CHEMICAL CONTROL OF ROUGH-LEAVED DOGWOOD

by

GLENN EDWARD BRUNKOW

B.S, Kansas State University, 1993

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Agronomy
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2009

Approved by:

Major Professor
Dr. Walter H. Fick

Copyright

GLENN E. BRUNKOW

2009

Abstract

Rough-leaved dogwood (*Cornus drummondii* Meyer) is one of the most invasive woody plants in rangeland of Kansas. Reduced prescribed burning due to drought and urban encroachment probably has contributed to its spread. Herbicides are commonly recommended for control of rough-leaved dogwood, but minimal data exists for recommendation development. Ten herbicide treatments were applied in June during late flowering at two locations in northeast Kansas in 2005 and 2006. Each treatment was replicated three times in a randomized complete block design with individual plot sizes of 3 x 3 m. Herbicides were applied with hand sprayers in 1017 L/ha solution. Visual evaluations of defoliation were made about 1 and 12 months after treatment (MAT) and mortality was estimated about 1 year after treatment (YAT). Defoliation 1 MAT varied among herbicides with significant location by year and herbicide by year interactions. Treatments providing greater than 70% defoliation 12 MAT both years were triclopyr + 2,4-D (1.12 + 1.06 kg ae/ha), triclopyr + fluroxypyr (1.83 + 0.61 kg ae/ha), picloram + fluroxypyr (0.41 + 0.41 and 0.82 + 0.82 kg ae/ha), and picloram + 2,4-D + triclopyr (0.66 + 2.44 + 2.44 kg ae/ha). Rough-leaved dogwood is difficult to control with a single herbicide application, but treatments exist that will substantially reduce stands. Tebuthiuron pellets (Spike 20P) are another control measure recommended for rough-leaved dogwood. Treatments of 4.4 kg ai/ha (3/4 oz per 100 square feet) tebuthiuron pellets were applied in December 2004. A visual estimate of control indicated tebuthiuron reduced dogwood cover by 65% compared to a 3% decrease on untreated plots. Dogwood density was reduced by 2.2 stems/m^2 ($P<0.08$). Total woody plant cover increased on untreated plots by 6.2 percentage units, but was decreased by 20.9 percentage units on tebuthiuron treated plots. Other woody plants decreased in both treated and untreated plots. Shading by a large elm tree likely caused variation between replications including increases in cover and density of rough-leaved dogwood on treated plots. Tebuthiuron is a photosynthetic inhibitor that often is not effective on shaded plants. Tebuthiuron pellets applied at 4.4 kg ai/ha was an effective control option for unshaded rough-leaved dogwood.

Table of Contents

List of Tables

Acknowledgements

I would like to thank Dr. Walt Fick for his support over this extended masters process. His support and understanding is greatly appreciated and I would never have completed this degree without his guidance. I would also like to thank Dr. Scott Staggenborg and Dr. Dallas Peterson for agreeing to serve on my committee and the guidance they provided.

A big thank you needs to go out to the Executive Board of the Pottawatomie County Extension Council for their support of my pursuit of this degree, and Dr. Dale Fjell for his support. I could not have completed this without the understanding of my fellow co-workers in Pottawatomie County, Della Sass, Barb Rickstrew and Jill Deters and for that I am very appreciative.

Finally, I owe a huge debt of gratitude to my family. It was with my wife, Jennifer's encouragement and support that I began my pursuit of this degree. Jennifer, Isaac and Tatum picked up the slack for me during the past six years and they are the reason I finished this process. I owe them everything.

.

CHAPTER 1 - Literature Review

Brush and the Prairie Ecosystem

The prairie ecosystem is one that is always in a state of flux. Climate, grazing, and fire influence the plant communities that exist on prairies. Fire is an important factor in maintaining bluestem prairie and for preventing the encroachment of first woody shrubs and then trees into this delicate ecosystem (Bragg and Hulbert 1976). Natural fire frequencies in the grasslands of the Great Plains are unknown, but fire may have occurred every 5 to 10 years (Wright and Bailey 1982). A 4-year burning frequency maintains grass-dominated prairies with few woody species (Gibson 1988). The lack of trees and frequent fire could have resulted in fewer roosts and cover for birds and other species, thus reducing the spread of woody plant seed. Drought, and more importantly urban encroachment, have made the use of fire very difficult. Increasingly brushy invading species have had to be dealt with using chemicals. One such invasive woody shrub is rough-leaved dogwood *(Cornus drummondii* Meyer).

Rough-Leaved Dogwood

Rough-leaved dogwood is found throughout the eastern two-thirds of Kansas. Typical habitats include: along fence rows, at the edge of woods, on stream banks, and in open prairies on dry, somewhat rocky soil. Dogwood thickets resemble those of the plum (*Prunus americana* Marsh.), but the plum thicket is more dense and the branches are purplish (Stephens 1969). Prolific resprouting from a widespread lateral root system results in dense thickets of rough-leaved dogwood. Encroachment by the shrub results in reduced production and availability of desirable forage for livestock grazing (Janicke and Fick 1998). Dogwood is an aggressive species that invades grasslands, especially in the northern Flint Hills (Bragg and Hulbert 1976).

Rough-leaved dogwood is considered a large shrub or small tree. The Kansas record in Doniphan County was a basal circumference of 45.7 cm (Stephens and Boyd 1967).

Rough-leaved dogwood has simple, opposite, deciduous, egg-shaped leaves. The plant flowers in May and June with clusters of white flowers. It produces fruit in September and October. The fruit are white, globular and very attractive to wildlife as food. Twigs are brown or reddish-gray and are often red when young. The trunk has bark that is gray-brown and wood that is hard and white.

Total nonstructural carbohydrates (TNC) are useful in determining when herbicides would be most useful. The low point in the TNC cycle for rough-leaved dogwood occurs at the full-leaf stage and/or early flowering stage of development (Janicke 1985a). Thereafter TNC increases steadily through floral development. Herbicide treatments are usually thought to be most effective when TNC are being most actively transferred into the roots. Dogwood that had been burned in the spring had a much longer period of low carbohydrate reserves (Janicke and Fick 1998). Stites (1985b), indicated the best time to control blackberry (*Rubus* spp.) was when the leaves were fully expanded but shoot elongation had not ceased. Early growth patterns in blackberry result in a decrease in TNC in the roots which would hinder downward translocation of herbicides. An increase in the downward movement of TNC was noted to occur between the full- leaf stage and flowering thus increasing the downward translocation of herbicide (Stites, 1985a).

Two other species of dogwood are found in Kansas. Flowering dogwood [*Cornus florida* (L.) Raf.] is found in extreme southeastern Kansas and swamp dogwood [*Cornus amomum* Mill., subsp. *obliqua* (Raf.) J. S. Wilson] is found on wet rocky soils in the eastern one third of Kansas. However, neither species commonly occur in prairie ecosystems and therefore not thought to be a threat.

Woody Species Control Through Fire

Periodic fire is necessary in order to preserve and maintain prairie ecosystems. In the absence of fire, woody species such as rough-leaved dogwood, Eastern redcedar (*Juniperus virginiana* L.), and American elm (*Ulmus americana* L.) invade (Towne and Owensby 1984). Prairie fire even at a 4-year frequency, is enough to suppress the incursion of woody plants (Gibson 1988), such as rough-leaved dogwood. In the absence of fire, colonies or “islands” of dogwood develop. Dogwood is a large enough plant that it often grows taller than native grasses and creates a canopy. This canopy reduces light penetration, thus suppressing the growth of native warm-season grasses and often causing them to disappear under the shade. Fire has a depressing effect on the development of these large colonies or “islands” of dogwood. This is done through the removal of top growth, causing up to 100% mortality to the existing above ground stems. However, the effect of fire on species such as rough-leaved dogwood may be variable. Existing above ground stems may be destroyed but resprouting can occur. Ngakane (1997) indicated greater rough-leaved dogwood stem densities the year of burn compared to unburned watersheds. Heisler et al. (2004) documented an increase of over 260% in new shoots following fire when compared to unburned areas. This can result in a reduction of grasses by 30% when compared to unburned colonies.

Fire alone is thought to be relatively ineffective for conrol of established dogwood. This is mainly due to the fact that most prescribed burns do not occur during a time of low carbohydrate reserves. It has been found that burning does shift the period of low carbohydrate reserve 30 to 60 days later in the season (Janicke and Fick 1998). This information may be useful to combine burning with herbicides to more effectively control dogwood.

Woody Species Control With Picloram

Picloram is a widely used restricted-use pesticide for the treatment of brush in rangelands. A foliar treatment containing picloram, 2,4-D, and triclopyr is recommended for the control of rough-leaved dogwood in Kansas (Thompson et al. 2009). Janicke (1985b), reported poor results in the reduction of dogwood canopy 14 months following treatment with picloram and 2,4-D. Canopy reduction was found to be 72% at 2 months and only 40% at 14 months after treatment. It was also noted that picloram treatments were more effective when applied in open areas with direct sunlight. Picloram (0.6 kg/ha) was found to be more effective in the control of blackberry canes when applied later in the growing season, June 9 versus May 15, with a reduction in live canes of 50 and 94%, respectively at 3 months post-treatment (Stites 1985b). This advantage was maintained 15 months post-treatment with the June 9 treatment resulting in an 85% reduction in live canes versus a 50% reduction for the May 15 treatment.

Woody Species Control With Triclopyr

Triclopyr is commonly used in tank mixes used to control brushy species in grasslands. Foliar tank mixes of triclopyr, 2,4-D, and picloram are commonly recommended by Kansas State University (Thompson et al. (2009).

Janicke (1985b) noted a rough-leaved dogwood canopy reduction of 88% with triclopyr used alone or with 2,4-D, when evaluated 14 months after treatment. Jacoby and Meadors (1983) studied triclopyr both in amine and ester formulations and tank mixes including 2,4-D, 2,4,5-T, dicamba and picloram to control honey mesquite (*Prosopis glandulosa* Torr.) in Texas. Triclopyr was at least as effective at defoliating and killing honey mesquite trees in all locations as the tank mix of picloram and 2,4,5-T, and more effective than 2,4,5-T by itself in most of the locations (Jacoby and Meadors 1983). Blackberry brambles are similar to rough-leaved dogwood in that they easily spread and are difficult to control with herbicide. Good control of blackberry brambles was reported regardless of treatment date (May 15 versus June 9) at a rate of 4.4 kg/ ha triclopyr with control reported at 94% reduction in live canes 3 months post treatment for both dates and 85% 15 months post-treatment for both dates (Stites, 1985b).

Woody Species Control With Dicamba

Dicamba is recommended for suppression of rough-leaved dogwood. Initially, dicamba plus 2,4-D was used as a replacement for 2,4,5-T and currently listed in Kansas recommendations (Thompson et al., 2009). Janicke (1985b) reported canopy reductions of 50 to 78% on rough-leaved dogwood 14 months after treatment. It was also noted that dicamba treatments seemed to be more effective in open areas with more direct sunlight.

Blackberries are spreading woody shrubs that are hard to kill. Dicamba and 2,4-D was found to be much more effective for blackberry control when applied early in the growing season providing 78% reduction in live canes when applied on May 15 versus a 23% reduction when applied on June 9 (Stites, 1985b).

Woody Species Control With 2,4-D

One of the oldest chemical brush control products still available is 2,4-D. It is recommended as a tank mix with most other herbicies used for rough-leaved dogwood (Thompson et al., 2009). including mixes with dicamba, triclopyr, or picloram. Janicke (1985b), reported canopy reduction of 88% with 2,4-D when mixed with triclopyr, 52% when mixed with dicamba, and 40% when mixed with picloram. Alone, 2,4-D was ineffective to control blackberry canes regardless of the timing of the application, with a live cane reduction of only 6% (Stites 1985b).

Woody Species Control With Tebuthiuron

Tebuthiuron has been in use as a method of brush control since the1970s. Tebuthiuron as a 20% pellet is recommended for control of buckbrush (*Symphoricarpos orbiculatus* Moench), cottonwood (*Populus deltoides* Marsh.), dogwood, elm (*Ulmus spp.*), multiflora rose (*Rosa multiflora* Thunb.), oaks (*Quercus* spp.), smooth sumac (*Rhus glabra* L.), and willow (*Salix* spp.) in Kansas (Thompson et al., 2009). It is to be applied evenly over the area occupied by the target woody species.

Jacoby and Meadors (1982), applied tebuthiuron as 5 or 20% ai pellets and picloram as 5 or 10% ai pellets for control of sand shinnery oak (*Querus havardii* Rydb.). This is a deciduous woody shrub in northwest Texas, eastern New Mexico and western Oklahoma. Herbicides were applied at rates of 0.6, 1.1 and 2.2 kg/ha at each of four locations in Texas. Pelleted herbicides were applied in January at two locations, March at one location, and in April at the fourth location. The plants were visually evaluated at different periods to determine mortality. Plants that did not display regrowth were determined to be dead. Mortality for the picloram treatments varied greatly between rates and sites. In general, there was no statistical difference between the 5 and 10% formulations. Mortality generally increased as rate increased. Sand shinnery oak mortality varied from 39 to 92%. Sand shinery oak mortality was 79 and 99% for the 1.1 and 2.2 kg/ha tebuthiruron treatments, respectively. Control was noted to last 5 years in the tebuthiuron treatment and 2 years for the picloram treatments.

Tebuthiuron has been used to treat mixed brush, but with varying degrees of success. Scifres et al. (1979) aerially applied treatments of 20% ai tebuthiuron at four different rates. Success varied greatly depending on species. Plants that were defoliated and did not resprout were considered dead. The plots were treated in the fall and evaluated during the summer of the next 2 years. Honey mesquite, guayacan [*Porlieria angustifolia* (Engelm) A. Gray] and twisted acacia [*Acacia totuosa* (L.) Willd.] were found to have a high tolerance to tebuthiuron at all four rates. However, they did show more mortality at the two higher rates (mortality rates of < 50% for the two lower rates and > 50% for the two higher rates). Whitebrush (*Aloysia lycioides* Cham.), spiny hackberry (*Celtis pallida* Torr.) and desert yaupon (*Schaefferia cunefolia* Gray.) were more susceptible to tebuthiuron, with mortality generally being > 60% (Scifres et al. 1979).

Tebuthiuron has been used to control big sagebrush (*Artemisia tridentata* Nutt.) in the western United States and also to increase species diversity. Olson et al. (1994) noted a dramatic decrease in the amount of big sagebrush from 35% of the total vegetative composition in the untreated to 5% with the highest rate of tebuthiuron. At the same time, the composition of grasses increased with the increasing rates of tebuthiuron. Studies done in Kansas and Missouri where 2.2 kg/ha tebuthiuron were applied resulted in a sevenfold increase in forage yields (Baker et al., 1980). Composition shifts occurred following tebuthiuron applications in Kansas. Warm-season annuals including yellow [*Setaria lutescens* (Weigel) Hubb.] and green foxtail [*Setaria viridis* (L.) Beauv.] increased while the cool-season grasses Scribner's panicum [*Dicanthelium oligosanthes* (Schult.) Gould var. *scribnerianum* (Nash) Gould] and Japanese brome (*Bromus japonicus* Thunb. ex Murr.) decreased (Nolte and Fick 1992).

Tebuthiuron 20% pellets were aerially applied in 1977 to mixed brush plots in Missouri and Kansas. At rates greater than 2.2 kg/ha, mortality of 100% was achieved on oaks, buckbrush, rough-leaved dogwood, elms, redbud (*Cercis canadensis* L.), hickories (*Cary*a spp.), black cherry (*Prunus serotina* Ehrh.), and hawthorns (*Crataegus* spp.) (Baker et al. 1980). Woody plant response to tebuthiuron in northeast Kansas was different. Osage orange [*Maclura pomifera* (Raf.) Schneid.], honey locust (*Gleditsia triacanthos* L.), and Siberian elm (*Ulmus pumila* L.) all responded to lower rates than previously used. However, black walnut (*Juglans nigra* L.), bur oak (*Quercus macrocarpa* Michx.), and shagbark hickory [*Carya ovata* (Mill.) K. Koch] responded to higher rates than previously used (Ohlenbusch and Fick 1982). A study conducted in the northern Flinthills of Kansas concluded that rough-leaved dogwood was less susceptible than Siberian elm and smooth sumac to tebuthiuron (Nolte and Fick 1992).

CHAPTER 2 - Rough-Leaved Dogwood Control Using Foliar-Applied Herbicides

Abstract

Rough-leaved dogwood (*Cornus drummondii* Meyer) is one of the most invasive woody plants in rangeland of Kansas. Lack of prescribed burning due to drought and urban encroachment has contributed to its spread. Herbicides have commonly been recommended for control of rough-leaved dogwood, but minimal data exists for basing recommendations. Field experiments were conducted at two locations in 2005 and 2006 to evaluate dogwood control with 10 herbicide treatments applied during the late flowering stage of dogwood growth. Each treatment was replicated three times in a randomized complete block design with individual plot sizes of 3 x 3 m. Herbicides were applied with hand sprayers in 1017 L/ha solution. Visual evaluations of defoliation were made about 1 and 12 months after treatment (MAT) and mortality was estimated about 1 year after treatment (YAT). Defoliation 1 MAT varied among herbicides with significant location by year and herbicide by year interactions. Treatments providing greater than 70% defoliation 12 MAT both years were triclopyr + 2,4-D ester (1.12 + 1.06 kg ae/ha), triclopyr + fluroxypyr (1.83 + 0.61 kg ae/ha), picloram + fluroxypyr (0.41 + 0.41 and 0.82 + 0.82 kg ae/ha), and picloram + 2,4-D amine + triclopyr (0.66 + 2.44 + 2.44 kg ae/ha). Triclopyr used alone or in combination with 2,4-D ester resulted in less than 20% mortality of rough-leaved dogwood 1 YAT. Triclopyr in combination with fluroxypyr (1.83 + 0.61 kg ae/ha), picloram + 2,4-D amine + triclopyr (0.66 + 2.44 + 2.44 kg ae/ha), and picloram + fluroxypyr (0.41 + 0.41 kg and 0.82 +0.82 kg ae/ha) all provided greater than 50% mortality of rough-leaved dogwood 1 YAT. Rough-leaved dogwood is difficult to control with a single herbicide application, but treatments exist that will substantially reduce stands.

Introduction

Rough-leaved dogwood is a woody invader of the Kansas Flint Hills. It is known for dense woody thickets that can choke out grass and forbs and can reach heights of 2 to 6 m (Great Plains Flora Association 1986). It has white blooms and flowers for a period of 2 to 3 weeks in the late spring to early summer.

Frequent burning prevents woody plant invasion in the Kansas Flint Hills (Bragg and Hubert 1976). However, prescribed burning in April does not effectively control existing rough-leaved dogwood colonies. Lack of dogwood control at that time may be due to the fact that the low point in the nonstructural carbohydrate cycle occurs later in the season (Janicke and Fick 1998). Small, newly established plants can be suppressed by fire, but if fire is removed from the management program, larger, more established shrubs can survive. Because of urban encroachment and recent droughts limiting fire in the Flint Hills, rough-leaved dogwood has become more of a problem.

Herbicides are a commonly used tool for control and/or suppression of woody plants. Recently labeled herbicides, including products containing fluroxypyr, have not been tested specifically for dogwood control in Kansas. A high-volume rescue treatment was also looked at in this study. This treatment uses 100 gallons of herbicide per acre and is only used in areas of heavy dogwood infestation where fire is no longer effective. The objective of this study was to compare the efficacy of these new products against older and more commonly recommended herbicide treatments for control of rough-leaved dogwood.

Materials and Methods

Locations.

Two locations, one in Pottawatomie County, KS and one in Riley County, KS were selected for this study. The Pottawatomie County site is located at approximately 39°26'44.04" N, 96°27'04.21"W with an approximate elevation of 409 m above sea level. The soil was classified as a Clime silty clay loam, with 20 to 40% slopes, and stony (Horsch et al. 1987). These soils are moderately deep, steep, well-drained on upland breaks and side-slopes. Average yearly precipitation for the Pottawatomie County site is 89.7 cm per year (Knapp 2009).

The Riley County site is located approximately 39°13'45.38"N, 96°36'01.83"W with an approximate elevation of 366 m above sea level. The soil was classified as a Clime-Sogn complex, with 5 to 20% slopes. These soils are silty clay loam in texture, take water in slowly, and are subject to much run-off (Jantz et al. 1975). The Riley County site receives 81.5 cm of precipitation annually (Knapp, 2009).

Herbicide Treatments.

Herbicides tested in 2005 and 2006 at both locations are listed with their rates and cost in Table 2.1. Herbicides were applied using a hand-held sprayer at a spray volume of 1017 L/ha spray solution. Each plot was 3 by 3 m and treatments were randomly organized in three separate blocks at each of the two locations. Each block had 10 herbicide treatments and an untreated check. Application dates, stage of growth, and environmental conditions are listed in Table 2.2. Herbicide treatments were evaluated approximately 1 MAT (July 5, 2005 and August 1, 2006 in Pottawatomie County and July 13, 2005 and August 1, 2006 in Riley County) and approximately 1 YAT (June 9, 2006 and July 25, 2007 in Pottawatomie County and June 13, 2006 and August 1, 2007 in Riley County).

Statistical Analysis.

Data were analyzed as a modified split-split plot using analysis of variance. Location was considered as the whole plot with herbicide treatment and year as subplots. Means were separated by Fisher's Protected LSD Procedure at $P \leq 0.10$.

Results and Discussion

Defoliation 1 Month After Treatment.

A significant year by location interaction occurred. In 2005 the percent defoliation 1 MAT was greater in Riley than Pottawatomie County (Table 2.3). In 2006, control was similar at both locations. The Riley County location had better control in 2005 than 2006. This is probably due to the increased rainfall and better growing conditions in 2005 (Table 2.4). There was also a difference between years in Pottawatomie County, favoring 2006. Better defoliation occurred despite drier conditions in 2006 (Table 2.5).

A significant year by treatment interaction ($p<0.07$) occurred, but the only treatment that was different between the two years was triclopyr + fluroxypyr at 1.83 + 0.61 kg ae/ha (Table 2.6). It should be noted that triclopyr + fluroxypyr at the 0.91 + 0.30 kg ae/ha was not different between 2005 and 2006. The untreated plots as well as those treated with dicamba + 2,4-D amine (0.56 + 2.13 kg ae/ha) and picloram + 2,4-D amine (0.28 + 1.12 kg ae/ha) all were observed to have less than 50% defoliation and were statistically lower than most other treatments. These compounds may not burn the leaves off as quickly or be as effective at these rates on rough-leaved dogwood. In contrast, Janicke (1985b) measured greater than 60% canopy reduction of rough-leaved dogwood 2 MAT using dicamba + 2,4-D amine (0.56 + 2.13 kg ae/ha) and picloram + 2,4-D amine (0.28 + 1.12 kg ae/ha).

The only two treatments providing at least 70% defoliation 1 MAT both years were triclopyr + 2,4-D ester (1.22 + 2.44 kg ae/ha) and picloram + 2,4-D amine + triclopyr (0.66 + 2.44 + 2.44 kg ae/ha) (Table 2.6). Janicke (1985b) reported greater than 80% defoliation of rough-leaved dogwood 2 MAT using the same rate of triclopyr + 2,4-D ester 1.22 + 2.44 kg ae/ha. In 2006, triclopyr + fluroxypyr (1.83 + 0.61 kg ae/ha) and picloram + fluroxypyr (0.82 + 0.82 kg ae/ha) also provided greater than 70% defoliation of rough-leaved dogwood 1 MAT.

Defoliation 1 Year After Treatment.

Overall, herbicide treatments were more effective in 2005 than 2006, providing 76 and 62% defoliation, respectively (Table 2.7). However, a significant treatment by year interaction was caused by three treatments being different in 2006 compared with 2005. Dicamba + 2,4-D amine (0.56 + 2.13 kg ae/ha), triclopyr + fluroxypyr at the 0.91 +0.30 kg ae/ha rate, and picloram + 2,4-D amine (0.28 + 1.12 kg ae/ha) all were more effective in 2005. This may be due to a significant decrease in rainfall in 2006 limiting translocation of herbicide to the roots (Table 2.4 and 2.5). All treatments except dicamba + 2,4-D amine (0.56 + 2.13 kg ae/ha) and picloram + 2,4-D amine (0.28 + 1.12) in 2006 provided greater than 50% defoliation.

The five best treatments, providing greater than 70% defoliation, in both 2005 and 2006 were picloram + 2,4- D amine + triclopyr (0.66 + 2.44 + 2.44 kg ae/ha), picloram + fluroxypyr at both 0.41 + 0.41 and 0.82 + 0.82 kg ae/ha, triclopyr + fluroxypyr at 1.83 + 0.61 kg ae/ha, and triclopyr + 2,4-D ester (1.12 + 1.06 kg ae/ha). In 2005, triclopyr + fluroxypyr at 0.91 + 0.30 and picloram + 2,4-D amine (0.28 + 1.12 kg ae/ha) provided control equivalent to the five best treatments. Janicke (1985b) also reported greater than 70% canopy reduction of rough-leaved dogwood using triclopyr + 2,4-D and picloram + 2,4-D at a site in western Riley County, Kansas.

Mortality 1 Year After Treatment

Mortality 1 year after treatment was also greater in 2005 than 2006, at 38 and 23% respectively (Table 2.8). This could be due to lower than normal precipitation (26 cm below the average at the Pottawatomie County site (Table 2.5) and 6 cm lower than normal at the Riley County site (Table 2.4) thus resulting in less translocation of herbicide to the roots and lower mortality. Mortality 1 year after treatment broke into two very distinct groups. Picloram + 2,4-D amine+ triclopyr (0.66 + 2.44 + 2.44 kg ae/ha), and picloram + fluroxypyr (0.41 +0.41 and 0.82 + 0.82 kg ae/ha) were the best treatments with an average mortality of greater than or equal to 60% (Table 2.8). Triclopyr + fluroxypyr at the 1.83 + 0.61 kg ae/ha level, had lower mortality than picloram + 2,4-D amine + triclopyr (0.66 + 2.44 + 2.44 kg ae/ha) but was not different from either picloram + fluroxypyr treatments at 51% mortality. Some minor differences existed among the second group but all treatments provided less than 30% mortality. Picloram + 2,4-D amine (0.28 + 1.12 kg ae/ha) provided the highest mortality in this group at 25% at 12 months post treatment. The least effective treatments were triclopyr (1.12 kg ae/ha) providing 10% and dicamba + 2,4-D amine (0.56 + 2.13 kg ae/ha) at 6% mortality.

Management Recommendations

Picloram + 2,4-D amine + triclopyr (0.66 + 2.44 + 2.44 kg ae/ha), picloram + fluroxypyr at (0.82 + 0.82 kg ae/ha) and triclopyr + 2,4-D ester (1.22 + 2.44 kg ae/ha) provided 70% or greater defoliation one month following treatment. All treatments except dicamba + 2,4-D amine (0.56 + 2.13 kg ae/ha) and picloram + 2,4-D amine (0.28 + 1.12 kg ae/ha) provided greater than 50% defoliation.

The rate of defoliation generally was higher one year following treatment, compared to 1 MAT, with four treatments providing greater than 80% defoliation: triclopyr + fluroxypyr (1.83 + 0.61 kg ae/ha), picloram + fluroxypyr at both 0.41 + 0.41 and 0.82 + 0.82 kg ae/ha and picloram + 2,4-D amine + triclopyr (0.66 + 2.44 + 2.44 kg ae/ha). Another five treatments provided better than 50% defoliation one year following treatment: triclopyr (1.12 kg ae/ha), triclopyr + 2,4-D ester (1.22 + 2.44 kg ae/ha), triclopyr + fluroxypyr (0.91 + 0.30 kg ae/ha), triclopyr + 2,4-D ester (1.12 + 1.06 kg ae/ha), and picloram + 2,4-D amine (0.28 + 1.12 kg ae/ha). Only two treatments, dicamba + 2,4-D amine (0.56 + 2.13 kg ae/ha), and the untreated check provided less than 50% defoliation. All herbicide treatments except dicamba + 2,4-D amine (0.56 + 2.13 kg ae/ha) provided good defoliation and should allow for some recovery of grasses and forbs. For management purposes, there is minimal difference in defoliation among the top nine treatments, with only dicamba + 2,4-D amine (0.56 + 2.13 kg ae/ ha) being an unacceptable treatment. Cost should be a deciding factor if defoliation is the goal (Table 1.1).

Mortality one year after treatment revealed some useful differences among the treatments. Picloram + 2,4-D amine + triclopyr (0.66 + 2.44 + 2.44 kg ae/ha) and picloram + fluroxypyr at both the 0.41 + 0.41 and 0.82 + 0.82 kg ae/ha levels provided the best control with greater than 60% mortality. Triclopyr + fluroxypyr at the 1.83 + 0.61 kg ae/ha level was above 50% and better than the next treatment. Price of the treatment may be an important consideration when choosing one of these treatments with picloram + fluroxypyr at the 0.41 + 0.41 kg ae/ha rate being the most economical, costing $79.00 to 166.00/ha less than the other effective herbicides (Table 1.1). The other seven treatments were at or below 20% in mortality and did not provide enough mortality to be a viable choice. Finally, it should be noted that the treatments recommended are high-volume, rescue treatments to be used only on heavy dogwood infestations where other more economical, less intensive treatments cannot be used such as fire, mechanical removal and general broadcast herbicides.

Chapter 2 - Tables

Table 2.1. Herbicide rates and costs used in Pottawatomie and Riley County, KS (2005-2006).

Herbicide	Rate	Cost[a]
	kg ae/ha	$/ha
Dicamba + 2,4-D amine	0.56 + 2.13	45.70
Triclopyr	1.12	69.16
Triclopyr + 2,4-D ester	1.12 + 1.06	82.90
Triclopyr + 2,4-D ester	1.22 + 2.44	167.96
Triclopyr + Fluroxypyr	0.91 + 0.3	86.45
Triclopyr + Fluroxypyr	1.83 + 0.61	172.90
Picloram + Fluroxypyr	0.41 + 0.41	79.66
Picloram + Fluroxypyr	0.82 + 0.82	159.32
Picloram + 2,4-D amine	0.28 + 1.12	52.18
Picloram + 2,4-D amine + Triclopyr	0.66 + 2.44 + 2.44	245.76
Untreated Check	--	--

[a] Approximate retail cost from 2009 Chemical Weed Control for Field Crops, Rangeland, and Noncropland, Kansas State University Agricultural Experiment Station and Cooperative Extension Service publication SRP 1007.

Table 2.2. Environmental conditions at the time of herbicide application in 2005 - 2006.

County	Application date	Stage of growth	Relative humidity	Air temperature	Wind
			%	C	m/sec
Pottawatomie	June 6, 2005	Full Bloom	63	31	<3.6
	June 12, 2006	Full Bloom	65	23	<2.3
Riley	June 13, 2005	Full Bloom/Early Seed	44	29	<6.3
	June 13, 2006	Full Bloom	58	24	<2.7

Table 2.3. Average rough-leaved dogwood defoliation by location 1 MAT.

Year	Pottawatomie County	Riley County
Defoliation	%	%
2005	42	66
2006	57	57

LDS 0.10 [compare year by location]= 5.5

Table 2.4. Growing season precipitation (cm) for Riley County, Kansas.[a]

Month	2005	2006	Average
	cm	cm	cm
May	7.13	7.85	11.61
June	28.24	4.24	11.91
July	8.18	11.56	9.78
August	15.85	21.11	8.48
September	5.13	6.25	8.99
Average annual	89.92	75.11	81.51

[a] Average precipitation based on 1971-2000 data (Knapp 2009)

Table 2.5. Growing season precipitation (cm) for Pottawatomie, County, Kansas.[a]

Month	2005	2006	Average
	cm	cm	cm
May	8.61	5.36	12.67
June	20.19	6.20	12.06
July	6.43	7.52	12.78
August	12.55	12.47	10.49
September	4.09	10.03	8.64
Average annual	89.41	63.35	89.59

[a] Average precipitation based on 1971-2000 data (Knapp 2009)

Table 2.6. Rough-leaved dogwood defoliation 1 month after treatment (averaged across locations within years).

Treatment	Rate	2005	2006
	kg ae/ha	%	%
Triclopyr	1.12	55	62
Triclopyr + 2,4-D ester	1.12 + 1.06	63	57
Dicamba + 2,4-D amine	0.56 + 2.13	47	40
Triclopyr + Fluroxypyr	0.91 + 0.30	50	60
Triclopyr + Fluroxypyr	1.83 + 0.61	53	77
Picloram + Fluroxypyr	0.41 + 0.41	57	60
Picloram + Fluroxypyr	0.82 + 0.82	62	78
Triclopyr + 2,4-D ester	1.22 + 2.44	75	75
Picloram + 2,4-D amine	0.28 + 1.12	42	37
Picloram + 2,4-D amine+ Triclopyr	0.66 + 2.44 + 2.44	70	80
Untreated	-----	18	2

LSD 0.10 [compare treatments within year or between years] = 16.6

Table 2.7. Rough-leaved dogwood defoliation 12 months after treatment (averaged across locations and dates within years).

Treatment	Rate	2005	2006
	kg ae/ ha	%	%
Triclopyr	1.12	67	57
Triclopyr + 2,4-D ester	1.12 + 1.06	83	73
Dicamba + 2,4-D amine	0.56 + 2.13	58	28
Triclopyr + Fluroxypyr	0.91 + 0.30	88	68
Triclopyr + Fluroxypyr	1.83 + 0.61	89	80
Picloram + Fluroxypyr	0.41 + 0.41	95	91
Picloram + Fluroxypyr	0.82 + 0.82	86	86
Triclopyr + 2,4-D ester	1.22 + 2.44	79	65
Picloram + 2,4-D amine	0.28 + 1.12	90	41
Picloram + 2,4-D amine+ Triclopyr	0.66 + 2.44 + 2.44	95	91
Untreated	-----	8	6
Average	----	76	62

LSD 0.10 [compare years] = 8.7

LSD 0.10 [compare treatments within year or between years] = 15.0

Table 2.8. Rough-leaved dogwood mortality 1 year after treatment (averaged across locations and dates within location).

Treatment	Rate	Average
	kg ae/ha	% mortality
Triclopyr	1.12	10de
Triclopyr + 2,4-D ester	1.12 + 1.06	17cd
Dicamba + 2,4-D amine	0.56 + 2.13	6de
Triclopyr + Fluroxypyr	0.91 + 0.30	20cd
Triclopyr + Fluroxypyr	1.83 + 0.61	51b
Picloram + Fluroxypyr	0.41 + 0.41	60ab
Picloram + Fluroxypyr	0.82 + 0.82	63ab
Triclopyr + 2,4-D ester	1.22 + 2.44	14cde
Picloram + 2,4-D amine	0.28 + 1.12	25c
Picloram + 2,4-D amine + Triclopyr	0.66 + 2.44 + 2.44	67a
Untreated	-----	0e

LSD 0.10 [compare treatments] = 14.9

CHAPTER 3 - Control of Rough-Leaved Dogwood with Tebuthiuron Pellets

Abstract

Rough-leaved dogwood (*Cornus drummondii* Meyer) is one of the most invasive woody plants in rangeland of Kansas. Lack of prescribed burning due to drought and urban encroachment have contributed to its spread. Herbicides have commonly been used for control of rough-leaved dogwood, and tebuthiuron pellets (Spike 20P) are often recommended. Baseline vegetation measurements were taken on October 15, 2004. Treatments of 4.4 kg ai/ha (3/4 oz per 100 square feet) tebuthiuron pellets were applied in December 2004. Paired plots, treated and untreated, were 5 by 10 meters in size and were replicated eight times. Live dogwood stem counts were taken along a 0.5 by 10-m belt transect within each plot. A total of 5, 0.1-m^2 frames per plot were used to estimate woody plant cover using the Daubenmire Canopy Coverage method. Woody plant cover and rough-leaved dogwood density were taken again on August 24, 2006. A visual estimate of control indicated tebuthiuron reduced dogwood cover by 65% compared to a 3% decrease on untreated plots. Dogwood density was reduced by 2.2 stems/m^2 ($P<0.08$). Total woody plant cover increased on untreated plots by 6.2 percentage units, but was decreased by 20.9 percentage units on tebuthiuron treated plots. Other woody plants decreased in both treated and untreated plots. Shading by a large elm tree likely caused variation between replications including increases in cover and density of rough-leaved dogwood on treated plots. Tebuthiuron is a photosynthetic inhibitor and often is not effective on species under tree canopies. Tebuthiuron pellets applied at 4.4 kg ai/ha appears to be an effective control option for rough-leaved dogwood.

Introduction

Rough-leaved dogwood is an aggressive woody shrub that invades grasslands, especially in the northern Flint Hills (Bragg and Hulbert 1976). Drought and urban encroachment have made the use of fire difficult to use as a control strategy in certain situations. Consequently, herbicides are commonly recommended for control of rough-leaved dogwood (Thompson et al. 2009).

Tebuthiuron can be applied in the dormant season before active growth in the spring and when the soil is not frozen. Dormant season application is recommended to minimize damaging effects on herbaceous plants (Dow AgroSciences 2008). The pelleted formulation and dormant season application eliminates the risk of drift and damage to off-target species.

Previous studies of tebuthiuron in Kansas and Missouri using 2.2 kg/ha indicated 100% control of rough-leaved dogwood (Baker et al. 1980). In northeastern Kansas, Nolte and Fick (1992) reported less than 40% canopy reduction of rough-leaved dogwood with 2 kg/ha tebuthiuron pellets. Differences in soils between southeast and northeast Kansas apparently result in differential response to tebuthiuron (Ohlenbusch and Fick, 1982). Soils in northeast Kansas contained 25-30% clay (Nolte and Fick 1992). Tebuthiuron is strongly adsorbed to clay (WSSA 2002).

Previous studies in northeast Kansas have looked at tebuthiuron at a 2.2 kg/ha rate. The objective of this study was to determine the efficacy of 4.4 kg/ha tebuthiuron pellets applied for rough-leaved dogwood control.

Materials and Methods

The study was established in Pottawatomie County Kansas at 39°28'09.21"N, 96°24'41.95"W with an elevation of 423 m above sea level. The soil is a Pawnee clay loam, with 3 to 6% slope, which typically contains 3-4% organic matter, 30-38% clay and a pH of 5.7-7.3 (Horsch et al. 1987) . The site receives 89.7 cm of precipitation annually (Knapp 2009). The site was dominated by rough-leaved dogwood. Other woody species included: American plum *(Prunus americana* Marsh.), Arkansas rose (*Rosa arkansana* Porter), aromatic sumac (*Rhus aromatica* Ait.), black raspberry (*Rubus occidentalis* L.), buckbrush (*Symphoricarpos orbicultas* Moench), leadplant (*Amorpha canescens* Pursh), New Jersey tea (*Ceanothus ovatus* Desf.), smooth sumac (*Rhus glabra* L.), blackberry (*Rubus spp*.), red elm (*Ulmus rubra* Muhl.), American bittersweet (*Celastrus scandens* L.), poison ivy (*Rhus radicans* L.), multiflora rose (*Rosa multiflora* Thunb.), black cherry (*Prunus serotina* Ehrh.) and honey locust (*Gleditsia triacanthos* L.). The understory consisted of a mixture of annual and perennial forbs with warm- and cool-season grasses.

Treated and untreated plots, 5 by 10 m in size, were replicated eight times. Tebuthiuron pellets were applied at 4.4 kg ai/ha (3/4 ounces Spike 20P per 100 square feet) in December

2004. Pellets were pre-weighed and spread by hand. Live dogwood stem counts were taken along two 0.5 x 10-meter belt transects per plot. Dogwood and other woody plant cover was determined using the Daubenmire Canopy Coverage method (Daubenmire 1959) using five, 0.1 m^2. The initial baseline vegetative measurements were taken on October 15, 2004. Subsequent dogwood stem density and woody plant cover were taken on August 24, 2006.

The Daubenmire Canopy Coverage method utilizes a visual rating of 1-6; 1= 0-5%, 2=6-25%, 3= 26-50%, 4=51-75%, 5=76-95%, 6= 96-100% vegetative cover. A transect was run down the middle of each plot and visual estimates were taken on alternating sides of that transect.

Data were recorded in an Excel spreadsheet and statistical analysis completed using two factor ANOVA at P=0.10. Statistical analysis was conducted on visual control of rough-leaved dogwood 20 months after treatment (MAT). Change in percent cover and density of dogwood between initial and 20 MAT where compared between treated and untreated plots. Change in total woody cover and woody cover other than dogwood were also analyzed.

Results

Visual estimation of the control of dogwood canopy cover indicated 30 to 95% decreases for the treated plots (P<0.001) and 0 to 20% for the untreated check (Table 3.1). The treated plots had an average reduction in dogwood cover of 65% while untreated plots declined 3.1%.

The Daubenmire canopy cover and density estimates both showed a significant reduction in dogwood (Table 3.2). The treated plots indicated a 68% reduction in the percent canopy cover of dogwood similar to that of the visual estimation and a 49% reduction in the stem density. The untreated plot resulted in an increase in the dogwood canopy of 74% and a stem density increase of 52%.

Total woody cover was reduced 61% on average in the treated plots (Table 3.3). Total woody cover increased 14% on untreated plots. Woody cover other than dogwood declined on both treated and untreated plots. The change in the woody cover between treated and untreated plots was not different.

Discussion

Tebuthiuron pellets appear to be a good tool to control heavy infestations of rough-leaved dogwood. Control levels were significant when evaluated as a percent cover control and number of live stems. Herbicides would probably be even more effective when combined with fire. However, fire should not be used until 2 years after herbicide treatment (Dow AgroSciences 2008). The half-life of tebuthiuron is about 12 to 15 months (WSSA 2002), thus adequate time should be allowed for the herbicide to be effective. Stem numbers tended to increase 2 years post-treatment and would probably be susceptible to fire at that time. Two plots, located under the canopy of a large elm tree, responded differently than the other tebuthiuron treated plots. The elm tree was controlled by tebuthiuron. Tebuthiuron is a photosynthetic inhibitor (WSSA 2002), thus the shading effect could reduce the impact on understory species. Tebuthiuron would be a good alternative for range managers because it can be applied in the winter when labor constraints may be less. However, it is also a somewhat expensive treatment, costing $37.40 per kg. The pellets may also be a poor option on severely sloping ground prone to runoff, due to offsite movement of the herbicide and potential damage to non-target species and environmental contamination.

The results on other woody species and total woody cover reduction was variable. Total woody cover was reduced significantly, but this could be related to a reduction of dogwood in heavily infested areas. Species other than dogwood on average declined in untreated and treated plots (Table 3.3). In the treated plots an increase in woody cover other than dogwood was probably caused by a lack of control on blackberries and black raspberries. Treated plots where other woody cover declined was probably due to partial or complete control of buckbrush and smooth sumac by tebuthiuron (Baker et al. 1980; Nolte and Fick 1992). Woody cover would generally be expected to increase over time on untreated plots, but woody cover other than dogwood actually declined. A decrease in woody plant cover other than dogwood in untreated plots could be due to a shading effect caused by dogwood and/or competition.

Tebuthiuron pellets at 4.4 kg/ha can provide good control of rough-leaved dogwood and may provide control of other woody species. Treatment with tebuthiuron pellets in combination with fire would probably provide enhanced control of rough-leaved dogwood and other woody species. The best use of tebuthiuron for control of rough-leaved dogwood would be as a spot treatment on heavy infestations. Application during the dormant season may have the added benefit of spreading out limited labor.

Tables - Chapter 3

Table 3.1. Percent visual control of rough-leaved dogwood by tebuthiuron 2 years after treatment (YAT) in Pottawatomie County, Kansas.

Treatment	Range	Average
Untreated	0-20	3.1
Treated	30-95	65.0

Table 3.2. Rough-leaved dogwood response to tebuthiuron (Spike 20P) 2 years after treatment (YAT) in Pottawatomie County, Kansas.

	Untreated	Treated
Cover	%	%
Initial	18.6	19.8
2 YAT	32.4	6.4
Change	13.8	-13.4
$P < 0.01$		
Density	stems/m^2	stems/m^2
Initial	5.2	4.3
2 YAT	7.9	2.1
Change	2.7	-2.2
$P < 0.08$		

Table 3.3. Tebuthiuron (Spike 20P) effects on woody plant cover 2 years after treatment (YAT) in Pottawatomie County, Kansas.

	Untreated	Treated
Total Woody Cover	**%**	**%**
Initial	**45.3**	**34.5**
2 YAT	**51.5**	**13.6**
Change	**6.2**	**-20.9**
P < 0.06		
Woody Cover minus Dogwood	**%**	**%**
Initial	**26.7**	**14.7**
2 YAT	**19.1**	**7.2**
Change	**-7.6**	**-7.5**
P >0.99		

CHAPTER 4 - References

Baker, B.J., D.E. Robinson, W.E. Russell, and R.W. Willemsen. 1980. Rangeland brush control in Kansas and Missouri with tebuthiuron. Proc. North Cent. Weed Control Conf. 35:128-129.

Bragg, T.B., and L.C. Hulbert. 1976. Woody plant invasion of unburned Kansas bluestem prairie. J. Range Manage. 29:19-24.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-64.

Dow AgroSciences. 2008. Specimen Label Spike 20P Specialty Herbicide. http://www.cdms.net/LDat/ld0B7009.pdf. Accessed October 2, 2009.

Gibson, D.J. 1988. Regeneration and fluctuation of tallgrass prairie vegetation in response to burning frequency. Bull. Torrey Bot. Club 115:1-12.

Great Plains Flora Association. 1986. Flora of the Great Plains. T.M. Barkley (ed.). University Press of Kansas, Lawrence, KS. 1392 p.

Heisler, J.T., J.M. Briggs, A.K. Knapp, J.M. Blair, and A. Seery. 2004. Direct and indirect effects of fire on shrub density and aboveground productivity in a mesic grassland. Ecology 85:2245-2257.

Horsch, M.L., P.R. Kutnick, D.A. Gier, B.D. Tricks, and W.A. Wehmueller. 1987. Soil Survey of Pottawatomie County, Kansas. USDA-SCS in cooperation with the Kansas Agr. Exp. Sta. 153 p.

Jacoby, P.W., and C.H. Meadors. 1982. Control of sand shinnery oak (*Quercus havardii*) with pelleted picloram and tebuthiuron. Weed Sci. 30:594-597.

Jacoby, P.W., and C.H. Meadors. 1983. Triclopyr for control of honey mesquite (*Prosopis juliflora* var. *glandulosa*). Weed Sci. 31:681-685.

Janicke, G. 1985a. Prescribed burning effects on the seasonal carbohydrate levels of roughleaf dogwood in the Kansas Flint Hills. M.S. thesis, Manhattan, KS: Kansas State University. 34 p.

Janicke, G. 1985b. Chemical control of roughleaf dogwood in the Kansas Flint Hills. M.S. thesis, Manhattan, KS: Kansas State University. 34 p.

Janicke, G.L., and W.H. Fick. 1998. Prescribed burning effects on total nonstructural carbohydrates of roughleaf dogwood. Trans. Kansas Acad. Sci. 101:39-48.

Jantz, D.R., R.F. Harner, H.T. Rowland, and D.A. Gier. 1975. Soil Survey of Riley County and Part of Geary County, Kansas. USDA-SCS in cooperation with the Kansas Agr. Exp. Sta. 71 p.

Knapp, M. 2009. K-State Research and Extension Weather Data Library. Precipitation Summary. http://www.ksre.ksu.edu/wdl/wdl/pmaps.htm. Accessed September 3, 2009.

Ngakane, S.R. 1997. Smooth sumac and roughleaf dogwood response to different fire frequencies. M.S. thesis, Manhattan, KS: Kansas State University. 42 p.

Nolte, D.L., and W.H. Fick. 1992. Tebuthiuron application for brush control in the northern Flint Hills, Kansas. Trans. Kansas Acad. Sci. 95:100-108.

Ohlenbusch, P.D., and W.H. Fick. 1982. Woody plant control with tebuthiuron in northeast Kansas. Proc. North Cent. Weed Control Conf. 37:99-100.

Olson, R, J. Hansen, T. Whitson, K. Johnson, 1994. Tebuthiuron to enhance rangeland diversity. Rangelands 16:197-201.

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

Stephens, H.A. 1969. Trees, Shrubs and Woody Vines in Kansas. Lawrence, KS: University Press of Kansas. 250 p.

Stephens, H.A., and I.L. Boyd. 1967. Record large trees, shrubs and vines of Kansas. Trans. Kansas Acad. Sci. 70:96-101.

Stites, H.L, 1985a. Nonstructural carbohydrate reserves of blackberry (*Rubus* sp.) and multiflora rose (*Rosa multiflora* Thunb.). M.S. thesis, Manhattan, KS: Kansas State University. 35 p.

Stites, H.L., 1985. Chemical control of blackberry (*Rubus* sp.) with foliar herbicides. M.S. thesis, Manhattan, KS: Kansas State University. 35 p.

Thompson, C.R., D.E. Peterson, W.H. Fick, P.W. Stahlman, and R.E. Wolf. 2009. Chemical weed control for field crops, pastures, rangeland, and noncropland, 2009. Rept. of Prog. SRP 1007. Kansas State Univ. Agr. Expt. Sta. and Coop. Ext. Ser. Manhattan.

Towne, G., and C. Owensby. 1984. Long-term effects of annual burning at different dates in ungrazed Kansas tallgrass prairie. J. Range Manage. 37:392-397.

Wright, H.A., and A.W. Bailey. 1982. Fire Ecology, United States and Southern Canada. New York: John Wiley & Sons. 501 p.

[WSSA] Weed Science Society of America. 2002. Tebuthiuron. Pages 412-413 *in* W.K. Vencill, ed. Herbicide Handbook. 8th ed. Lawrence, KS: Weed Science Society of America.

Appendix A- Analysis of Variance Tables

Table A.1 Foliar Herbicides of Rough-Leaved Dogwood Defoliation 1 Month After Treatment

SOV	df	SS	MS	F	Probability
Location	1	5345.45	5345.45	4.92	
B (location)	4	4342.43	1085.61		
Treatment	10	42,393.56	4239.36	17.00	<0.001
T x L	10	2200.38	220.04	0.88	>0.50
Error (b)	40	9974.24	249.36		
Year	1	334.09	334.09	1.65	0.246
Y x L	1	4609.09	4609.09	22.70	<0.001
Y x T	10	3911.74	391.17	1.93	0.066
Y x L x T	10	2636.74	263.67	1.30	0.261
Error	44	8933.33	203.03		

Table A.2 Foliar Herbicides of Rough-Leaved Dogwood 1 Year After Treatment

SOV	df	ss	ms	F	Probability
Location	1	285.12	285.12	2.48	>0.10
B (Location)	4	461.30	115.08		
Treatment	10	77,756.41	7775.64	46.41	<0.001
T x L	10	2739.05	273.91	1.63	0.131
Error (b)	40	6701.36	167.53		
Year	1	6191.03	6191.03	26.79	<0.001
Y x L	1	291.03	291.03	1.26	0.267
Y x T	10	6036.14	603.61	2.61	0.013
Y x L x T	10	2747.80	274.78	1.19	0.323
Error (c)	44	10,167.00	231.07		

Table A.3 Foliar Herbicides of Rough-Leaved Dogwood Mortality 1 Year After Treatment

SOV	df	ss	ms	F	Probability
Location	1	83.52	83.52	0.89	>0.25
B (Location)	4	397.73	99.43		
Treatment	10	73,767.05	7376.71	15.98	<0.001
T x L	10	1401.89	140.19	0.30	>0.75
Error (b)	40	18,460.61	461.52		
Year	1	7350.19	7359.19	14.21	<0.001
Y x L	1	418.37	418.37	0.81	>0.25
Y X T	10	4768.56	476.86	0.92	>0.50
Y x L x T	10	6617.05	661.71	1.28	0.271
Error (c)	44	22,758.33	517.24		

Table A.4 Percent Rough-Leaved Dogwood Cover

ANOVA

SOV	*df*	*SS*	*MS*	*F*	*P-value*	*F critical*
Rows	7	0.179544	0.025649	0.581907	0.754028	3.787051
Columns	1	1.531406	1.531406	34.74335	0.000603	5.59146
Error	7	0.308544	0.044078			
Total	15	2.019494				

Table A. 5 Stem Density Rough- Leaved Dogwood

ANOVA

SOV	*Df*	*SS*	*MS*	*F*	*P-value*	*F critical*
Rows	7	34.70938	4.958482	0.211482	0.971188	3.787051
Columns	1	92.64063	92.64063	3.951177	0.087179	5.59146
Error	7	164.1244	23.44634			
Total	15	291.4744				

Table A.6 Percent Other Woody Cover

ANOVA

SOV	*df*	*SS*	*MS*	*F*	*P-value*	*F critical*
Rows	7	639.6094	91.37277	0.685736	0.684477	3.787051
Columns	1	43.89063	43.89063	0.329391	0.58398	5.59146
Error	7	932.7344	133.2478			
Total	15	1616.234				

Table A.7 Percent Total Woody Cover

ANOVA

SOV	*df*	*SS*	*MS*	*F*	*P-value*	*F critical*
Rows	7	4119.688	588.5268	1.136093	0.435323	3.787051
Columns	1	2376.563	2376.563	4.587721	0.06944	5.59146
Error	1	3626.188	518.0268			
Total	15	10122.44				