	5.27±0.52	21.09±0.76	10.57±1.48	4.88±0.66	5.79±0.19	19.51±1.45
	5	5.32±0.09	22.12±0.87	9.05±1.37	4.57±0.29	6.03±0.18	21.83±.179

APPENDIX B

MEAN (±SE) PERCENT IN VITRO DRY MATTER DIGESTIBILITY

OF SELECT BROWSE COLLECTED SEASONALLY FROM

FROM THE CROSS TIMBERS

EXPERIMENTAL RANGE

APPENDIX B

IN VITRO DRY MATTER DIGESTIBILITY OF BROWSE SPECIES COLLECTED SEASONALLY FROM THE CROSS TIMBERS EXPERIMENTAL RANGE

Key to abbrevations:

CB = CORALBERRY
BL = BLACKBERRY
DW = DOGWOOD
EM = ELM
HA = HACKBERRY
GB = GREENBRIAR
SM = SMOOTH SUMAC

Treatment:

1 = TEBUTHIURON
2 = TEBUTHIURON + FIRE
3 = TRICLOPYR
4 = TRICLOPYR + FIRE
5 = CONTROL

SPECIES	TRT	WI88	SP88	SU88	FA88	WI89	SP89
CB	1	42.56±1.24	45.43±7.30	45.66±2.06	45.66±2.06	42.06±0.94	52.13±1.46
	2	41.28±1.71	39.73±4.80	43.56±3.82	44.25±3.38	38.36±1.09	57.67±2.68
	3	42.28±1.66	43.75±6.36	38.73±2.87	44.69±2.34	43.62±0.93	61.89±0.62
	4	40.60±0.83	46.06±5.36	33.93±1.43	44.71±1.88	38.07±5.28	62.28±1.94
	5	37.96±2.78	45.87±4.58	43.01±4.48	39.35±0.10	31.50±8.46	56.05±2.32
BL	1	38.29±1.71	41.16±5.04	47.27±5.97	38.23±2.48	32.36±1.14	53.49±0.68
	2	36.77±1.28	43.20±2.14	40.28±2.14	42.90±4.69	30.02±2.93	55.93±2.62
	3	35.30±2.28	48.75±3.80	32.30±3.31	47.25±2.61	36.44±4.36	56.70±1.41
	4	31.15±1.55	54.54±1.20	31.87±1.02	48.83±3.43	35.65±2.81	57.68±1.42
	5	25.41±1.22	42.09±4.18	33.67±4.16	43.22±2.85	26.69±4.78	50.18±1.59
DW	1	30.51±2.74	56.19±0.69	51.62±4.44	42.56±2.72	30.23±0.76	54.67±2.64
	2	31.46±2.42	56.39±0.75	45.60±4.99	43.88±2.99	30.21±0.74	58.95±2.81
	3	31.61±0.58	51.01±2.90	45.18±3.39	42.06±3.47	21.17±1.09	62.03±0.18
	4	28.42±0.90	59.06±0.90	39.19±1.04	41.34±1.30	28.11±1.31	63.69±1.91
	5	25.33±1.95	54.47±2.56	48.81±4.66	39.53±4.66	39.53±1.96	51.72±2.17
EM	1	41.42±12.26	41.46±3.02	40.99±4.90	26.17±4.35	23.72±4.35	50.15±4.05
	2	22.60±2.56	42.54±4.37	52.25±14.61	37.93±2.28	20.23±0.85	55.06±3.04
	3	27.70±1.55	45.95±3.26	36.96±5.26	25.00±3.47	20.25±1.19	46.13±5.11
	4	27.83±1.28	47.04±1.99	33.65±0.58	35.02±1.07	18.65±1.61	50.96±3.62
	5	35.25±13.30	43.40±2.58	37.42±2.44	33.61±2.44	24.54±1.22	48.76±2.12
HA	1	28.39±1.26	51.86±3.29	42.67±1.56	31.50±1.51	42.06±0.94	50.15±4.05
	2	19.21±1.09	52.85±2.97	42.77±1.04	34.60±2.05	38.36±1.09	55.06±3.04
	3	21.88±0.58	52.02±2.14	42.38±1.95	37.66±1.61	43.62±0.93	46.13±5.11
	4	20.39±0.50	56.38±1.27	43.59±1.63	38.41±3.16	38.07±5.28	50.96±3.62
	5	19.44±0.90	50.43±2.90	42.49±1.93	32.47±3.12	31.50±8.46	48.76±2.12
GB	1	25.62±0.81	53.87±2.00	36.64±2.03	29.68±2.37	46.44±1.72	23.46±0.86
	2	20.68±1.76	56.03±1.88	34.04±2.85	32.14±1.46	53.62±2.38	20.80±0.85
	3	20.60±0.34	52.66±2.30	35.02±2.51	36.21±2.86	57.32±2.86	21.07±2.28
	4	18.62±1.11	58.46±1.79	34.82±3.11	34.07±2.18	52.34±3.22	23.66±2.78
	5	17.25±0.56	46.83±4.28	35.45±1.19	31.05±2.54	48.65±2.42	23.24±1.86
SU	1	36.84±1.45	56.52±3.41	55.80±1.84	24.40±2.36	32.41±1.02	59.87±1.97
	2	32.15±1.39	61.10±2.84	53.12±1.70	33.77±7.12	30.18±1.69	60.89±0.88
	3	32.17±2.62	57.05±3.31	50.15±2.52	31.89±5.12	24.56±2.90	59.21±2.82
	4	32.09±0.27	59.84±0.59	48.52±3.01	26.84±8.78	25.74±0.72	64.73±1.72
	5	26.18±1.83	57.01±2.86	54.07±1.84	23.79±2.85	25.45±2.19	58.74±2.38

APPENDIX C

MEAN (±SE) PERCENT MOISTURE (FRESH TISSUE) CONTENT OF SELECT BROWSE SPECIES COLLECTED SEASONALLY FROM THE CROSS TIMBERS EXPERIMENTAL RANGE

APPENDIX C

PERCENT MOISTURE (FRESH TISSUE) OF SELECTED BROWSE SPECIES COLLECTED SEASONALLY FROM THE CROSS TIMBERS EXPERIMENTAL RANGE

Key to abbrevations:

CB = CORALBERRY
BL = BLACKBERRY
DW = DOGWOOD
EM = ELM
HA = HACKBERRY
GB = GREENBRIAR
SU = SMOOTH SUMAC

Treatment:

1 = TEBUTHIURON
2 = TEBUTHIURON + FIRE
3 = TRICLOPYR
4 = TRICLOPYR + FIRE
5 = CONTROL

SPECIES	TRT	SP88	SU88	FA88	WI89	SP89
CB	1	63.13±2.23	47.96±2.66	61.60±0.92	39.01±6.03	63.45±2.54
	2	62.28±5.08	49.00±2.07	58.50±1.80	39.39±5.97	61.88±1.39
	3	67.67±2.25	50.26±1.91	54.90±3.06	43.55±5.10	66.31±1.71
	4	72.02±5.63	48.54±2.11	62.14±0.66	43.62±2.70	66.34±1.28
	5	69.51±5.44	53.44±3.79	54.62±1.28	37.64±2.45	64.92±1.45
BL	1	75.18±0.37	57.70±2.31	56.17±1.01	38.64±1.80	68.09±1.04
	2	69.08±9.27	59.06±2.21	57.60±2.29	37.71±2.00	68.87±0.81
	3	75.52±1.69	63.92±2.58	59.27±2.80	50.52±9.97	71.93±1.21
	4	72.67±1.76	66.47±2.80	58.35±3.88	42.13±5.45	71.18±1.85
	5	77.64±0.49	61.28±1.59	61.17±3.78	39.78±1.97	73.10±1.44
DW	1	53.34±0.52	54.71±1.58	67.06±0.28	46.78±0.23	66.85±1.16
	2	57.19±4.45	55.26±1.79	65.44±3.45	41.20±1.00	65.93±1.31
	3	54.58±2.04	58.49±1.84	69.58±1.43	49.22±6.55	65.97±0.59
	4	56.85±0.76	58.78±2.43	69.03±0.87	40.92±1.63	67.28±1.04
	5	58.48±1.22	54.81±3.09	69.21±0.58	40.93±10.16	66.69±0.99
EM	1	48.58±0.77	55.43±1.35	72.58±0.95	41.41±0.93	72.73±2.80
	2	52.47±1.81	58.42±1.36	53.81±16.99	41.03±0.49	74.26±1.07
	3	50.79±2.92	54.82±1.28	74.07±1.22	41.63±10.07	77.16±0.43
	4	52.85±2.20	56.19±0.91	75.17±0.58	28.40±2.49	76.39±1.01
	5	56.52±2.10	57.33±1.19	76.40±2.70	39.81±3.14	72.01±0.93
HA	1	48.69±2.08	52.75±1.50	76.38±0.47	33.26±2.23	74.79±1.55
	2	52.70±3.23	54.51±2.15	71.93±2.86	31.91±2.03	74.10±0.70
	3	51.81±2.90	55.47±1.91	76.78±0.47	33.69±14.70	76.52±0.80
	4	52.37±2.61	58.04±1.91	77.51±0.73	26.49±0.94	64.95±12.05
	5	56.47±1.75	54.32±2.89	79.39±2.47	34.49±0.86	80.72±4.06
SM	1	87.01±0.84	60.28±2.35	54.39±0.92	46.87±0.40	83.69±0.85
	2	85.21±2.47	61.64±2.48	57.91±2.35	43.15±1.64	84.20±0.66
	3	86.06±2.05	63.12±2.81	58.32±2.15	45.74±0.82	84.88±0.93
	4	86.76±1.23	65.11±2.99	60.65±1.51	42.88±2.16	84.30±0.59
	5	88.59±0.61	66.08±2.13	63.56±0.45	46.49±0.97	86.02±0.53
SU	1	76.35±1.47	56.95±0.74	52.57±1.64	40.93±0.60	74.73±1.08
	2	71.91±6.42	57.20±0.83	41.82±6.57	40.16±0.84	74.25±0.30
	3	76.67±1.32	57.96±0.92	50.13±3.41	32.03±5.67	74.55 ----
	4	76.27±0.44	56.63±13.12	45.59±1.43	45.59±1.43	74.97±1.51
	5	78.25±0.99	56.99±5.01	54.62±10.79	37.84±1.97	75.17±3.49

APPENDIX D

MEAN (±SE) PERCENT NEUTRAL DETERGENT FIBER (DRY MATTER)

CONCENTRATIONS OF SELECT BROWSE SPECIES

COLLECTED SEASONALLY FROM THE

CROSS TIMBERS EXPERIMENTAL

RANGE

APPENDIX D

PERCENT NEUTRAL DETERGENT FIBER (DRY MATTER) CONCENTRATIONS OF SELECTED BROWSE SPECIES COLLECTED SEASONALLY FROM THE CROSS TIMBERS EXPERIMENTAL RANGE

Key to abbrevations:

CB = CORALBERRY
BL = BLACKBERRY
DW = DOGWOOD
EM = ELM
HA = HACKBERRY
GB = GREENBRIAR
SU = SMOOTH SUMAC

Treatments:

1 = TEBUTHIURON
2 = TEBUTHIURON + FIRE
3 = TRICLOPYR
4 = TRICLOPYR + FIRE
5 = CONTROL

SPECIES	TRT	WI88	SP88	SU88	FA88	WI89	SP89
CB	1	43.59±0.50	42.79±4.33	40.32±3.67	37.51±0.61	46.80±0.61	28.31±2.54
	2	44.33±1.68	41.18±2.71	42.55±2.41	28.72±0.59	49.42±0.91	25.06±1.27
	3	45.10±1.13	32.72±3.29	44.95±1.80	41.09±1.59	43.05±0.80	24.73±0.73
	4	44.07±0.40	40.63±4.38	42.64±2.53	49.47±2.53	49.47±6.29	24.35±0.82
	5	40.88±1.67	38.59±3.22	42.64±2.13	41.81±2.73	56.58±9.38	27.77±1.39
BL	1	47.62±1.59	32.91±0.53	37.42±2.02	33.56±1.01	51.74±1.01	28.04±0.90
	2	50.27±2.24	33.68±0.34	36.77±1.77	33.16±1.39	56.90±9.28	27.02±0.83
	3	52.95±2.19	31.58±0.57	37.72±1.15	35.91±1.10	35.91±1.10	26.71±0.34
	4	52.57±1.56	31.61±0.27	35.80±3.57	29.93±1.60	43.12±3.73	26.63±0.80
	5	56.80±2.39	35.79±1.54	45.02±5.53	33.21±5.53	64.07±11.61	30.57±0.35
DW	1	56.48±0.11	22.90±0.10	27.72±3.42	23.98±1.40	58.12±0.86	20.47±0.67
	2	58.61±4.16	23.81±0.55	24.41±0.88	26.33±0.92	65.01±8.60	21.06±1.91
	3	56.12±0.60	28.24±5.98	25.38±2.07	28.97±3.72	66.13±7.74	19.33±0.31
	4	56.32±0.35	21.81±0.14	27.77±4.44	28.47±2.63	56.23±0.17	19.84±0.49
	5	54.67±1.42	23.35±0.52	25.55±1.93	30.36±0.97	56.18±0.57	21.15±0.56
EM	1	59.74±0.52	41.21±5.76	42.08±6.51	51.55±8.27	64.04±2.56	28.86±1.25
	2	68.08±5.77	39.67±2.97	42.21±5.19	43.07±3.55	61.17±2.00	28.24±1.34
	3	61.36±1.06	35.33±1.89	47.29±2.32	49.81±0.85	68.59±0.85	35.15±5.84
	4	60.84±1.30	33.35±1.14	47.18±0.99	46.82±3.38	70.14±1.19	30.50±1.53
	5	58.58±0.88	40.02±3.36	47.23±5.11	53.85±6.85	62.09±1.61	29.78±0.93
HA	1	71.09±0.62	30.29±2.64	37.43±2.71	41.14±0.88	71.50±2.33	27.65±0.51
	2	68.43±4.15	32.26±1.27	35.80±1.10	38.32±1.00	70.66±1.11	25.05±0.72
	3	69.54±0.54	30.11±1.71	36.55±2.07	35.18±1.01	71.08±0.41	22.02±1.90
	4	71.06±2.55	28.93±2.26	39.18±3.17	38.18±2.91	72.49±0.96	24.07±0.63
	5	67.56±0.83	30.53±1.43	39.76±1.25	40.34±1.65	67.84±0.53	26.95±1.58
SM	1	75.07±0.90	33.42±2.39	48.91±3.95	51.82±1.96	46.87±0.74	33.19±0.85
	2	74.02±2.33	36.09±1.23	49.56±1.91	49.89±1.76	76.87±0.58	30.37±1.52
	3	76.57±0.39	32.52±1.55	48.27±2.93	44.61±3.35	72.84±2.92	29.44±2.12
	4	75.40±0.54	30.07±0.96	47.44±5.39	48.94±0.44	69.75±2.87	33.90±3.39
	5	74.72±0.77	40.35±6.07	54.15±0.81	52.62±0.81	71.97±4.36	29.69±1.85
SU	1	47.02±0.63	18.99±0.64	23.28±2.39	40.72±4.87	51.41±2.43	16.38±1.44
	2	41.45±0.28	18.81±1.17	26.75±2.73	40.24±2.65	58.73±8.57	16.00±0.82
	3	48.08±0.83	18.15±1.28	28.21±5.90	41.60±2.58	55.45±2.48	27.77±2.58
	4	46.86±0.26	19.68±0.80	32.10±7.34	49.62±7.34	55.13±0.65	18.08±0.21
	5	46.06±1.29	17.68±1.47	28.77±2.82	47.40±2.96	56.00±1.27	17.27±1.10

APPENDIX E

MEAN (±SE) PERCENT ACID DETERGENT FIBER (DRY MATTER) CONCENTRATIONS OF SELECT BROWSE SPECIES COLLECTED SEASONALLY FROM THE CROSS TIMBERS EXPERIMENTAL RANGE

APPENDIX E

PERCENT ACID DETERGENT FIBER (DRY MATTER) CONCENTRATION OF SELECT BROWSE SPECIES COLLECTED SEASONALLY FROM THE CROSS TIMBERS EXPERIMENTAL RANGE

Key to abbrevations:

CB = CORALBERRY
BL = BLACKBERRY
DW = DOGWOOD
EM = ELM
HA = HACKBERRY
GB = GREENBRIAR
SU = SMOOTH SUMAC

Treatment:

1 = TEBUTHIURON
2 = TEBUTHIURON + FIRE
3 = TRICLOPYR
4 = TRICLPOYR + FIRE
5 = CONTROL

SPECIES	TRT	WI88	SP88	SU88	FA88	WI89	SP89
CB	1	28.04±0.62	22.41±3.74	26.43±3.48	34.51±0.38	29.23±2.92	15.63±0.49
	2	28.41±0.74	24.76±2.28	27.15±2.08	24.06±0.55	31.31±0.83	14.54±1.11
	3	29.23±1.05	17.94±2.60	26.48±1.39	29.39±1.85	27.21±1.03	15.24±0.98
	4	28.58±0.58	23.08±2.64	28.23±0.87	22.97±0.79	32.39±5.17	13.54±0.25
	5	28.77±2.83	22.20±3.54	25.80±1.86	26.32±2.07	38.34±8.10	15.76±0.42
BL	1	31.52±1.57	16.84±.017	17.63±1.00	17.15±1.01	33.53±1.08	11.58±2.46
	2	34.00±2.09	16.58±0.70	17.48±0.46	16.31±1.95	40.09±8.69	13.33±0.24
	3	37.23±2.09	15.19±0.50	18.17±0.80	17.90±1.12	33.95±11.36	14.47±0.51
	4	37.12±1.22	15.00±0.49	17.90±1.55	29.93±1.60	25.77±4.01	17.30±3.47
	5	40.94±1.83	19.18±2.20	20.76±1.06	33.21±5.53	47.10±10.95	16.71±0.40
DW	1	39.38±0.36	14.09±0.52	14.29±1.84	14.41±0.94	39.79±0.97	13.82±0.58
	2	41.44±3.64	12.27±0.71	13.71±0.70	15.82±1.21	47.70±8.04	13.95±1.19
	3	40.12±0.46	12.70±0.49	13.92±0.87	18.34±3.06	47.59±3.06	12.58±0.25
	4	39.90±0.54	12.06±0.36	14.83±1.80	16.92±1.72	39.31±1.12	12.96±0.37
	5	37.21±1.58	14.34±0.87	13.49±0.85	18.63±0.75	40.17±0.63	13.66±0.27
EM	1	44.10±1.13	21.65±1.42	21.83±3.88	34.35±10.02	47.82±3.35	17.66±0.83
	2	48.19±4.37	20.42±2.75	21.41±1.86	23.08±1.16	45.33±1.78	18.64±1.06
	3	45.61±0.94	19.82±1.57	23.36±1.79	25.45±1.95	51.78±0.66	20.21±1.84
	4	45.54±1.10	16.81±1.40	29.36±1.24	24.15±2.38	53.57±0.87	17.95±1.53
	5	44.84±0.59	22.90±2.26	24.91±1.44	38.28±7.34	47.64±1.25	19.31±1.05
HA	1	51.78±0.67	17.19±1.31	22.30±1.55	28.91±0.98	50.74±1.51	17.61±0.89
	2	50.15±3.75	15.93±0.76	21.81±0.37	25.32±0.95	52.86±0.67	16.81±0.71
	3	53.84±1.81	14.89±0.88	21.79±1.86	25.52±3.61	51.22±0.38	14.47±0.93
	4	51.34±0.44	28.29±2.26	24.71±2.65	24.28±2.27	53.32±0.65	16.08±0.94
	5	50.46±0.47	18.88±1.28	23.86±1.44	28.25±1.19	49.32±0.59	17.45±1.04
SM	1	54.22±0.71	18.91±0.63	32.38±4.06	34.28±1.31	51.80±0.74	26.85±1.68
	2	53.63±2.45	18.03±0.98	33.61±2.44	31.20±1.32	56.71±0.34	29.94±1.62
	3	56.98±0.94	17.37±0.83	33.27±2.60	28.27±2.05	51.08±3.24	33.82±2.15
	4	55.56±0.72	16.57±0.49	33.15±4.47	30.95±0.44	51.82±1.67	29.41±1.92
	5	54.88±0.68	23.27±3.70	36.89±1.00	35.85±0.77	51.79±4.09	31.96±1.85
SU	1	32.66±0.81	12.80±0.36	13.43±1.00	27.45±4.01	33.97±1.92	11.27±0.68
	2	33.97±0.39	11.48±1.03	15.00±2.36	24.59±3.24	43.71±8.00	10.91±0.65
	3	33.57±0.88	10.28±0.74	16.83±2.96	28.77±3.37	35.20±3.37	21.04±7.35
	4	33.11±0.39	11.36±0.65	21.02±6.87	34.77±6.84	40.80±0.67	13.11±0.51
	5	33.99±1.04	11.41±1.12	19.14±2.50	31.58±1.69	39.46±0.83	11.87±0.56

APPENDIX F

MEAN (±SE) PERCENT HEMICELLULOSE (DRY MATTER)
OF SELECT BROWSE SPECIES COLLECTED
SEASONALLY FROM THE CROSS
TIMBERS EXPERIMENTAL
RANGE

APPENDIX F

PERCENT HEMICELLULOSE (DRY MATTER) IN SELECTED BROWSE SPECIES COLLECTED SEASONALLY FROM THE CROSS TIMBERS EXPERIMENTAL RANGE

Key to abbrevations:

CB = CORALBERRY
HA = HACKBERRY
BL = BLACKBERRY
GB = GREENBRIAR
DW = DOGWOOD
SM = SMOOTH SUMAC
EM = ELM

Treatment:

1 = TEBUTHIURON
2 = TEBUTHIURON + FIRE
3 = TRICLOPYR
4 = TRICLOPYR + FIRE
5 = CONTROL

SPECIES	TRT	WI88	SP88	SU88	FA88	WI89	SP89
CB	1	15.55±0.13	20.56±4.30	13.88±0.55	13.48±0.60	17.57±0.49	12.67±1.17
	2	15.92±1.06	16.41±1.06	15.39±0.86	14.65±0.36	18.11±0.43	10.52±0.48
	3	15.87±0.47	14.77±0.78	18.47±2.35	14.70±0.31	15.84±0.45	9.49±1.41
	4	15.50±0.24	17.54±2.30	14.41±0.28	18.40±3.30	17.08±1.17	10.81±0.66
	5	12.12±4.04	16.39±0.72	16.76±0.74	15.50±0.67	18.24±1.32	11.99±1.06
BL	1	16.10±0.12	16.07±0.40	19.79±1.36	16.41±0.20	18.21±0.20	16.45±2.64
	2	16.29±0.54	17.10±0.54	19.29±1.36	16.85±1.12	16.80±0.63	13.69±1.05
	3	15.72±0.10	16.39±0.20	19.56±0.71	18.00±0.32	17.23±1.18	12.25±0.53
	4	15.45±0.38	16.34±0.25	17.90±2.17	15.01±2.09	17.35±0.30	9.34±3.17
	5	15.95±0.56	16.62±1.25	24.26±0.75	13.39±4.61	16.97±1.04	13.85±0.70
DW	1	17.10±0.31	8.81±0.47	13.43±1.61	9.56±0.51	18.32±0.27	6.65±0.85
	2	17.16±0.70	11.54±0.98	10.70±0.28	10.70±0.28	17.31±0.56	7.41±0.84
	3	16.00±0.22	15.54±6.30	11.46±1.27	10.46±0.66	18.53±0.28	6.75±0.52
	4	16.41±0.38	9.76±0.28	12.94±2.69	11.55±1.06	16.92±1.11	6.88±0.37
	5	17.45±1.84	9.01±0.43	12.06±2.31	11.73±0.78	16.01±0.46	7.49±0.41
EM	1	15.64±0.72	19.56±4.49	20.25±2.84	17.21±3.10	16.23±1.49	11.20±0.94
	2	19.89±2.27	19.25±0.83	20.80±0.66	15.85±0.71	15.85±0.71	9.60±1.05
	3	15.75±0.33	15.51±2.65	23.94±1.57	24.36±1.15	16.81±1.35	14.94±4.03
	4	15.30±1.18	16.51±1.47	17.83±0.93	22.68±1.22	16.57±0.58	12.55±0.67
	5	13.74±0.30	17.12±1.79	22.31±4.14	15.57±1.08	14.46±0.55	10.46±1.01
HA	1	19.31±0.54	13.10±1.31	15.13±1.33	12.23±0.50	20.77±0.77	9.98±0.49
	2	18.28±0.59	16.33±1.22	14.00±0.75	13.01±0.26	17.80±0.44	8.24±0.89
	3	15.70±1.31	15.23±1.64	14.76±1.59	9.66±2.63	19.85±0.28	7.55±1.05
	4	19.72±2.22	12.83±0.68	14.47±0.57	13.90±0.84	18.97±0.82	8.63±0.48
	5	17.09±0.57	11.47±0.37	15.91±0.29	12.10±0.47	18.33±0.35	9.50±0.76
SM	1	20.85±0.23	14.51±1.87	16.54±0.20	17.53±0.70	23.32±0.47	10.80±1.17
	2	20.40±0.17	18.06±0.60	15.95±0.54	18.69±0.71	20.16±0.57	9.84±0.65
	3	19.59±0.82	15.15±0.96	14.99±0.56	16.34±1.36	21.77±0.47	9.53±1.15
	4	19.84±0.57	13.50±0.74	14.29±1.11	18.00±0.50	17.93±1.57	12.39±1.05
	5	19.84±0.63	17.08±2.57	17.27±0.91	16.77±0.66	20.18±0.30	16.83±1.26
SU	1	14.37±0.47	6.19±0.82	9.84±1.44	13.27±1.00	17.44±1.78	5.14±0.81
	2	14.47±0.46	7.32±0.24	11.75±1.26	15.65±1.33	15.01±0.73	5.08±0.21
	3	14.51±0.06	7.87±1.17	11.53±3.39	12.83±1.29	20.25±7.82	6.73±0.94
	4	13.75±0.29	8.32±1.11	11.17±1.56	14.91±0.79	14.33±0.80	4.97±0.29
	5	14.07±0.46	6.26±0.61	9.62±0.48	15.28±1.50	16.54±0.63	5.40±0.54

VITA

Roderick Brian Soper

Candidate for the degree of

Master of Science

Thesis: EFFECTS OF BRUSH MANAGEMENT ON WHITE-TAILED DEER (ODOCOILEUS VIRGINIANUS) IN THE CROSS TIMBERS REGION OF OKLAHOMA

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