BRUSH CONTROL AND ASSOCIATED BOTANICAL CHANGES FOLLOWING TEBUTHIURON APPLICATION IN KANSAS

by

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B. S., Kansas State University, 1979

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

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ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Dr. Walter Fick, his advisor, for his assistance, guidance and constructive criticism throughout the course of this study.

A note of thanks is given to the assistance of other members of his graduate committee, Dr. Loren Moshier and Dr. Clenton Owensby.

A special note of appreciation is given to his parents, James and Fern Nolte, for their support throughout his college years. Additional thanks is also extended to his mother for typing the final copy.

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BRUSH CONTROL AND ASSOCIATED BOTANICAL CHANGES FOLLOWING TEBUTHIURON APPLICATION IN KANSAS

INTRODUCTION

There are approximately 6.7 million hectares of rangeland and 1 million hectares of tame pasture in Kansas. Over 2 million hectares have brush growing on them. Brush dense enough to reduce forage production occurs on about 400 thousand hectares of Kansas rangeland (Ohlenbusch 1981, personal communication).

The primary herbicides previously used for brush control have been 2,4,5-T([2,4,5,-trichlorophenoxy] acetic acid) and to a lessor extent 2,4-D([2,4-dichlorophenoxy] acetic acid). Potential spray drift to adjacent susceptible crops, rigid timing requirements relative to plant phenology, and differential responses of brush species in mixed stands are problems associated with foliar sprays (Scifres and Mutz 1978). Pelleted herbicides are less subject to drift and timing requirements for application are reduced since absorption is dependent on root uptake. Tebuthiuron (N-[5-(1,1-dimethylethyl)-1,2,3-thiadiazol-2-yl]-N,N'-dimethylurea), a recently developed soil applied herbicide, has shown promise for control of several woody species in Kansas.

A study conducted under an experimental use permit demonstrated the effectiveness of tebuthiuron for brush control in Kansas (Baker et al. 1980). Tebuthiuron applied at a rate of 2.2 kg/ha or greater completely controlled oaks (Quercus spp.), roughleaf dogwood (Cornus drummondi), elms (Ulmus spp.), eastern redbud (Cercis canadensis), hickories (Carya spp.), black cherry (Prunus serotina), and hawthorn (Crataegus spp.) three years after application at several different locations. Additional studies on tebuthiuron effectiveness in Kansas are incomplete. However, studies in other states with related species showed tebuthiuron to be effective on woody species normally found in Kansas. Scifres et al. (1981) reported total canopy reduction of post oak (Quercus stellata), blackjack oak (Quercus marilandica), water oak (Quercus nigra), winged elm (Ulmus alata) and cedar elm (Ulmus crassifolia) 14 months after 2.2 kg/ha tebuthiuron was aerially applied. Buckbrush (Symphoricarpos orbiculatus), common honeylocust (Gleditsia triacanthos) and black hickory (Carya texana canopies were initially reduced but recovered within 36 months after application. Eastern redcedar (Juniperus virginiana), a problem in Kansas, was not effectively controlled. Tebuthiuron aerially applied at 2 and 4 kg/ha in eastern Oregon caused necrosis in crowns but incomplete control of western juniper (Juniperus occidentalis) (Britton and Sneva 1981). Shroyer et al. (1979) reported greater defoliation and subsequent control of live oak (Quercus virginiana) and winged elm with tebuthiuron application than with 2,4,5-T.

Associated changes in the available forage within a treated area is concomitant to brush reduction. Biondini and Pettit (1979, 1980) report that forages treated with tebuthiuron have higher protein values, slightly higher phosphorous content, increased water content, and increased 24-hour *in vitro* dry matter digestibility than untreated forages. Scifres and Mutz (1978) reported a 66% increase in grass standing crop 17 months after treating whitebrush (*Aloysia lycioides*) with 1 kg/ha tebuthiuron. Average dry weight of grasses on pastures treated with 2.2 kg/ha tebuthiuron for oak control was almost four times that of untreated pastures (Scifres et al. 1981). In addition, the proportion of grasses in the good to excellent grazing value category increased following tebuthiuron application, while the proportion of grasses of poor grazing value decreased. Livestock responses are expected to favorably reflect the improved changes in forage quality and quantity.

The purposes of this study were 1) to determine effectiveness of 2 kg/ha aerially applied tebuthiuron for controlling selected woody species and 2) to determine tebuthiuron effects on botanical composition and ground cover.

STUDY AREAS

Three sites, located in the Kansas Flint Hills region, were used in this study. Sites in the northern Flint Hills were in Pottawatomie and Geary Counties. Cowley County, in the southern portion of the Flint Hills, was the location of the third site.

GEARY COUNTY

Soils at the Geary County site were Irwin silty clay loam, a member of the fine mixed, mesic family of Pachic Argiustolls and Sogn complex, a member of the loamy mixed, mesic family of Lithic Haplustolls. Soil in the upper profile is clay, clay loam, loam or sandy loam, with a pH of 7.1 to 7.9 and organic matter content between 3.6 and 4.8% (Appendix, Table 1). Limy upland was the major range site present. White City, the nearest reporting weather station received 522 mm of precipitation in 1980 and 973 mm in 1981 (Appendix, Table 4). Primary brush species were smooth sumac (Rhus glabra), aromatic sumac (Rhus aromatica) and buckbrush. Predominant grasses were big bluestem (Andropogon gerardi), sideoats grama, (Bouteloua curtipendula), Japanes brome (Bromus japonicus), rice cutgrass (Leersia oryzoides), fall witchgrass (Leptoloma cognatum), yellow bristlegrass (Setaria lutescens), green bristlegrass (Setaria viridis), tall dropseed (Spoobulus var. asper) and purpletop (Tridens flavus).

COWLEY COUNTY

Soils at the Cowley County site were Clime series, a member of the fine, mixed, mesic family of Udic Haplustolls. Soil in the upper profile was a clay loam, with a pH of 6.2 to 7.0 and organic matter content between 4.3 and 4.8% (Appendix, Table 2). Range sites present were limy upland and loamy upland. Dexter, the nearest reporting weather station, received 510 mm of precipitation the first year following tebuthiuron application, almost 350 mm below the yearly annual average. Dexter recorded 923 mm precipitation in 1981 (Appendix, Table 4). Primary brush species present were dwarf chinquapin (Quercus prinoides), smooth sumac and buckbrush. Predominant grasses in the understory were big bluestem, little bluestem (Andropogon scoparius), sideoats grama and buffalograss (Buchloe dactyloides).

POTTAWATOMIE COUNTY

Soils at the Pottawatomie County site were Benfield Florence silty clay loam, a member of the fine, mixed mesic family of Udic Argiustolls and Clime-stony silty clay loam which is member of the fine, mixed, mesic family of Udic Haplustolls. Soil in the upper profile is a clay loam or sandy clay loam with a pH of 6.8 to 7.7 and organic matter between 4.0 and 5.8 (Appendix, Table 3). Range sites were limy upland and loamy upland. Tuttle Creek Lake, the nearest reporting weather station received 590 mm of precipitation in 1980 and 803 mm in 1981 (Appendix, Table 4). Primary brush species were leadplant (Amorpha canescens), aromatic sumac, eastern redbud, chinquapin oak (Quercus muhlenbergia), roughleaf dogwood, black walnut (Juglans nigra), eastern cottonwood (Populus deltoides), bur oak (Quercus macrocarpa), and Siberian elm (Ulmus pumila). Predominant grasses were big bluestem, little bluestem, sideoats grama, switchgrass (Panicum virgatum), Indiangrass (Sorghastum nutans), green bristlegrass and purpletop.

METHODS

Tebuthiuron (20% a.i. pellet formulation) was aerially applied to 4 ha plots at each study site at 2 kg/ha during December, 1979, Permanent line transects 25 m in length were randomly located on tne treated and an adjacent untreated site. Each site in Geary and Pottawatomie Counties had ten permanent transects established on each of the treated and untreated areas. Eight transects were used on each of the treated and adjacent untreated sites in Cowley County.

Brush control was evaluated by recording changes in canopy cover and densities of selected woody species. Canopy cover was a measure of the downward vertical projection of the canopy on the permanent line transect, maximum possible canopy cover for a particular species being 100%. Density was measured with belt transects, 30-cm x 25-m for shrubs and 2-m x 25-m for trees. Botanical information was determined from 100 points collected along each permanent line transect using the modified step-pointer (Owensby 1973). Botanical information included proportion of forbs and grasses, basal cover, bare ground and litter. Grasses were categorized according to season of growth and life span. Canopy cover, density and botanical information were collected during the fall of 1980 and fall of 1981.

Herbaceous production following tebuthiuron treatment was determined only at the Pottawatomie County site. Two 0.25 m^2 plots, randomly placed along each permanent line transect, were clipped in the fall of 1980 and 1981. Herbaceous vegetation, separated according to grass, forbs and litter, was oven-dried for 72 hr at 60 C prior to weighing.

A sample was removed from the upper 10 cm of the soil profile at two randomly selected points along each permanent line transect at each site. Soil pH and organic matter were determined by the Kansas State University Soil Testing Laboratory using standard methods and textural components were determined using the hydrometer method (Foth et al. 1976).

Changes in density and canopy cover of woody species and botanical changes between the fall of 1980 and fall of 1981 were compared between the treated and untreated sites using LSD analysis. Analyses of variance were calculated using subsamples as an estimate of error variance, since the experiment was not replicated, though not considered strictly statistically valid, the analyses aid in interpretation.

RESULTS AND DISCUSSION

BRUSH CONTROL

Since precipitation in 1980 was lower than normal and effectiveness of tebuthiuron is dependent on sufficient rainfall, data collected the fall after application served as an indication of a study area's condition prior to treatment. Visual observation confirmed that minimal herbicide activity occurred the year following tebuthiuron application. Canopy cover and density changes occurring on treated and untreated sites, between fall of 1980 and fall of 1981 were used to detect woody species controlled following 2 kg/ha tebuthiuron application.

GEARY COUNTY

Smooth sumac canopy cover changed differentially with respect to treatment, decreasing under 2 kg/ha tebuthiuron application and increasing on the untreated site (Table 1). Smooth sumac density did not change between treated and untreated sites. Aromatic sumac showed no significant changes induced by tebuthiuron application in either canopy cover or density. The second fall after 2 kg/ha tebuthiuron application, density of buckbrush was reduced, while its canopy cover was not altered. Reduction in density not accompanied by a canopy cover reduction was caused by dense stands of buckbrush. Tebuthiuron application reduced density, but a sufficient number of plants persisted to retain the original canopy.

COWLEY COUNTY

None of the species selected to evaluate tebuthiuron efficacy, (dwarf chinquapin oak, smooth sumac, buckbrush) showed any change induced by 2 kg/ha tebuthiuron application (Table 2).

POTTAWATOMIE COUNTY

Leadplant, a desirable shrub in certain quantities for its browsing value, showed a significant density increase following tebuthiuron application (Table 3). Canopy cover changes of leadplant on the treated site were not different from changes on the untreated site. Aromatic sumac showed no significant change in canopy cover, while its density was reduced. Density reduction without a corresponding canopy cover change, was a result of thinning dense stands. Changes in eastern redbud canopy cover were different between the treated and untreated sites. A 30% canopy cover reduction of redbuds treated with 2 kg/ha tebuthiuron contrasted with a 46% increase on the untreated site. Changes in redbud density were not different between treated and untreated sites. Significant reduction of chinquapin oak density occurred without a similar reduction of canopy cover. Chinquapin oaks controlled following tebuthiuron application were saplings beneath larger trees. Total chinquapin oak canopy cover remained unchanged because the overstory was unaffected. Roughleaf dogwood, black walnut, eastern cottonwood, bur oak, and siberian elm showed no significant changes induced by tetuthiuron application in either canopy cover or density.

Table 1. Changes in density and canopy cover of brush species at the Geary County site, fall of 1980 and fall of 1981, following aerial application of 2 kg/ha tebuthiuron.

	Canopy Cover (%)		Density (#/m^2)	
	Treated	Untreated	Treated	Untreated
Smooth sumac				
Fall 1980	2.06	3.19	0.32	0.91
Fall 1981	1.14	5.68	0.09	0.78
Change	- 0.92	+ 2.49	- 0.23	- 0.13
	LSD 5% = 3.951[1]		LSD 5% = 0.459	
	10% = 3.082		10% = 0.358	
Aromatic sumac				
Fall 1980	1.16	2.54	0.27	1.06
Fall 1981	1.01	3.40	0.13	1.13
Change	- 0.15	+ 0.86	- 0.14	+ 0.07
	LSD 5% = 1.649		LSD 5% = 0.434	
	10% = 1.186		10% = 0.338	
Buckbrush				
Fall 1980	1.56	0.06	2.31	0.45
Fall 1981	0.25	0.04	0.28	0.45
Change	- 1.31	- 0.02	- 2.03	0.00
	LSD 5% = 1.654		LSD 5% = 1.914	
	10% = 1.357		10% = 1.493	

[1]Least significant differences ($P < .05$, $P < .10$) refer only to change in canopy cover or density.

Table 2. Changes in density and canopy cover of brush species at the Cowley County site, fall of 1980 and fall of 1981, following aerial application of 2 kg/ha tebuthiuron.

	Canopy Cover (%)		Density (#/m^2)	
	Treated	Untreated	Treated	Untreated
Dwarf chinquapin				
Fall 1980	0.92	0.70	5.00	2.19
Fall 1981	0.99	0.74	4.74	4.38
Change	+ 0.07	+ 0.04	- 0.26	+ 2.19
	LSD 5% = 0.812[1]		LSD 5% = 4.311	
	10% = 0.666		10% = 3.539	
Smooth sumac				
Fall 1980	0.97	1.93	0.30	10.22
Fall 2981	0.05	1.48	0.13	12.31
Change	- 0.92	- 0.45	- 0.17	+ 2.09
	LSD 5% = 1.604		LSD 5% = 3.827	
	10% = 1.316		10% = 3.141	
Buckbrush				
Fall 1980	3.28	3.69	2.31	2.39
Fall 1981	0.71	2.65	0.85	3.12
Change	- 2.57	- 1.04	- 1.46	+ 0.73
	LSD 5% = 4.864		LSD 5% = 3.626	
	10% = 3.994		10% = 2.976	

[1] Least significant differences ($P < .05$, $P < .10$) refer only to change in canopy cover or density.

Table 3. Changes in density and canopy cover of brush species at the Pottawatomie County site, fall of 1980 and fall of 1981, following aerial application of 2 kg/ha tebuthiuron.

	Canopy Cover (%)		Density (#/m^2)	
	Treated	Untreated	Treated	Untreated
Leadplant				
Fall 1980	1.16	3.41	0.51	0.97
Fall 1981	1.10	1.46	0.71	0.97
Change	- 0.06	- 1.95	+ 0.20	0.00
	LSD 5% = 2.424[1]		LSD 5% = 0.212	
	10% = 2.000		10% = 0.175	
Aromatic sumac				
Fall 1980	1.03	0.17	0.65	0.03
Fall 1981	0.85	0.41	0.20	0.09
Change	- 0.18	+ 0.24	- 0.45	+ 0.06
	LSD 5% = 0.572		LSD 5% = 0.257	
	10% = 0.472		10% = 0.212	
Eastern redbud				
Fall 1980	2.52	1.09	0.14	0.10
Fall 1981	1.82	1.71	0.07	0.07
Change	- 0.70	+ 0.62	- 0.07	- 0.03
	LSD 5% = 1.481		LSD 5% = 0.064	
	10% = 1.222		10% = 0.053	
Chinquapin oak				
Fall 1980	3.90	4.63	0.05	0.06
Fall 1981	2.36	5.75	0.03	0.06
Change	- 1.54	+ 1.12	- 0.02	0.00
	LSD 5% = 4.324		LSD 5% = 0.014	
	10% = 3.568		10% + 0.012	
Roughleaf dogwood				
Fall 1980	4.71	6.41	1.43	2.34
Fall 1981	2.55	6.07	0.67	2.01
Change	- 2.16	- 0.34	- 0.76	- 0.33
	LSD 5% = 4.100		LSD 5% = 0.899	
	10% = 3.386		10% = 0.742	
Black walnut				
Fall 1980	1.96	1.16	0.02	0.02
Fall 1981	2.39	1.88	0.02	0.02
Change	+ 0.43	+ 0.72	0.00	0.00
	LSD 5% = 1.768		LSD 5% = 0.000	
	10% = 1.459		10% = 0.000	
Eastern cottonwood				
Fall 1980	5.60	6.08	0.09	0.05
Fall 1981	3.00	8.05	0.05	0.04
Change	- 2.60	+ 1.97	- 0.04	- 0.01
	LSD 5% = 6.735		LSD 5% = 0.093	
	10% = 5.559		10% = 0.077	
Bur oak				
Fall 1980	8.21	2.44	0.01	0.01
Fall 1981	6.69	2.60	0.01	0.01
Change	- 1.52	+ 0.16	0.00	0.00
	LSD 5% = 3.053		LSD 5% = 0.013	
	10% = 2.519		10% = 0.011	
Siberian elm				
Fall 1980	3.54	3.99	0.14	0.31
Fall 1981	2.54	2.88	0.05	0.16
Change	- 1.00	- 1.11	- 0.09	- 0.15
	LSD 5% = 5.447		LSD 5% = 0.163	
	10% = 4.496		10% = 0.135	

[1]Least significant differences (P .05, P .10) refer only to change in canopy cover or density.

Based on these results the 2 kg/ha tebuthiuron rate used in this study, in conjunction with low rainfall was not adequate for complete control of evaluated species. Previous studies evaluating tebuthiuron control in Kansas showed at least 2.24 kg/ha was required for complete control of similar species (Baker et al. 1980). Under these conditions the 2 kg/ha tebuthiuron rate would at least partially control buckbrush aromatic sumac, and chinquapin oak, and reduce the canopies of smooth sumac and eastern redbud. Leadplant density increased following tebuthiuron application. Dwarf chinquapin oak, roughleaf dogwood, black walnut, eastern cottonwood, bur oak and Siberian elm were not affected.

VEGETATIVE RESPONSE

Forty species of grasses were encountered on the study sites with 21 common to all locations (Table 4). Most were perennial, warm-season grasses.

GEARY COUNTY

Ground cover in Geary County was 4.6% basal cover and 72.8% litter the fall following tebuthiuron application (Table 5). The next fall, basal cover and litter decreased to 3.5% and 57.2%, respectively. Bare ground changed accordingly from 22.6% to 42.3% in respective falls following treatment. A decrease in basal cover on the treated site was not different from a corresponding change on the untreated site. Changes in litter and bare ground between fall collection dates were greater on the treated site than on an adjoining untreated site. Grazing

Table 4. Grasses, their season of growth, life span and sites encountered.

Grass		Season of Growth	Life Span	Sites Found: Geary County	Cowley County	Pottawatomie County
Western wheatgrass	Agropyron smithii	C[1]	P[2]	X	X	X
Big bluestem	Andropogon gerardi	W[3]	P	X	X	X
Silver bluestem	Andropogon saccharoides	W	P	X	X	X
Little bluestem	Andropogon scoparius	W	P	X	X	X
Prairie threeawn	Aristida oligantha	W	A[4]	X		X
Sideoats grama	Bouteloua curtipendula	W	P	X	X	X
Blue grama	Bouteloua gracilus	W	P	X	X	
Hairy grama	Bouteloua hirsuta	W	P	X	X	X
Smooth brome	Bromus inermis	C	P	X		
Japanese brome	Bromus japonicus	C	A	X	X	X
Buffalograss	Buchloe dactyloides	W	P	X	X	X
Sedge[5]	Carex spp.	C	P	X	X	X
Sandbur	Cenchrus pauciflorus	W	A	X		
Windmillgrass	Chloris verticillata	W	P	X	X	X
Large crabgrass	Digitaria sanquinalis	W	A	X		
Barnyardgrass	Echinochloa crusgalli	W	A	X		
Canada wildrye	Elymus canadensis	C	P	X		X
Virginia wildrye	Elymus virginicus	C	P	X	X	X
Stinkgrass	Eragrostis cilianensis	W	A	X		
Purple lovegrass	Eragrostis spectabilis	W	P	X	X	X
Prairie cupgrass	Eriochloa contracta	W	P	X		
Six-week fescue	Festuca octoflora	C	A		X	
Rice cutgrass	Leersia oryzoides	C	P	X		X
Fall witchgrass	Leptoloma cognatum	W	P	X	X	X
Green muhly	Muhlenbergia racemosa	W	P	X		X
Roch muhly	Muhlenbergia sobolifera	W	P		X	X
Common witchgrass	Panicum capillare	W	A	X		X
Fall panicum	Panicum dichotomiflorum	C	A	X		X
Scribner panicum	Panicum scribnerianum	C	P	X	X	X
Switchgrass	Panicum virgatum	W	P	X	X	X
Sand paspalum	Paspulum stramineum	W	P	X		
Kentucky bluegrass	Poa pretansis	C	P	X		X
Tumblegrass	Schedonnardus paniculatus	W	P	X	X	X
Yellow bristlegrass	Setaria lutescens	W	A	X	X	X
Green bristlegrass	Setaria viridis	W	A	X		X
Indiangrass	Sorghastum nutans	W	P	X	X	X
Tall dropseed	Sporobolus asper	W	P	X	X	X
Sand dropseed	Sporobolus cryptandrus	W	P	X	X	X
Poverty dropseed	Sporobolus vaginiflorus	W	P			X
Purpletop	Tridens flavus	W	P	X	X	X

[1] Cool-season [2] Perennial [3] Warm-season [4] Annual [5] Grass-like plant

occurred at this site and may have influenced the results. Biondini and Pettit (1979) reported tebuthiuron application increased grass palatability. Increased palatability could cause grazing pressure on sites treated with tebuthiuron to exceed grazing pressure on untreated sites, reducing available forage for litter accumulation.

Proportions of grasses and forbs did not change following 2 kg/ha tebuthiuron application in Geary County (Table 6). Although changes in proportion of total grasses did not occur, composition of grass stand relative to season of growth and life span was affected (Table 7). The proportion of warm-season annuals on the treated site increased in conjunction with a decrease in cool-season annuals and perennials. Reduction in cool-season grasses was a result of herbicide injury and warm-season annuals filled the void created with their absence. Cool-season perennials which decreased were scribner panicum and sedges (Table 8). Japanese brome was the cool-season annual to decline following treatment. Yellow bristlegrass and green bristlegrass were warm-season annuals that increased following 2 kg/ha tebuthiuron application. Proportion of warm-season perennials did not change following tebuthiuron application (Table 7).

COWLEY COUNTY

None of the criteria selected (% basal cover, % litter, % bare ground, proportion of total grass and forbs, warm-and cool-season annuals and warm-and cool-season perennials) to evaluate vegetative response following brush control with tebuthiuron showed any change induced by 2 kg/ha tebuthiuron application (Tables 5, 6 and 7).

POTTAWATOMIE COUNTY

Ground cover in Pottawatomie County was 4.0% basal cover and 72.2% litter the fall following tebuthiuron application (Table 5). The next fall basal cover decreased to 1.4%, while litter increased. Bare ground changed accordingly, decreasing as litter increased. Changes in basal cover were the same on treated and untreated sites. Litter increased and bare ground decreased on both treated and untreated sites after tebuthiuron application, but changes on the untreated site were significantly greater.

Proportions of grasses and forbs did not change following 2 kg/ha tebuthiuron application (Table 6) and neither did the grass stand composition relative to season of growth and life span (Table 7).

Changes in grass production and litter after 2 kg/ha tebuthiuron application were not different between treated and untreated stands (Table 9). Forb production decreased on both treated and untreated sites, but reduction was greater on the untreated site. Forb production may have decreased less on the treated site, because of a reduction in competition with tebuthiuron controlled woody species.

Botanical changes associated with brush control are concomittant to the susceptibility of brush species to treatment. Brush reduction following 2 kg/ha tebuthiuron application was limited and often did not occur until the second year, leaving inadequate time for vegetative changes. Hence, vegetative responses were minimal.

Table 5. Changes in basal cover, litter, and bare ground, fall of 1980 and fall of 1981, following aerial application of 2 kg/ha tebuthiuron at sites in Geary, Cowley and Pottawatomie Counties.

	Basal Cover (%)		Litter (%)		Bare Ground (%)	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
Geary County						
Fall 1980	4.6	3.8	72.8	58.3	22.6	38.0
Fall 1981	3.5	2.4	57.2	55.9	42.3	41.6
Change	- 1.1	- 1.4	-15.6	- 2.4	+19.7	+ 3.6
	LSD	5% = 2.010[1]	LSD	5% = 8.424	LSD	5% = 9.706
		10% = 1.568		10% = 6.570		10% = 7.570
Cowley County						
Fall 1980	7.2	7.2	20.6	17.2	72.2	75.5
Fall 1981	5.8	4.8	51.0	40.8	43.4	54.5
Change	- 1.5	- 2.3	+31.6	+23.6	-28.8	-21.0
	LSD	5% = 3.587	LSD	5% = 16.214	LSD	5% = 17.427
		10% = 2.945		10% = 13.312		10% = 14.308
Pottawatomie County						
Fall 1980	4.0	4.5	72.2	62.5	23.8	33.0
Fall 1981	1.4	1.3	90.6	92.2	8.0	6.5
Change	- 2.6	- 3.2	+18.4	+29.7	-15.8	-26.5
	LSD	5% = 2.323	LSD	5% = 11.889	LSD	5% = 10.575
		10% = 1.917		10% = 9.234		10% = 8.728

[1]Least significant differences (P<.05, P<.10) refer only to changes in basal cover, litter and bare ground.

Table 6. Changes in herbaceous botanical composition, fall of 1980 and fall of 1981, following aerial application of 2 kg/ha tebuthiuron at sites in Geary, Cowley and Pottawatomie Counties.

	Grass (%)		Forbs (%)	
	Treated	Untreated	Treated	Untreated
Geary County				
Fall 1980	88.3	70.8	7.3	26.8
Fall 1981	91.0	71.6	5.3	26.9
Change	+ 2.7	+ 0.8	- 2.0	+ 0.1
	LSD 5% =	7.581[1]	LSD 5% =	7.107
	10% =	5.913	10% =	5.544
Cowley County				
Fall 1980	90.8	90.1	5.3	7.8
Fall 1981	92.6	89.8	4.8	6.1
Change	+ 1.8	- 0.3	- 0.5	- 1.7
	LSD 5% =	3.074	LSD 5% =	2.257
	10% =	2.524	10% =	1.853
Pottawatomie County				
Fall 1980	73.5	68.8	12.8	15.2
Fall 1981	79.2	74.0	13.3	14.6
Change	+ 5.7	+ 4.2	+ 0.5	- 0.6
	LSD 5% =	8.540	LSD 5% =	4.306
	10% =	7.048	10% =	3.554

[1]Least significant differences ($P<.05$, $P<.10$) refer only to changes in herbaceous botanical composition.

Table 7. Changes in grasses according to season of growth and life span, fall of 1980 and fall of 1981, following aerial application of 2 kg/ha tebuthiuron at sites in Geary, Cowley, and Pottawatomie Counties.

	Warm-Season Perennial (%)		Warm-Season Annual (%)		Cool-Season Perennial (%)		Cool-Season Annual (%)	
	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated
Geary County								
Fall 1980	61.4	70.4	6.8	0.1	5.0	0.4	15.2	0.4
Fall 1981	68.0	68.3	16.3	1.0	3.2	2.1	3.3	0.1
Change	+ 6.6	− 2.1	+ 9.5	+ 0.9	− 1.8	+ 1.7	−11.9	− 0.3
	LSD 5% = 11.749[1]		LSD 5% = 9.542		LSD 5% = 2.935		LSD 5% = 6.595	
	10% = 9.165		10% = 7.443		10% = 2.290		10% = 5.144	
Cowley County								
Fall 1980	81.0	79.4	0.0	0.0	8.8	8.7	0.3	1.0
Fall 1981	81.8	81.1	0.0	0.0	10.8	8.0	0.1	0.3
Change	+ 0.8	+ 1.7	0.0	0.0	+ 2.0	− 0.7	− 0.2	− 0.7
	LSD 5% = 4.958		LSD 5% = 0.000		LSD 5% = 5.223		LSD 5% = 3.245	
	10% = 4.070		10% = 0.000		10% = 4.288		10% = 2.665	
Pottawatomie County								
Fall 1980	63.5	47.9	3.0	5.3	7.1	15.6	0.0	0.0
Fall 1981	66.7	55.6	6.8	5.2	5.6	12.5	0.1	0.7
Change	+ 3.2	+ 7.7	+ 3.8	− 0.1	− 1.5	− 3.1	+ 0.1	+ 0.7
	LSD 5% = 8.465		LSD 5% = 5.631		LSD 5% = 5.901		LSD 5% = 1.107	
	10% = 6.986		10% = 4.647		10% = 4.870		10% = 0.914	

[1]Least significant differences ($P<.05$, $P<.10$) refer only to change in grasses according to season of growth and life span.

Table 8. Changes in selected grasses at the Geary County site, fall of 1980 and fall of 1981, following aerial application of 2 kg/ha tebuthiuron.

	Treated	Untreated
Scribner panicum (%)		
Fall 1980	0.8	0.1
Fall 1981	0.1	0.5
Change	- 0.7	+ 0.4
	LSD 5% = 1.151[1]	
	10% = 0.950	
Sedges[2] (%)		
Fall 1980	3.7	0.1
Fall 1981	2.0	1.0
Change	- 1.7	+ 0.9
	LSD 5% = 2.658	
	10% = 2.193	
Japanese brome (%)		
Fall 1980	15.2	0.4
Fall 1981	3.3	0.2
Change	-11.9	- 0.2
	LSD 5% = 6.595	
	10% = 5.144	

	Treated	Untreated
Yellow bristlegrass (%)		
Fall 1980	1.8	0.0
Fall 1981	5.8	0.0
Change	+ 4.0	0.0
	LSD 5% = 4.225	
	10% = 3.505	
Green bristlegrass (%)		
Fall 1980	2.7	0.0
Fall 1981	8.0	0.0
Change	+ 5.3	0.0
	LSD 5% = 5.568	
	10% = 4.619	

[1]Least significant differences (P<.05, P<.10) refer only to change in grasses.

[2]Grass-like plant.

Table 9. Changes in grass and forb production and accumulated litter at the Pottawatomie County site, fall of 1980 and fall of 1981, following aerial application of 2 kg/ha tebuthiuron.

	Grass (kg/ha)		Litter (kg/ha)		Forb (kg/ha)	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
Fall 1980	2580	1445	964	1379	267	709
Fall 1981	2374	1754	3095	3510	195	213
Change	- 206	+ 309	+2131	+2131	- 72	- 496
	LSD 5% = 2850[1]		LSD 5% = 1487		LSD 5% = 365	
	10% = 2352		10% = 1227		10% = 302	

[1]Least significant differences ($P<.05$, $P<.10$) refer only to change in grass and forb production and accumulated litter

LITERATURE CITED

Baker, B.J., D.E. Robinson, W.E. Russell and R.W. Willemsem. 1980. Rangeland and brush control in Kansas and Missouri with tebuthiuron. North Central Weed Control Conference. 35:128.

Biondini, M. and R.D. Pettit. 1979. Quality of sandyland forages improved with graslan. Nox. Brush Weed Contr. Res. Highlights. 10:30.

Biondini, M. and R.D. Pettit. 1980. Graslan increases digestibility of forages on sandy soils. Nox. Brush Weed Contr. Res. Highlights. 11:59.

Britton, C.M., and F.A. Sneva. 1981. Effects of tebuthiuron on western juniper (Juniperus occidentalis subsp. occidentalis) control. J Range Manage. 34:30-32.

Foth, H.D., L.V. Withee, H.S. Jacobs, and S.J. Thien. 1976. Laboratory manual for introductory soil science. Laboratory Exercises. Pages 12-13. Wm.C. Brown Company Publishers, Dubuque, Iowa.

Owensby, C.E. 1973. Modified step-point system for botanical composition and basal cover estimates. J. Range Manage. 26:302-303.

Scifres, C.J. and J.L. Mutz. 1978. Herbaceous vegetation changes following applications of tebuthiuron for brush control. J. Range Manage. 31:375-378.

Scifres, C.J., J.W. Stuth, D.R. Kirby and R.F. Angell. 1981. Forage and livestock production following oak control with tebuthiuron. Weed Sci. 29:535-539.

Shroyer, J.P., J.F. Stritzke, and L.I. Croy. 1979. Carbohydrate levels and control of blackjack oak and winged elm treated with tebuthiuron and 2,4,5-T. J. Range Manage. 32:60-62.

LITERATURE REVIEW

Tebuthiuron is a member of the substituted urea family of herbicides. It differs from most of the substituted urea herbicides in that it has a thiadiazol group substituted in place of the phenyl group (Figure 1).

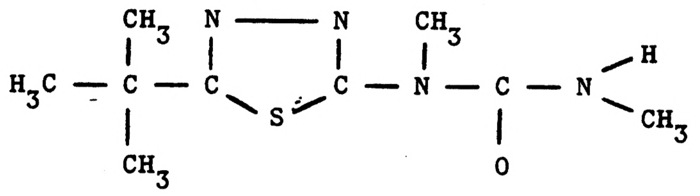

Figure 1. Chemical Structure of Tebuthiuron

Tebuthiuron with a water solubility of 2500 ppm at 25°C is one of the most water soluble urea herbicides. Only fenuron (3-phenyl-1,1-dimethylurea) with a solubility of 3850 ppm is more water soluble.

UPTAKE AND TRANSLOCATION

Uptake of substituted urea herbicides is by the root when soil applied and translocated through the plant by way of the xylem. Haun and Peterson (1954) using ^{14}C-labeled monuron (3-[p-chlorophenyl]-1,1-dimethylurea) on several species found that absorption by roots was rapid. Leonard et al. (1966) observed that ^{14}C-labeled diuron (3-[3,4-dichlorophenyl]-1,1-dimethylurea) was mobile only in the xylem or cell walls of grapes[1], with a rapid movement of diuron occurring from the roots to the shoots following root absorption.

Information on uptake and translocation of tebuthiuron is limited, but thought to be similar to the other substituted urea herbicides. Baur and Bovey (1975) reported tebuthiuron applied to the basal hypocotyl of cowpea seedlings was much more effective in inhibiting growth than were applications to one unifoliate leaf. Their studies also showed that tebuthiuron translocation is limited to the nonliving tissue of the plant. Research on western ragweed and rye (Steinert and Stitzke 1977) showed some uptake and translocation of tebuthiuron after a foliar application, but activity was primarily due to root uptake and translocation via the apoplast system.

Various studies on control of woody species have demonstrated the need for tebuthiuron to be available to the roots. Meyer and Bovey (1980b) found that tebuthiuron applied in rows 6 m apart failed to reduce the canopy cover of huisache. Apparently root systems of plants growing between the rows failed to absorb lethal amounts of herbicide. Sosebee (1978) found that the effectiveness of tebuthiuron depended on sufficient rainfall following application to dissolve the herbicide pellet and allow

1 Common and scientific names of all plant species are listed in Appendix, Table 5.

it to penetrate into the root zone. Scifres et al. (1979) reported honey mesquite treated with tebuthiuron defoliated after each rainfall and refoliated as the soils dried.

MODE - OF - ACTION

Urea herbicides are generally regarded as being translocated in the xylem to the leaves where they exert their effect by inhibiting photosynthesis (Bayer and Yamaguchi 1965). Photosynthesis involves two light reactions, photosystem I and photosystem II. Urea herbicides may affect both; however, the primary site of action appears to be photosystem II at or near the oxygen evolving step. Damage to the plant is probably a result of either starvation caused by a lack of photosynthate or due to a secondary phytotoxic substance formed in the oxygen-liberating pathway of photosynthesis (Ashton and Crafts 1981). Shroyer et al. (1979) found reduced total nonstructural carbohydrate (TNC) levels in roots of plants treated with tebuthiuron. Winged elm roots in areas treated with tebuthiuron in February averaged 7% TNC on October 13, compared to 32% TNC for unteated trees. Treated blackjack oak roots contained 6% TNC in October and untreated plant roots contained 35% TNC. A comparison of TNC in roots of either species one year after treatment was not possible because all trees treated with tebuthiuron were dead.

ACTIVITY IN SOILS

Tebuthiuron will remain on the soil surface with little or no apparent loss in activity until a sufficient amount of rainfall occurs for it to penetrate the root zone (Sosebee 1978). Perkins et al. (1976) reported that tebuthiuron applied to a clay soil has a half-life of 12 to 15 months. A study to determine persistence of tebuthiuron indicated a gradual loss regardless of treatment rate. Fourteen months after application there was 8 to 12% of the total amount applied still present with a 9.0 kg/ha treatment, 5 to 15% with a 4.5 kg/ha treatment, and 2 to 11% with a 2.2 kg/ha treatment. The greatest concentrations were retained by soil layers high in organic matter and clay content. A study by Chang (1975) showed that the highest amount of tebuthiuron residue was found where the herbicide was applied, with no significant runoff down slope. Bovey et al. (1982) reported that detectable tebuthiuron residues persisted for over 2 years in soils of the Claypan Resource Area of Texas. Concentrations from aerial applications were generally higher in plots treated with 4.4 kg/ha than 2.2 kg/ha with no consistent differences in tebuthiuron content occurring between soil depths of 0 to 15 or 15 to 30 cm.

Adsorption is the most important factor by which herbicides become unavailable in the soil (Wood 1977). Tebuthiuron adsorption increases and herbicide effectiveness decreases as organic matter, cation exchange capacity, and clay content increase. Adsorption may be less affected by cation exchange capacity than by clay content or organic matter. No correlation exists between adsorption and pH (Chang 1975, Fischer and

Stritzke 1978). Chang (1975) also found that soils with the greatest amount of herbicide adsorption showed the least amount of desorption.

Fischer and Stritzke (1978) found that tebuthiuron applied to a soil containing 12.5% clay killed 98% of the oaks present. Using the same application on a soil containing 60% clay none of the oaks were killed. They estimated that when clay content increases from 15 to 30% the rate of tebuthiuron must be doubled to get comparable results.

BRUSH CONTROL

Baker et al. (1980) demonstrated the effectiveness of tebuthiuron as a brush control herbicide in Kansas. Under an experimental use permit tebuthiuron was aerially applied in the fall to mixed brush plots in Kansas and Missouri. The treatments ranged from 1.7 to 4.5 kg/ha using 10% tebuthiuron pellets on 4.1-ha plots. Three years after application, tebuthiuron applied at rates of 2.2 kg/ha or more, killed 100% of oaks, roughleaf dogwood, elms, redbud, hickories, black cherry and hawthorn at all locations.

Scifres et al. (1981a) reported that tebuthiuron was effective in controlling post oak and blackjack oak in Texas Post Oak Savanah. The study area originally supported 2320 live woody plants per hectare with a total canopy cover of 43%. Aerially applied tebuthiuron at 2.2 kg/ha reduced the canopy of the oaks by 90% within four months after application with total canopy removal after 14 months. The site was dominated by post oak and blackjack oak, with an understory of yaupon, winged elm, gum bumelia, buckbrush, water oak, willow baccharis, downy hawthorn, saw greenbriar, American beautyberry, honey locust, persimmon, cedar elm, southern dewberry, eastern redcedar and occasionally honey mesquite, Texas persimmon and granjeno plants.

Response of winged elm, water oak, gum bumelia and cedar elm to tebuthiuron application was similar to the response of post and blackjack oak (Scifres et al. 1981a). Willow baccharis, yaupon and downy hawthorn were controlled but at a slower rate. A time period of 36 months was required for a 90% or greater canopy reduction. Canopy reduction initially occurred on buckbrush, persimmon, honey locust, southern dewberry and black hickory; however, after 36 months all species had either recovered or showed less than 50% canopy reduction. Eastern redcedar, honey mesquite and Texas persimmon were not effectively controlled. Growth of American beautyberry and saw greenbriar increased following tebuthiuron application and was attributed to a reduction in competition for sunlight, since the increase occurred particularly in areas previously dominated by oak and yaupon species.

Studies with mixed brush stands in southern Texas were conducted to evaluate tebuthiuron applied at 1.1, 2.2, 3.4, and 4.5 kg/ha on sites dominated by honey mesquite, guayacan, huisache and whitebrush (Scifres et al. 1979). Honey mesquite and guayacan both showed an increase in canopy reduction as tebuthiuron rates increased. Neither species was controlled after 3 years when tebuthiuron was applied at 1.1 or 2.2 kg/ha. Tebuthiuron killed 16% of the honey mesquite and 37% of the guayacan at 3.4 kg/ha rate and killed 37% of the honey mesquite and 55% of the guayacan at the 4.5 kg/ha rate. Tebuthiuron at 3.4 kg/ha killed 66% of the huisache and 100% of the whitebrush 3 years later. Understory vegetation species that were effectively controlled by tebuthiuron applications were spiny hackberry and Berlandier wolfberry. Only partial control of lotebush, blackbrush acacia, ceniza, Texas colubrina, javalina bush, quajillo, quayacan, desert yaupon and twisted acacia was obtained, and essentially no control of pricklyash, Texas persimmon, pricklypear and tasajillo was obtained.

Britton and Sneva (1981) studied tebuthiuron's effects on western juniper in eastern Oregon. Tebuthiuron when aerially applied at 2 and 4 kg/ha dessicated crowns but did not effectively control western juniper. Aerial applications at the 2 and 4 kg/ha rates effectively controlled the understory vegetation species such as low sagebrush, green rabbitbrush and big sagebrush. Tebuthiuron treatments at 20 or 40 grams per plant killed 80% or more of the western junipers less than 2 m in height.

HERBICIDE COMPARISON

Comparisons of herbicides on several oak species consistently showed tebuthiuron to be the most effective. Karbutilate, picloram and tebuthiuron applied at 9.0 kg/ha effectively controlled blackjack and post oak but tebuthiuron was equally effective at 2.2 kg/ha (Meyer et al. 1978). Bromacil was slightly less effective on post oak, and dicamba essentially had no effect. Live oak control with tebuthiuron treatments was variable but was generally greater than control with other herbicides (Meyer and Bovey 1980a). Karbutilate and tebuthiuron were equally effective in controlling live oak at 4.5 kg/ha and both herbicides afforded greater control than either bromacil or picloram applied at the same rate. In another study Meyer and Bovey (1980b) reported hexazinone and tebuthiuron applied at 1.1 kg/ha were equally effective for live oak control. Shroyer et al. (1979) reported greater defoliation and control of live oak with tebuthiuron than with 2,4,5-T. Pettit (1979) reported comparable control of sand shinnery oak with either 1.0 kg/ha tebuthiuron or 2.0 kg/ha picloram.

Meyer et al. (1978) compared the effectiveness of herbicides on species associated with oak communities. Most herbicides reduced canopy on yaupon, but tebuthiuron and picloram were most effective at 4.5 kg/ha in controlling the plants. Bromacil and karbutilate controlled slightly fewer species and dicamba was least effective. The same study showed the most effective treatments for tree huckleberry were picloram alone at 4.5 kg/ha or mixtures of picloram and tebuthiuron. Winged elm and white ash were effectively controlled only by tebuthiuron at 2.2 and 4.5 kg/ha, respectively. Percent control for both species was reduced when picloram was added to tebuthiuron.

Karbutilate and tebuthiuron effectively controlled honey mesquite at rates of 9.0 kg/ha, reducing the canopy 98% and controlling 95% of the plants (Meyer and Bovey 1979). Subsurface application of karbutilate and tebuthiuron at 4.5 kg/ha and prometone at 9.0 kg/ha also reduced honey mesquite canopy and controlled some plants. Bromacil, diuron, picloram, or 2,3,6-TBA applied or injected into the soil were not effective for honey mesquite control. In a comparison of the same herbicides on Macartney rose, only picloram and tebuthiuron were effective. Subsurface applications of picloram at 4.5 kg/ha and tebuthiuron at 2.2 and 4.5 kg/ha killed a significant number of plants. Tebuthiuron applied as a soil surface spray was ineffective. Bromacil, diuron, karbutilate, prometon and 2,3,6-TBA all failed to control Macartney rose regardless of rate or placement.

Meyer and Bovey (1980b) compared bromacil, hexazine and tebuthiuron on huisache. The treatments that killed a significant number of huisache plants were subsurface sprays of bromacil and hexazinone at 9.0 kg/ha and tebuthiuron at 4.5 kg/ha. In another study Bovey and Meyer (1978) reported a 4.5 kg/ha application of prometone, tebuthiuron and bromacil controlled more huisache than other herbicides tested at the same rate. Picloram, prometone, karbutilate and diuron controlled 50% or more huisache with subsurface application at a rate of 9.0 kg/ha.

FORAGE QUALITY

Biondini and Pettit (1979) reported on several studies conducted to determine the effect of tebuthiuron applications on forage quality. Tebuthiuron applications increased crude protein content in treated little bluestem, purple threeawn, sand dropseed and red lovegrass. Phosphorous content of grasses treated with tebuthiuron were slightly higher than in untreated plants. Forage water content was significantly increased by tebuthiuron treatments. Cell wall content was not affected. Twenty-four hour *in vitro* dry matter digestibility values for little bluestem were increased 20 to 25% after tebuthiuron application (Biondini and Pettit 1980). These results indicate that forages treated with tebuthiuron may be more palatable than untreated forages.

FORAGE PRODUCTION

Forage production has increased following tebuthiuron application. Seventeen months after treating whitebrush with 1 kg/ha tebuthiuron, the grass standing crop increased by 66% (Scifres and Mutz 1978). Following oak control with tebuthiuron the average dry weight of grasses on pastures treated with 2.2 kg/ha was almost four times that of untreated pastures (Scifres et al. 1981b). Pettit (1979) found grass yields to increase dramatically following treatment of sand shinnery oak. Removing the canopy and allowing forage species to compete for sunlight and moisture are the primary reasons for better production. Forage production increase is dependent on the susceptibility of the brush species to tebuthiuron treatment.

BASAL COVER

Scifres and Mutz (1978) found that after 3 years, tebuthiuron rates were reflected by an increase in basal cover of grasses. Where 1.12 kg/ha tebuthiuron was applied the basal cover was 17.2%, 18.4% where 2.24 kg/ha was applied, 17.8% where 3.36 kg/ha was applied, and 19.8% following application of 4.48 kg/ha. These values compared to 15.9% basal cover on untreated plots. Scifres et al. (1981a) found similar results 27 months after 2.2 and 4.4 kg/ha tebuthiuron was applied to oaks. Basal cover was greater on treated than untreated pastures; no difference was found between application rates. Spring application of tebuthiuron tended to reduce basal cover initially, with a favorable response the following growing season. Both studies (Scifres and Mutz 1978; Scifres et al. 1981a) showed bare ground decreased after tebuthiuron treatment. This was due primarily to increases in grass cover in response to brush control and increases in litter from leaf drop of herbicide affected woody plants.

BOTANICAL COMPOSITION

Grazing value rating of grasses after tebuthiuron application reflected changes in botonical composition (Scifres et al. 1981b). The year following application, composition of the grass stand relative to grazing value was unaffected by tebuthiuron. Two years and even more evident 3 years after application the proportion of grasses with good to excellent grazing values had increased. Good to excellent range grasses made up 9.5 to 15% of the total grasses prior to treatment near LaPryor, Texas (Scifres and Mutz 1978). Two years after treatment, they made up 22% of the grasses. Primary grasses to increase in the good to excellent category were little bluestem, multiflowered false rhodesgrass, bell rhodesgrass, hooded windmillgrass, plains bristlegrass, southwestern bristlegrass, Florida paspalum and sideoats grama.

Tebuthiuron treatment has also been used to reduce forbs. Western ragweed, common ragweed, Arkansas dozedaisy, Lindheimer croton, Texas croton, common dogwood, prairie peppergrass, common lantana and Lindheimer bladderpod were the most abundant forbs found on untreated plots near LaPryor, Texas (Scifres and Mutz 1978). Plots treated with 3.4 or 4.5 kg/ha tebuthiuron contained only Texas croton and Lindheimer bladderpod. Meyer and Baur (1979) reported tebuthiuron was an effective herbicide for controlling smutgrass. Broom snakeweed can be controlled with 0.56 kg/ha tebuthiuron on sandy soils and 1.12 kg/ha on loamy soils (Sosebee 1979).

LIVESTOCK RESPONSE

Scifres et al. (1981b) reported average daily gain (ADG) and total daily gain (TDG) in the fall of 1977 were greater on pastures aerially treated the previous spring with a 2.2 kg/ha tebuthiuron than on untreated pastures. Increased gains were attributed to improved forage quality since herbage production had not increased. During the summer of 1978 treated pastures averaged 51 grazing days/ha more than untreated pastures. The same study was repeated in the spring of 1978 with tebuthiuron aerially applied at 2.2 kg/ha and 4.4 kg/ha. In this study ADG and TDG were reduced on the pastures treated with 2.2 kg/ha and significantly reduced with the 4.4 kg/ha treatment. Available grazing days were also reduced with the higher rate. Two years after treatment, given time to recover from any initial forage injury, both studies showed improved ADG, TDG, and available grazing days after tebuthiuron application. Livestock responses are expected to be concomitant with changes in forage availability and quality relative to shifts in botanical composition.

LITERATURE CITED

Ashton, F.M. and A.S. Crafts. 1981. "Ureas" pp. 367-393 in Mode of Action of Herbicides. Wiley-Interscience Publications, New York.

Baker, B.J., D.E. Robinson, W.E. Russell and R.W. Willemsen. 1980. Rangeland and brush control in Kansas and Missouri with tebuthiuron. North Central Weed Control Conference. 35:128.

Baur, J.R. and R.W. Bovey. 1975. Herbicidal effects of tebuthiuron and glyphosate. Agron. J. 67:547-553.

Bayer, D.E. and S. Yamaguchi. 1965. Absorption and distribution of diuron-C^{14}. Weeds. 13:232-235.

Biondini, M. and R.D. Pettit. 1979. Quality of sandy land forages improved with graslan. Nox. Brush Weed Contr. Res. Highlights. 10:30.

Biondini, M. and R.D. Pettit. 1980. Graslan increases digestibility of forages on sandy soils. Nox. Brush Weed Contr. Res. Highlights 11:59.

Bovey, R.W. and R.E. Meyer. 1978. Control of huisache with soil applied herbicides. J. Range Manage. 31:179-181.

Bovey, R.W., R.E. Meyer, H. Hein, Sr. 1982. Soil persistence of tebuthiuron, the claypan resource area of Texas. Weed Sci. 30: 140-144.

Britton, C.M. and F.A. Sneva. 1981. Effects of tebuthiuron on western juniper (Juniperus occidentalis subsp. occidentalis) control. J. Range Manage. 34:30-32.

Chang, S.S. 1975. Adsorption, desorption, movement and dissipation of tebuthiuron in soils. Master Thesis, Oklahoma State University 41 pp.

Fischer, M.L. and J.F. Stritzke. 1978. Effects of various soil physical properties on phytotoxicity of tebuthiuron. Proc. South. Weed Sci. Soc. 31:204.

Haun, J.R. and J.H. Peterson. 1954. Translocation of 3-p-chlorophenyl)-1,1-dimethylurea in plants. Weeds. 3:177-187.

Leonard, O.A., L.A. Lider and R.K. Glenn. 1966. Absorption and translocation of herbicides by Thompson seedless (sultania) grape (Vitis vinifera L). Weed Res. 6:37-49.

Meyer, R.E. and J.R. Baur. 1979. Smutgrass (Sporobulus poiretii) control in pastures with herbicides. Weed Sci. 27:361-366.

Meyer, R.E., R.W. Bovey, and J.R. Baur. 1978. Control of an oak (Quercus)complex with herbicide granules. Weed Sci. 26:444-453.

Meyer, R.E., and R.W. Bovey. 1979. Control of honey mesquite (Prosopis julifora var. gladulosa) and macartney rose (Rose bracteata) with soil-applied herbicides. Weed Sci. 27:280-284.

Meyer, R.E., and R.W. Bovey. 1980a. Control of live oak (Quercus virginiana) and understory vegetation with soil-applied herbicides. Weed Sci. 28:51-58.

Meyer, R.E., and R.W. Bovey. 1980b. Hexazinone and other herbicides on Texas woody plants. Weed Sci. 28:358-362.

Perkins, A.T., G.B. Johnson, T.L. Gee, and D.J. Stroud. 1976. Tebuthiuron the total vegetation control herbicide-a progress report. Proc. North Cent. Weed Contr. Conf. 31:119-120.

Pettit, R. 1979. Effects of picloram and tebuthiuron pellets on sand shinnery oak communities. J. Range Manage. 32:196-200.

Scifres, C.J. and J.L. Mutz. 1978. Herbaceous vegetation changes following applications of tebuthiuron for brush control. J. Range Manage. 31:375-378.

Scifres, C.J., J.L. Mutz and W.T. Hamilton. 1979. Control of mixed brush with tebuthiuron. J. Range Manage. 32:155-158.

Scifres, C.J., J.W. Stuth, and R.W. Bovey. 1981a. Control of oaks (Quercus spp.) and associated woody species on rangeland with tebuthiuron. Weed Sci. 29: 270-275.

Scifres, C.J., J.W. Stuth, D.R. Kirby and R.F. Angell. 1981b. Forage and livestock production following oak control with tebuthiuron. Weed Sci. 29:535-539.

Shroyer, J.P., J.F. Stritzke, and L.I. Croy. 1979. Carbohydrate levels and control of blackjack oak and winged elm treated with tebuthiuron and 2,4,5-T. J. Range Manage. 32:60-62.

Sosebee, R.E. 1978. Mesquite control with tebuthiuron. Nox. Brush Weed Contr. Res. Highlights. 9:34-35.

Sosebee, R.E. 1979. Tebuthiuron continues to control broom snakeweed. Nox. Brush Weed Contr. Res. Highlights. 10:20.

Steinert, W.G. and J.F. Stritzke. 1977. Uptake and phytotoxicity of tebuthiuron. Weed Sci. 25:390-395.

Wood, P.A. 1977. "Herbicides and the Soil" pp. 171-200 in Weed Science Principles. West Publishing Company, St. Paul.

Appendix Table 1. Soil pH, organic matter, textural components and textural class of soil in the upper profile for each permanent line transect at the Geary County site.

Line Transect Number	pH	Organic Matter(%)	Textural Components Clay(%)	Silt(%)	Sand(%)	Textural Class
1	7.2	4.8	26.4	37.6	36.0	Clay loam
2	7.6	3.8	24.4	41.6	34.0	Loam
3	7.6	4.5	22.4	37.6	40.0	Loam
4	7.8	4.7	18.4	48.4	32.2	Loam
5	7.9	4.3	14.4	32.4	53.2	Sandy loam
6	7.8	4.5	20.4	44.4	35.2	Loam
7	7.1	4.8	34.4	42.4	23.2	Clay loam
8	7.8	3.6	24.4	31.6	44.0	Loam
9	7.5	4.5	24.4	27.6	48.0	Sandy loam
10	7.8	4.0	40.4	35.6	24.0	Clay

Appendix Table 2. Soil pH, organic matter, textural components and textural class of soil in the upper profile for each permanent line transect at the Cowley County site.

Line Transect Number	pH	Organic Matter(%)	Textural Components Clay(%)	Silt(%)	Sand(%)	Textural Class
1	6.3	4.8	30.4	29.6	40.0	Clay loam
2	6.4	4.8	28.4	30.4	41.2	Clay loam
3	6.2	4.3	28.4	36.4	35.2	Clay loam
4	6.4	4.5	32.4	28.4	39.2	Clay loam
5	6.2	4.8	36.4	34.4	29.2	Clay loam
6	7.0	4.4	28.4	31.6	40.0	Clay loam
7	6.3	4.6	26.4	36.2	37.4	Clay loam
8	7.0	4.5	34.4	34.8	30.8	Clay loam

Appendix Table 3. Soil pH, organic matter, textural components and textural class of soil in the upper profile for each permanent line transect at the Pottawatomie County site.

Line Transect Number	pH	Organic Matter(%)	Textural Components Clay(%)	Silt(%)	Sand(%)	Textural Class
1	6.9	4.8	38.4	29.6	32.0	Clay loam
2	7.5	4.0	36.4	23.6	40.0	Clay loam
3	7.6	4.1	30.4	35.6	34.0	Clay loam
4	7.1	4.5	34.4	31.6	34.0	Clay loam
5	7.3	4.8	36.4	29.6	34.0	Clay loam
6	6.8	4.5	26.4	33.6	40.0	Clay loam
7	7.5	5.8	22.4	30.8	46.8	Sandy clay loam
8	7.7	4.4	34.4	33.6	32.0	Clay loam
9	7.6	5.5	28.4	35.6	36.0	Clay loam
10	7.4	5.5	26.4	14.8	58.8	Sandy clay loam

Appendix Table 4. Monthly precipitation received and normal monthly precipitation at the nearest reporting stations to Geary (White City), Cowley (Dexter), and Pottawatomie (Tuttle Creek Lake) Counties.

	White City		Dexter		Tuttle Creek Lake	
	Monthly Precipitation(mm)		Monthly Precipitation(mm)		Monthly Precipitation(mm)	
	Received	Normal	Received	Normal	Received	Normal
Oct. 1979	134	56	49	67	172	66
Nov. 1979	35	3	125	39	36	31
Dec. 1979	4	60	17	29	1	32
Jan. 1980	32	32	31	24	0	24
Feb. 1980	17	17	47	27	27	24
March 1980	101	101	84	42	98	56
April 1980	26	26	101	92	33	85
May 1980	52	52	54	116	49	118
June 1980	30	30	38	128	74	155
July 1980	17	17	0	100	26	100
Aug. 1980	83	83	41	81	64	100
Sept. 1980	46	46	25	107	50	105
Oct. 1980	57	56	51	67	95	66
Nov. 1980	3	3	13	39	0	31
Dec. 1980	60	60	26	29	76	32
Jan. 1981	2	32	1	24	2	24
Feb. 1981	10	17	9	27	17	24
March 1981	61	101	32	42	32	56
April 1981	35	26	38	92	40	85
May 1981	174	52	257	116	137	118
June 1981	244	30	106	128	178	155
July 1981	117	17	113	100	109	100
Aug. 1981	69	83	113	81	67	100
Sept. 1981	72	46	40	107	42	105
Oct. 1981	46	56	108	67	57	66

Appendix Table 5. Common and scientific names of plants.

Common Name	Scientiric Name
Grasses	
Bell rhodesgrass	Chloris gayana
Florida paspalum	Paspalum floridanum
Hooded windmillgrass	Chloris cucullata
Little bluestem	Andropogon scoparius
Long-spike silver bluestem	Bothriochloa saccharoides
Multiflowered false rhodesgrass	Chloris pluriflora
Plains bristlegrass	Setaria leucopila
Purple threeawn	Aristida purpurea
Red lovegrass	Erogrostis oxylepis
Sand dropseed	Sporobolus cryptandrus
Sideoats grama	Bouteloua curtipendula
Smutgrass	Sporobolus cryptandrus
Southwestern bristlegrass	Setaria scheeki
Forbs	
Arkansas dozedaisy	Aphanostephus skirrhobasis
Broom snakeweed	Gutierrezia sarothrae
Common dogwood	Dyssodia pentachaeta
Common lantana	Lantana lorrida
Common ragweed	Ambrosia artemisifolia
Cowpea	Vigna unguiculata
Lindheimer bladderpod	Lesquerella lindheimeri
Lindheimer croton	Croton gladulosa var. lindheimer
Prairie peppergrass	Lepidium densiflorum
Texas croton	Croton texenis
Western ragweed	Ambrosia psilostachya

Brush and Trees

American beautyberry	Callicarpa americana
Berlandier wolfberry	Lycium berlandieri var. berlandieri
Big sagebrush	Artemisia tridentata
Blackbrush acacia	Acacia rigidula
Black cherry	Prunus serotina
Black hickory	Carya texana
Blackjack oak	Quercus marilandica
Buckbrush	Symphoricarpos orbiculatus
Cedar elm	Ulmus crassifolia
Ceniza	Leucophylum frutescens
Common persimmon	Diospyros virginiana
Desert yaupon	Schaefferia cunefolia
Downy hawthorn	Crataegus mollis
Eastern redcedar	Juniperus virginiana
Elms	Ulmus spp.
Green rabbitbrush	Chrysothamnus viscidiflorus
Quajillo	Acacia berlandieri
Guayacan	Porlieria angustifolia
Gum bumelia	Bumelia lanuginosa
Hawthorn	Crataegus crusgalli
Hickories	Carya spp.
Honeylocust	Gleditsia triacanthos
Honey mesquite	Prosopis glandulosa var. glandulosa
Huisache	Acacia farnesiana
Javalin bush	Microchamnus ericoides
Lime pricklyash	Zanthoxylum fagara
Live oak	Quercus virginiana
Lotebrush	Condalia obtusifolia
Low sagebrush	Artemisia arbuscula
Macartney rose	Rosa bracteata
Oaks	Quercus spp.
Post oaks	Quercus stellata
Pricklypear	Optunia spp.
Redbud	Cercis canadensis

Roughleaf dogwood	Cornus drummondi
Sand shinnery oak	Quercus havardii
Saw greenbriar	Smilax bona-nox
Southern dewberry	Rubus trivalis
Spiny hackberry	Celtis pallida
Tasajillo	Optunia leptocaulis
Texas colubrina	Colubrina texensis
Texas persimmon	Diospyros texana
Tree huckleberry	Vaccinum arboreum
Twisted acacia	Acacia tortuosa
Water oak	Quercus nigra
Western juniper	Juniperus occidentalis subsp. occidentalis
White brush	Aloysia lycioides
Willow baccharis	Baccharis salicina
Winged elm	Ulmus alata
Yaupon	Ilex vomitoria

BRUSH CONTROL AND ASSOCIATED BOTANICAL CHANGES FOLLOWING TEBUTHIURON APPLICATION IN KANSAS

by

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B. S., Kansas State University, 1979

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

The purpose of the study was to determine brush control and associated botanical changes following tebuthiuron application in Kansas. Tebuthiuron was aerially applied to 4 ha plots in Geary, Pottawatomie and Cowley counties at a rate of 2 kg/ha during December, 1979. Permanent line transects 25-m in length were randomly placed on the treated and an adjacent untreated site. Canopy cover, density and botanical composition were determined 10 and 22 months after application. Canopy cover was a measure of the vertical projection of the canopy on the permanent line transect. Density was measured using belt transects, 30 cm x 25 m for shrub species and 2 m x 25 m for trees, placed along the permanent line transects. Botanical composition was determined from points taken along the permanent line transect using the modified step-point system.

The 2 kg/ha tebuthiuron rate used in this study in conjunction with low rainfall was not adequate for complete control of species evaluated. Tebuthiuron applied at 2 kg/ha showed at least partial control of buckbrush (*Symphoricarpos orbiculatus*), aromatic sumac (*Rhus aromatica*) and chinquapin oak (*Quercus muhlenbergia*), and reduced the canopies of smooth sumac (*Rhus glabra*) and eastern redbud (*Cercis canadensis*). Leadplant (*Amorpha canescens*) density increased following tebuthiuron application. Dwarf chinquapin (*Quercus prinoides*), roughleaf dogwood (*Cornus drummondi*), black walnut (*Juglans nigra*), eastern cottonwood (*Populus deltoides*), bur oak (*Quercus macrocarpa*) and siberian elm (*Ulmus pumila*) were not affected by 2 kg/ha tebuthiuron application. Since associated botanical changes were concomittant to degree of brush control, and only partial control occurred, botanical changes were minimal.