I - PRESCRIBED BURNING EFFECTS ON THE SEASONAL CARBOHYDRATE LEVELS OF ROUGHLEAF DOGWOOD IN THE KANSAS FLINT HILLS

II - CHEMICAL CONTROL OF ROUGHLEAF DOGWOOD IN THE KANSAS FLINT HILLS

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ABSTRACT

Roughleaf dogwood (*Cornus drummondii* Meyer) is a major invading shrub of the bluestem prairie, decreasing production and availability of desirable forage species. Total nonstructural carbohydrate (TNC) reserves as related to phenological development were determined in the roots and stems of roughleaf dogwood during the 1983 and 1984 growing seasons. The effect of late-spring burning on TNC levels was determined to provide information for development of an integrated (burning + herbicide) control method. Root TNC concentrations were the best indicator of phenological changes. The stem materials showed little or no fluctuation with changes in plant development. Unburned root TNC levels rapidly decreased in the spring to the full-leaf stage of development then rapidly increased to higher concentrations during floral development. The low-point in TNC concentration was extended 4 to 6 weeks later into the growing for the burned plants. The greatest reduction of root TNC occurred during mid-June to mid-July in the burned samples. Burning for two consecutive years reduced TNC significantly compared to one-year of burning, extending the low-point into August.

INTRODUCTION

When natural controls such as fire and year-long conservative grazing are absent, woody species gradually increase, reducing livestock carrying capacity on rangeland (Dyksterhuis 1958, Launchbaugh and Owensby 1978). Roughleaf dogwood(*Cornus drummondii* Meyer.) is a resprouting brush species readily invading grassland communities, especially in the northern Flint Hills of Kansas (Bragg and Hulbert 1976). A widespread lateral root system allows this species to form dense thickets, resprouting readily at the perimeter, and reduces desirable forage production and availability.

Numerous studies have linked carbohydrate reserves to plant vigor and susceptiblity to control efforts (Aldous 1930, Wilson et al. 1975, Brady 1976). Organic reserves in plants fluctuate with their seasonal physiological growth stages (Woods et al. 1959, Jones and Laude 1960, McConnell and Garrison 1966, Coyne and Cook 1970). Cook (1966) states that periods of low reserve concentrations in the storage organs may vary widely among plant species. Coyne and Cook (1970) indicated that delineation of seasonal carbohydrate reserve cycles in non-defoliated plants is fundamental to studying the effects of defoliation on carbohydrate reserves. Burning, as a method of defoliation and reducing carbohydrate reserves, is a common management practice on grasslands (Launchbaugh and Owensby 1978).

The objectives of this study were to determine the total nonstructural carbohydrate (TNC) cycle of roughleaf dogwood in relation to phenological development and as affected by prescribed burning. Information gained from this study will be used to ~~develope~~ an integrated approach to controlling roughleaf dogwood using prescribed burning and herbicides.

MATERIALS AND METHODS

The study was conducted at 2 locations near Manhattan, Kansas, in the Flint Hills region of the True Prairie. The Keats pasture, located 13 km northwest of Manhattan, has not been burned for several years, whereas the Smith pasture, 5 km southeast of Manhattan, has been burned consecutively for many years. The soil type at the Keats location is a Benfield-Florence association. The Benfield soil series is a silty clay loam (fine, mixed, mesic, Udic Argiustoll). The Florence soil series is a cherty silty clay loam (clayey-skeletal, montmorillonitic, mesic, Udic Argiustoll).

Roughleaf dogwood dominated the woody vegetation at the Keats pasture experimental area in association with red cedar (*Juniperus virginiana* L.), siberian elm (*Ulmus pumila* L.), and smooth sumac (*Rhus glabra* L.). Dominant grass cover on this loamy upland range site consists of big bluestem (*Andropogon gerardi* Vitman), little bluestem (*Andropogon scoparius* Michx.), indiangrass [*Sorghastrum nutans* (L.) Nash.] and blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.]. Kentucky bluegrass (*Poa pratensis* L.) and Japanese brome (*Bromus japonicus* Thunb.) are invading cool-season grasses at this location.

The Smith pasture is comprised of stony steep land (30 to 50% slopes). The woody vegetation at the Smith pasture location was not dominated by roughleaf dogwood. As a result of yearly prescribed burning and frequent application of herbicides, populations were excluded to small struggling clumps in the open pasture or under a heavy bur oak (*Quercus macrocarpa* Michx.) and chinquapin oak (*Quercus muehlenbergii* Engelm.) canopy cover. Dominant grasses on this breaks range site in excellent condition consist of big bluestem, little bluestem, indiangrass and sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.].

The northern Flint Hills of Kansas have a typical fluctuating continental climate with an average precipitation of 850 mm. Generally about three-fourths of this precipitation falls during the growing season. While this study was in progress the plot areas experienced periods of extreme drought even though annual precipitation amounts were normal.

The Keats and Smith pastures were both burned in the late spring (first week in May) in 1983 and 1984 and treatment plots (5 X 10 m) were established. Plots were protected at the Keats location in 1984 to compare the effects of a single years burn with 2 years of burning. Root and stem samples from the unburned plants and roots of burned plants were randomly collected bimonthly during the growing season (April to October) and monthly when possible during the dormant period. Entire plants were collected intact to ensure an adequate sample (10 to 15 g) from the bud zone and secondary stems. Phenological growth stages were recorded on each sampling date (Table 1). The roots and stems were separated, cleaned with a brush and water, oven-dried at 70^{o} C for a minimum of 72 hours and shredded in a hammermill prior to grinding in a Wiley Mill to pass a 1mm screen. All samples were assayed for TNC concentrations (mg/g tissue dry matter) by hydrolizing and extracting 500 mg samples using an enzyme (mycolase) as described by Smith (1969). Reducing power of the resulting solutions was determined by the Shaeffer-Somogyi copperiodometric titration method (Heinze

Table 1. Phenological stages of development for roughleaf dogwood.

1. Winter quiescence
2. Apical bud swelling
3. Mid-leaf size
4. Full-leaf size
5. Floral bud development
6. Full bloom
7. Seed set
8. Small seed size
9. Mid-seed size
10. Hard seed
11. Milky seed
12. Mature seed (purple color)

and Murneek 1940). Further hydrolysis with 0.1N sulfuric acid was initially tried but discontinued because it did not influence TNC extracted.

The study was completely randomized with 4 replications of each treatment at each location each year. Data were analyzed using a two-way analysis of variance and means seperated using Fisher's protected L.S.D. test at the 5% level of probability (Snedecor and Cochran 1980).

RESULTS AND DISCUSSION

Phenological Effects

The annual cycling of root carbohydrate reserves in roughleaf dogwood follows a pattern found in many woody plants (Jones and Laude 1960, Cook 1966, McConnell and Garrison 1966, Donart 1969, Coyne and Cook 1970,Trlica and Cook 1971, Menke and Trlica 1981, Boo and Pettit 1975, Fick and Sosebee 1981). The root carbohydrate reserve pattern in roughleaf dogwood at both locations in either burned or unburned sites is V-shaped (Fig.1-4), typified by a rapid drawdown of reserves for initiation of spring growth followed by a steady accumulation to the milky seed to seed maturity stages (mid-August to early September). During the growing season another significant drawdown occurred in roughleaf dogwood at the Smith location coincident with the seed set to small seed stages of phenological development (early July) (Fig. 2). Coyne and Cook (1970) also reported a late season drawdown period in a study of desert brush species. The TNC high-point in roughleaf dogwood occurred 1 to 2 months prior to the average freeze date (Fig. 3 and 4). Senescence began after the milky seed stage and reserve concentrations declined by 17 to 30 mg/g of sample, representing 19 to 32% of the maximum stored reserve level. Reserve losses were significant during the late-season period in 1983 and 1984 at both locations. Reserves continued to decline throughout quiescence.

Root TNC concentrations were significantly greater than stem materials for both years at both locations (Fig. 1 and 2). Minimum TNC concentrations occurred in the stems and roots near the same stage of development, although, there was little or no significant ($p>0.05$) fluctuations noted for either year or location in the stems. The stems had an extended V-shaped TNC pattern similar to fringed sagewort (*Artemisia frigida* Willd.) as reported by Menke and Trlica (1981).

Keats Pasture

Root TNC of unburned plants in 1983 and 1984 declined steadily from bud initiation to the full leaf phenological stages of development (Fig. 1). The full leaf + stage (occurring the last 10 days of May in both study years) coincided with the low-point in TNC reserves. During leaf development stem TNC declined comparably reaching 23 and 20 mg/g in 1983 and 1984, respectively (Fig. 1). Between the full leaf and full bloom developmental stages (the last 10 days of June both years) root TNC increased 27 and 13 mg/gram during 1983 and 1984, respectively, indicating downward translocation of carbohydrates. Stems TNC, however, increased only slightly, 19 mg/g, in 1984, with no difference in 1983. Between seed set and milky seed stages (mid to late August) carbohydrates were intensively translocated to the roots with TNC levels of 107 and 96 mg/g, respectively, in 1983 and 1984. Stem TNC concentrations also peaked at this stage of development. Once this high point was achieved root and stem TNC concentrations declined toward dormancy.

Smith Pasture

The low-point in TNC reserves occurred at the mid to full leaf stages in 1983 and 1984 (Fig. 2). Total nonstructural carbohydrate concentration in the roots increased rapidly to 62 mg/g both years at full-bloom. Carbohydrates rapidly declined in the roots after full bloom until the small seed stage. Root carbohydrates were replenished with the maximum TNC levels of 93 mg/g at the milky seed stage in 1983 and 106 mg/g at the mature seed stage in 1984 (Fig. 2). Reserve concentrations declined to dormancy. The decline in the late growing season may be the result of root growth. Another plausible explanation may be that leaf senescence causes a reduction in photosynthate production which in turn results in translocation from the roots to stem materials satisfying energy requirements for respiration. Stem TNC concentration also declined to maturity from the milky seed stage after steadily increasing from the low-point at the full leaf stage (Fig. 2).

Prescribed Burning Effects

Keats Pasture

Root TNC of burned plants in 1983 was significantly reduced at apical bud swelling, mid-leaf, full bloom, seed set and milky seed stages of phenological development when compared to unburned plants (Fig. 3). Steinke and Booysen (1968) and Menke and Trlica (1981) both report a drawdown on carbohydrate reserves after foliage removal to form new photosynthate producing plant materials. The late season decline (July 22 to Aug 19) in root reserves ofnon-flowering burned plants, during reproductive growth period of unburned plants is likely the result of energy consumption during new plant tissue production. Boo and Pettit (1975) noted a similiar late-season decline in sand shin oak (*Quercus harvardii* Rahb.). Steinke (1969) stated that when downward translocation was delayed by severe defoliation and adverse environmental conditions, leaf and stem tissue death caused severe reduction in size of the root system. Consequently, once aerial plant material is replenished, root regrowth must occur.

A similar trend occurred in 1984 when plots burned only in 1983 were compared to unburned plots (Fig. 3). The concentration of root TNC was significantly less ($p<0.05$) at apical bud swelling, full leaf, seed set and mid seed stages of development in roughleaf dogwood 1 year after burning compared to unburned plants. This trend may possibly continue until the defoliated burned plant regains reproductive capability.

Plots burned 2 consecutive years showed a trend similar to unburned or 1-year burned plots (Fig. 3). Root TNC concentrations in plants burned 2 years were significantly reduced at full leaf, floral bud, and mid seed stages of development compared to 1-year burned plots. Two consecutive years of burning extended the TNC low-point later into the season but reserves were completely recovered when roughleaf dogwood went into dormancy.

Smith Pasture

The concentration of carbohydrate reserves were significantly reduced by burning at the full bloom, milky seed, mature seed and dormant stages of phenological development in 1983 (Fig. 4). In 1984 (Fig. 4) the concentration of TNC was significantly reduced by burning at floral bud development, full bloom, mid seed, milky seed and mature seed stages of development. The concentration of reserves declined during the late growing season. Total nonstructural carbohydrate concentrations were equal for burned and unburned plants entering dormancy in 1984. These results agree with the 2 year consecutive burned plots at the Keats pasture (Fig. 3). Longterm annual burning in the Smith pasture has not eliminated roughleaf dogwood since the TNC levels replenish to comparable levels as unburned plants.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Root TNC concentrations fluctuated sharply during plant developmental stages, whereas, stem materials fluctated very little. The low-point in TNC reserves occurred at the full leaf stage of development, with energy reserves being translocated from the leaves to the roots between the full leaf stage and full bloom. A second major interval of increased TNC levels in the roots occurred between early-seed set and the milky-seed stage. Herbicide treatment would be most effective during these 2 periods when root TNC levels are increasing.

Prescribed burning is generally ineffective in controlling roughleaf dogwood since the low-point in the TNC cycle occurs 3 to 4 weeks after burning normally occurs. Prescribed burning would remove existing photosynthetic tissue, requiring an added expenditure of energy for structural replacement. However, root carbohydrate reserves are sufficiently high enough to provide necessary energy for structural replacement. Burning reduced TNC in roughleaf dogwood and shifted the low-point in the root TNC cycle 4 to 6 weeks later into the season. Intergation of prescribed burning and herbicides during the same season appears to be a plausible method for control of roughleaf dogwood.

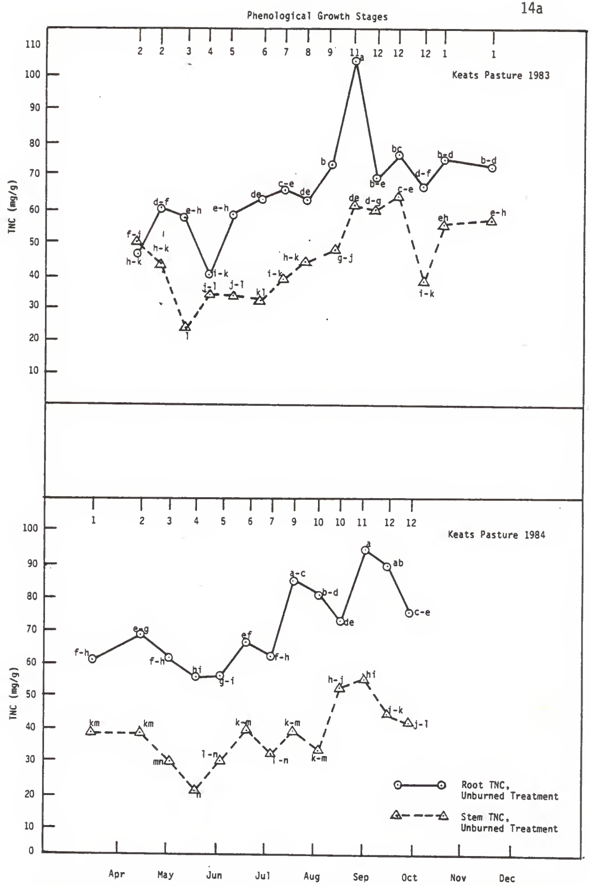

Figure 1. Total nonstructural carbohydrate (TNC) concentration of roughleaf dogwood roots and stems as related to phenological stages at the Keats location.

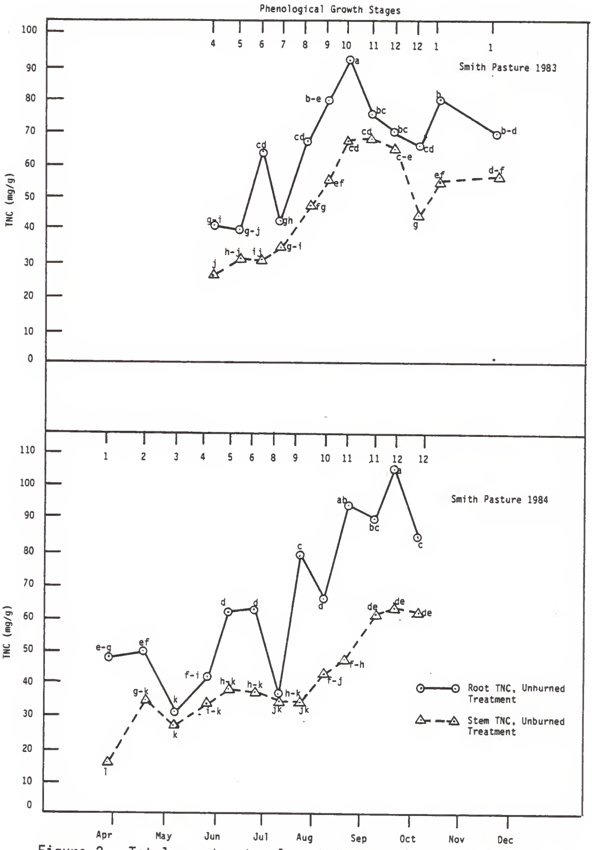

Figure 2. Total nonstructural carbohydrate (TNC) concentration of roughleaf dogwood roots and stems as related to phenological stages at the Smith location.

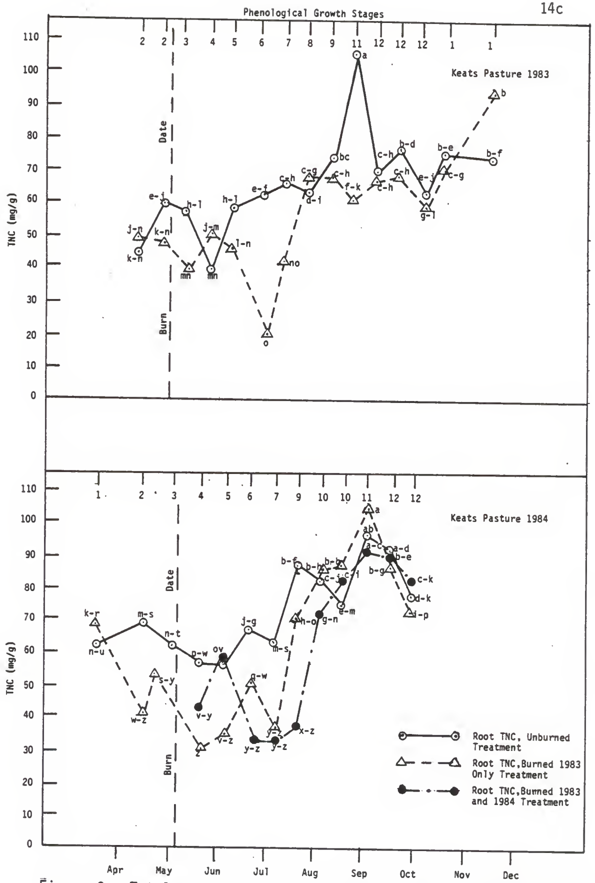

Figure 3. Total nonstructural carbohydrate (TNC) concentration of roughleaf dogwood roots at the Keats location as affected by burning and phenological stages.

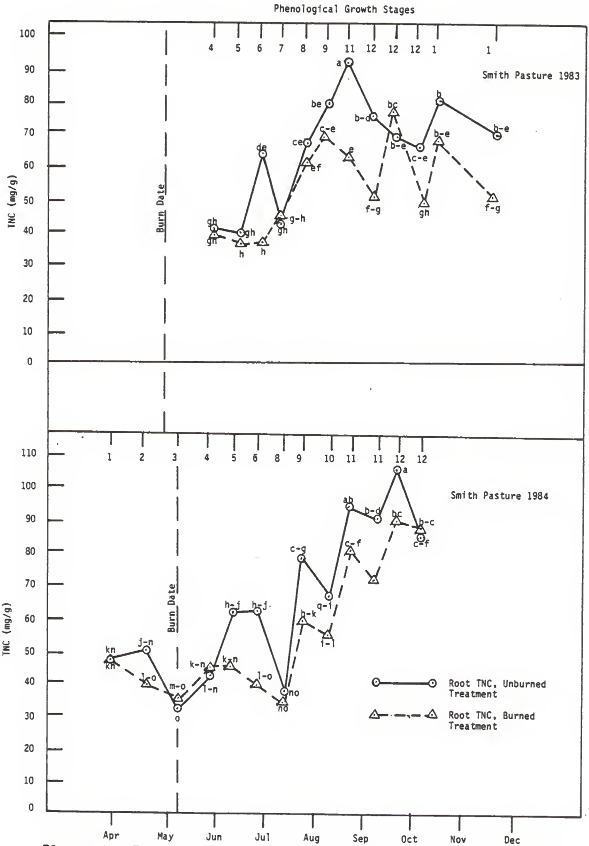

Figure 4. Total nonstructural carbohydrate (TNC) concentration of roughleaf dogwood roots at the Smith location as affected by burning and phenological stages.

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II - CHEMICAL CONTROL OF ROUGHLEAF DOGWOOD IN THE KANSAS FLINT HILLS

ABSTRACT

The recommended treatment for control of roughleaf dogwood (Cornus drummondii Meyer) has been a 1:1 mixture of 2,4-D [(2,4-dichlorophenoxy) acetic acid] and 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid]. Since 2,4,5-T has been removed from use, new treatments must be evaluated for substitution. Roughleaf dogwood was treated with several foliar-applied herbicides at 2 locations in the Flint Hills of Kansas. Triclopyr ester [(3,5,6-trichloro-2-pyridinlyoxy) acetic acid] at 2.2 kg/ha or in combination with 2,4-D (1 + 1 kg/ha), triclopyr amine alone (2.24 kg/ha) or in combination with 2,4-D (1 + 1 kg/ha) and picloram (4-amino-3,5,6,-trichloro-2-pyridinecarboxylic acid) at 0.56 kg/ha were all equally effective ($p<0.05$) at controlling roughleaf dogwood at both locations providing greater than 62% canopy cover reduction. Sunlight intensity differences between the 2 plot locations affected the amount of defoliation. The triclopyr formulations were unaffected by light intensity whereas 2,4-D + 2,4,5-T, picloram + 2,4-D, and dicamba + 2,4-D treatments provided less control under reduced light intensities.

INTRODUCTION

Roughleaf dogwood (*Cornus drummondii* Meyer.) is a resprouting species readily invading grassland communities, especially in the northern Flint Hills of Kansas (Bragg and Hulbert 1976). Normal growth patterns of this species on rangeland result in dense thickets, resprouting readily at the perimeter, reducing desirable forage production and availability.

Several researchers have suggested a relationship between increased carbohydrate translocation and plant susceptibility (Fisher et al. 1959, Upchurch 1969, Brady and Hall 1976). Boo and Pettit (1975) cite premature leaf size, export of photosynthates, and development of surface leaf wax as reasons for erratic control results of sand shinnery oak (*Quercus harvardii* Rydb.). Hull et al. (1974) also cited leaf surface wax as a negative factor in control results. Muzik (1976) considers species susceptibility, stage of growth and environmental conditions as the determining factors of selectivity of foliar- applied herbicides.

Presently, the herbicidal control recommendation for roughleaf dogwood includes the foliar application of 2,4,5-T

[(2,4,5-trichlorophenoxy) acetic acid] (Launchbaugh and Owensby 1978, Ohlenbusch 1984). Since this herbicide is no longer available, alternative chemicals must be evaluated. The objective of this study was to determine an effective chemical control treatment for roughleaf dogwood to replace the recommended application of 2,4,5-T.

MATERIALS AND METHODS

Selected herbicides were foliarly applied in 1983 to roughleaf dogwood at 2 locations near Manhattan, Kansas, in the Flint Hills region of the True Prairie. One experimental area is the Keats pasture, located 13 km northwest of Manhattan. The soil type is a Benfield-Florence association. The Benfield soils series is a silty clay loam (fine, mixed, mesic, Udic Argiustoll). The Florence soil series is a cherty silty clay loam (clayey-skeletal, montmorillonitic, mesic, Udic Argiustoll). Roughleaf dogwood dominated the woody vegetation at the Keats pasture location in association with red cedar (*Juniperus virginiana* L.), siberian elm (*Ulmus pumila* L.), and smooth sumac (*Rhus glabra* L.). Dominant grass cover on this loamy upland range site consists of big bluestem (*Andropogon gerardi* Vitman), little bluestem (*Andropogon scoparis* Michx.), indiangrass [*Sorghastrum nutans* (L). Nash.] and blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.]. Kentucky bluegrass (*Poa pratensis* L.) and Japanese brome (*Bromus japonicus* Thunb.) are invading cool-season grasses at this location.

A second set of studies were conducted on the Smith pasture located 5 km southeast of Manhattan. The soil type consisted of stony steep land (30 to 50 % slope). Roughleaf dogwood was not the dominant shrub species at the Smith pasture location. As a result of yearly prescribed burning and frequent herbicide applications, populations were confined to small struggling clumps in the open pasture or under a heavy bur oak (*Quercus macrocarpa* Michx.) and chinquapin oak (*Quercus muehlenbergii* Engelm.) canopy cover. Dominant grasses on this breaks range site in excellent condition consist of big bluestem, indiangrass, little bluestem and sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.].

The northern Flint Hills of Kansas have a typical fluctuating continental climate with an average precipitation of 850 mm. Generally about three-fourths of this precipitation falls during the growing season. During 1983 the plot areas experienced periods of extreme drought even though total annual precipitation was normal.

Herbicides were applied in 934 L/ha aqueous solution using a low pressure hand held sprayer on 9 June and 24 June, 1983 at the Keats location and 17 June and 1 July, 1983 at the Smith pasture location. The following 10 herbicide treatments (kg a.e./ha) were applied at each experimental area: 1) the propylene glycol butyl ether esters of 2,4-D [(2,4-dichlorophenoxy) acetic acid] + 2,4,5-T (1.1 + 1.1), 2) picloram (4-amino-3,5,6,- trichloropyridinecarboxylic acid), (0.6) 3) picloram + the alkanolamine salts of 2,4-D (0.3 + 1.1), 4) the dimethylamine salts of dicamba (3,6-dichloro-o-anisic acid) + 2,4-D, (0.6 + 2.2), 5) the ethylene glycol butyl ether ester of triclopyr {[(3,5,6-trichloro-2-pyridinyl)oxy] acetic acid}, (2.2) 6) triclopyr ester + the butoxy ethyl ester of 2,4-D (1.1 + 1.1), 7) the triethylamine salt of triclopyr (2.2), 8) triclopyr amine + the alkanolamine salts of 2,4-D (2.2), 9) the monoethanolamine salt of clopyralid (3,6-dichloro-2-pyridinecarboxylic acid) (2.2), and 10) the alkanolamine salts of clopyralid + 2,4-D (0.6 + 2.2). Phenological development and environmental conditions at the time of treatment are listed in Table 2. Percent canopy reduction was determined 2 and 14 months (two growing seasons) after application.

Treatment plots were established in a completely

Table 2. Phenological growth stages and environmental conditions on 4 dates of herbicide application in 1983.

	Location and Dates of Application			
	Keats pasture		Smith pasture	
Parameter	9 June	24 June	17 June	1 July
Stage of growth	early bud	full bloom	early bud	full bloom
Air temp. (°C)	30	28	26	29
Relative Humidity (%)	50	59	53	66
Wind speed (cm/sec)	0.9-2.2	0.9-1.8	0.9-2.2	2.2

randomized design with 2 spray dates and 2 replications per treatment for each spray date. Plots (3.3 X 3.3 m) were established at both locations for all dates except the first date at Keats which was 10 X 10 m. All plots contained a minimum of 10 live roughleaf dogwood plants. Data were analyzed separately for each location and evaluation date using a split-plot analysis of variance. Date of herbicide application represented the whole plots and herbicide treatments the split plots. Percent canopy reduction data were transformed using arcsin $(\%/100)^{1/2}$ before analysis of variance was conducted (Snedecor and Cochran 1980). Means were separated using Fisher's protected L.S.D. at the 5% level of probability (Snedecor and Cochran 1980).

RESULTS AND DISCUSSION

Keats Pasture

Dates of application were significantly different ($P<0.10$) 14 months post treatment at Keats with an average of 67 and 59% canopy reduction, respectively, for the 9 June and 24 June treatments. The date x herbicide interaction was nonsignificant ($P>0.50$). Numerous researchers have reported an increased mortality rate when treatment coincides with carbohydrate translocation to the root system (Fisher et al. 1959, Upchurch et al. 1969, Brady 1971, Wilson et al. 1975, and Brady and Hall 1976. Carbohydrate reserves were accumulating in the roots of roughleaf dogwood on 9 June (early flower bud stage) whereas on 24 June (full bloom) further accumulation of carbohydrate reserves was not occurring (Janicke 1985).

Roughleaf dogwood control was similar ($P<0.05$) at the Keats pasture for all herbicide treatments, except for the clopyralid and clopyralid + 2,4-D treatments when evaluated at 2 or 14 months after herbicide application (Table 3). Percent canopy reduction had a tendency to decline between the 2 and 14 month evaluations as roughleaf dogwood was resprouting from basal or limb buds. A 1:1 mixture of 2,4-D + 2,4,5-T (1.1 + 1.1 kg/ha) defoliated 91% of the roughleaf dogwood plants 14 months after treatment. The remaining effective treatments rated between 62 and 82% canopy reduction. Clopyralid alone or in combination with 2,4-D provided less than 18% defoliation (Table 3).

Smith Pasture

The shading effect from the oak canopy cover at the Smith pasture retarded the progression of phenological development of the roughleaf dogwood by about 1 week compared to the

Table 3. Foliar applied herbicide control results (2 and 14 month evaluation), averaged across 2 treatment dates, at the Keats location in 1983.

Herbicide	Rate (kg/ha)	% CANOPY COVER REDUCTION 2 Months	14 Months
2,4-D + 2,4,5-T	1.12 + 1.12	89 a[1]	91 a
Picloram + 2,4-DA	0.28 + 1.12	95 a	82a
Triclopyr ester	2.24	92 a	80 a
Dicamba + 2,4-DA	0.56 + 2.24	84 a	78 a
Picloram	0.56	90 a	78 a
Triclopyr ester + 2,4-D LVE	1.12 + 1.12	82 a	70 a
Triclopyr amine	2.24	88 a	64 a
Triclopyr amine + 2,4-DA	1.12 + 1.12	89 a	62 a
Clopyralid + 2,4-D	0.56 + 2.24	30 b	18 b
Clopyralid	1.12	18 b	11 b

[1] % Canopy cover reductions within each column followed by the same letter are not significantly different (p>0.05).

Keats location (Table 2). Date of herbicide application and the date x herbicide interaction were nonsignificant at the Smith Pasture location. Clopyralid at 1.1 kg/ha and dicamba + 2,4-D amine at 0.6 + 1.1 kg/ha were less effective than 2,4-D + 2,4,5-T when evaluated 2 months after application (Table 4). The remaining treatments all provided greater than 72% defoliation at initial evaluation. Basal bud and limb resprouting again reduced canopy reduction between the 2 and 14 month evaluations. Triclopyr ester (2.2 kg/ha) alone or combined with 2,4-D (1.1 + 1.1 kg/ha) was a more effective ($p<0.05$) treatment than 2,4-D + 2,4,5-T (1.1 + 1.1 kg/ha) at the Smith pasture location 14 months after application. The triclopyr ester treatments provided a canopy cover reduction of 88%, whereas, 2,4-D + 2,4,5-T resulted in only 65% canopy reduction. The remainder of the herbicide treatments with the exception of clopyralid (1.1 kg/ha) were equally effective ($p<0.05$) as 2,4,-D + 2,4,5_T. Bovey et al. (1981) also reported that triclopyr ester (0.6 kg/ha) was a more effective herbicide than 2,4,5-T in reducing canopy cover of whitebrush [*Aloysia gratissima* (Gill. & Hook.)Tromcoso.] and honey mesquite in greenhouse studies. However, this same study reports that clopyralid (0.6 kg/ha) was as effective as triclopyr in reducing the canopy of honey mesquite. Bovey and Mayeux (1980) also found triclopyr ester to be as effective as 2,4,5-T on honey mesquite.

Table 4. Foliar applied herbicide control results (2 and 14 month evaluation), averaged over 2 treatment dates at the Smith location in 1983.

Herbicide	Rate (kg/ha)	% CANOPY COVER REDUCTION 2 Months	14 Months
Triclopyr ester	2.24	94 a[1]	88 a
Triclopyr ester + 2,4-D LVE	1.12 + 1.12	92 a	88 a
Triclopyr amine	2.24	93 a	82 ab
Picloram	0.56	75 ab	78 abc
Triclopyr amine + 2,4_DA	1.12 + 1.12	95 a	72abc
2,4-D + 2,4,5-T	1.12 + 1.12	92 a	65 bcd
Clopyralid + 2,4-D	0.56 + 2.24	84 ab	52 cd
Dicamba + 2,4-DA	0.56 + 2.24	64 b	50 cd
Picloram + 2,4-DA	0.28 + 1.12	72 ab	40 d
Clopyralid	1.12	18 c	10 e

[1] % Canopy cover reductions within each column followed by the same letter are not significantly different (p>0.05).

Applications of 2,4-D + 2,4,5-T, picloram + 2,4-D, and dicamba + 2,4-D appeared to be more effective at the Keats pasture location. The Keats pasture experimental area was open to direct sunlight intensity, whereas, the plot location on the Smith pasture was limited to full sunlight intensity by an overstory canopy cover of oak trees. Brady (1969) reported a decline in absorption of 2,4,5-T in post oak (*Quercus stellata* Wangenh.) when sunlight intensity was limited, citing increased transpiration, photo-oxidation of enzymes, closing of stomates, and excessive respiration as possible causes of this negative effect. Reduced light intensity would be expected to decrease absorption of most herbicides. A considerable amount of herbicide was applied to the soil when treating roughleaf dogwood. Application of 2,4,5-T to the soil was less effective on honey mesquite than formulations of triclopyr (Bovey and Mayeux 1980). Dicamba and 2,4-D were readily absorbed by the roots of white ash (*Fraxinus americana* L.) and red maple (*Acer rubrum* L.) but were usually less effective or equal to 2,4,5-T in controlling these species (Perry and Upchurch 1968). Consequently 2,4-D and dicamba might expectedly be less effective in controlling woody plants than triclopyr when applied to the soil. Another possible reason for superior canopy reduction using triclopyr ester compared to dicamba +

2,4-D at the Smith location (reduced light intensity) is the longer persistence of triclopyr (Weed Science Society of America Handbook Committee 1983).

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APPENDIX

REVIEW OF LITERATURE

SECTION I: CARBOHYDRATE STORAGE AND DISTRIBUTION IN WOODY PLANTS

INTRODUCTION

Energy substances are photosynthetic products manufactured in the leaves of plants. Once photosynthate is produced in excess of demand the assimilated carbon is stored as reserve compounds for later utilization (Mooney 1972, Kramer and Koslowski 1979). Reserve compounds may be stored temporarily in most perennating plant parts (Bonner and Galston 1952). Reserves are accumulated largely in parenchyma cells (Ziegler 1964). The most common storage organs are the roots, rhizomes, stem bases and twigs of woody species (Winkler 1945, Cook et al. 1959).

Several researchers have stated that carbohydrates are the primary energy reserve compound (McIlvanie 1942, Cook 1966, Kramer and Koslowski 1979). Carbohydrates are composed of monosaccharides (glucose, fructose), oligosacchsarides (sucrose, maltose), and polysaccharides (starch and cellulose) (Koslowski 1971). Cook (1966) stated that carbohydrates are utilized by the plant for respiration and slight growth during the winter, for initial growth and subsequent rapid growth during the spring, secondary growth in the fall, and production of new photosynthetic tissue if defoliation occurs.

Weinmann (1947) analyzed carbohydrate substances for reducing sugars, nonreducing sugars, fructosans, dextrins and starch terming these combined fractions as total available carbohydrates (TAC). These carbohydrate fractions are readily available as energy to the plant. Smith (1969) suggested the term total nonstructural carbohydrate (TNC), which is more applicable to both animal and plant investigations.

SEASONAL CYCLE

The carbohydrates formed by photosynthesis have several possible roles including a primary use for growth. After translocation to the stem, root tips, cambium, and reproductive structures, TNC are converted into new protoplasm, cell walls, and other products of metabolism (Koslowski 1971). Mooney (1972) states that carbon assimilated in excess of demands may be stored as reserve compounds and later utilized during periods when construction demands are high. A considerable amount of carbohydrate is also oxidized in respiration (Kramer and Kozlowski 1979).

Ziegler (1964) states that fruit and seed formation is a main role of reserve material. Kramer and Kozlowski (1960) report that reproductive tissues are able to divert foods from vegetative tissues. Cameron and Borst (1938) found much lower starch content throughout the summer and autumn in branches of bearing avocado trees (Persea americana Mill.) than in non-bearing ones. Fruiting caused a decrease in starch reserves of Coffea trees and in total carbohydrate content of roots during the season of maximum growth (Navarette 1954). Tew (1970) observed that the length of time during which root suckers were produced by aspen (Populus tremuloides Michx.) was related to the amount of carbohydrate reserves, and Schier and Zasada (1973) found positive correlations between the weight of aspen suckers and the amount of carbohydrate reserves.

The importance of carbohydrate reserves for bud opening and shoot expansion is emphasized by rapid reserve depletion (Kozlowski and Keller 1966). Quinlan (1969) noted mobilization of ^{14}C labeled reserves to bud and shoot areas. Hansen (1971) estimated that one-half to two-thirds of the carbohydrate requirements for growth of flowers and shoots of apple (Pyrus Malus L.) trees very early in the growing season were supplied from reserves rather than from current photosynthate. This applied only to the period of development of the first 5 to 6 leaves, after which growth of fruits and shoots was attributed to utilization of products of current photosynthesis.

Kramer and Koslowski (1979) report marked variations exist in amounts of carbohydrates in various parts of woody plants and also large seasonal variations in amounts and kinds of carbohydrates present. Koslowski and Keller (1966) comment on the importance of distinguishing between total quantity and concentration of carbohydrates in different parts of trees. High concentrations often occur in tissues comprising a low proportion of total dry weight of the tree. Wenger (1953) and Kramer and Kozlowski (1960) found the concentration of carbohydrates is usually higher in the roots than tops. The carbohydrates in stems are concentrated in living cells, although living plus dead cells are usually used as the dry-weight base for calculating concentrations. This results in a very low concentration and is misleading as to quantitative distribution (Koslowski and Keller 1966). Apple trees studied by Murneek (1942) had a higher carbohydrate concentration in the roots than in stems, yet above-ground parts, which were about three times as heavy as the roots, contained more total carbohydrates.

PHENOLOGICAL EFFECTS

Stage of growth is the most important factor influencing carbohydrate reserve concentrations in plants (Coyne and Cook 1970). Regrowth following a dormant period or defoliation has been correlated with the carbohydrate reserve status of the plant (Smith 1962, Steinke and Booysen 1969 and Trilica and Cook 1971,1972). Koslowski and Keller (1966) stated that seasonal depletion and accumulation of carbohydrate reserves reflect variations among species in demands made on reserves by vegetative and reproductive growth. Trees that grow in intermittent flushes deplete small amounts of carbohydrates at each flush often showing several maxima and minima of reserves (Koslowski and Keller 1966).

Carbohydrate reserves are rapidly utilized to produce growth in early spring (Boo and Pettit 1975). McConnell and Garrison (1966) reported root carbohydrate to be depleted during the early growing season and during seed formation in bitterbrush [*Purshia tridentata* (Pursh) DC.]. Carbohydrates were translocated to the roots until leaf fall. Jones and Laude (1960) working with chamise (*Adenostoma fasciculatum* H. & A.) noted decreasing root reserves coincident with early spring twig growth.

Total nonstructural carbohydrates (TNC) of roots vary with phenological growth stages (Jones and Laude 1960, Jameson 1963, McConnell and Garrison 1966, Cook 1966, Boo and Pettit 1975). Donart (1969) related carbohydrate reserves of 6 mountian species to growth and development. Minimum root reserves were reached during early spring growth after approximately 15% of the total annual growth had been produced. Coyne and Cook (1970) studied seasonal trends in total available carbohydrates with respect to phenological stage of development for 8 salt-desert range species and concluded that maximum plant vigor in relation to carbohydrate reserves depended upon quantity stored at the end of the growing season. Respiration and slight growth during the dormant period causes a decline in stored reserves (Cook 1966).

DEFOLIATION

Any defoliation during the growing period results in reduced carbohydrate reserves (Cook 1966). Woods et al. (1959) reported a reduction in root carbohydrate content in turkey oak (Quercus laevis Walt.) and bluejack oak (Quercus incana Bartr.), which remained low for at least 12 weeks after top removal. When root reserves are limited the rate of growth may be reduced. Donart and Cook (1970) analyzed carbohydrate reserve levels in rabbitbrush [Chrysothamnus *viscidiflorus* (Hook) Nutt.] after foliage removal. Regrowth of rabbitbrush was slower and fewer stems produced when clipped at the low reserve level.

Many grassland ecologists consider fire as a natural and integral part of most grassland environments prior to the arrival of European man in North America (Aldous 1934, Komarek 1965, Bragg and Hulbert 1976). Love (1970) stated that the most extensive use of fire for range purposes is brush control to improve livestock grazing. The use of fire has been advocated in management of grassland preserves, particularly in tall-grass prairies where woody plant invasion is a problem (Anderson 1972). Woody plants have difficulty invading established grassland that is healthy and subject to recurring fires (Lemon 1970). Bragg and Hulbert (1976) report a 34% increase of woody plants on unburned (1937-1969) bluestem prairie in the Kansas Flint Hills in contrast to 1% increase on burned areas.

SECTION II: CHEMICAL CONTROL OF WOODY PLANTS

Successful chemical control of sprouting woody plant species has been variable and inconsistent (Sosebee 1983).

Physiological considerations are critical to effective control for this group of plants. Muzik (1976) considers species susceptibility (ecotype or variety), stage of growth and environmental conditions of the growing plant as the determining factors affecting selectivity to foliar-applied herbicides.

Brady (1971) found herbicidal control of deciduous plant species in the southern United States to be most effective during late spring and early summer. Coble et al. (1969) reported more effective control on fully mature leaves than on immature leaf sizes. Upchurch et al. (1969) increased control from 42 to 54% when trees were sprayed between mid-September and mid-October. The authors suggest a relationship between increased carbohydrate translocation and plant susceptibility. Susceptible species were found to be accumulating carbohydrates in root materials during the period when herbicides are most effective (Brady and Hall 1976).

Mesquite (*Prosopis* sp.), a sprouting woody plant species has been studied extensively to determine effective control parameters. Fisher et al. (1959) reported root reserve carbohydrates increase in honey mesquite (*Prosopis glandulosa* Torr.) from mid-May through early July and again during early August. Wilson et al. (1975) reported root reserves accumulate at 3 different times during the growing season. Late-season spraying of mesquite was found to be less effective than in the early growing season. Boo and Pettit (1975) reported premature leaf size, export of photosynthates, and development of leaf wax as reasons for erratic control results with sand shinnery oak (Quercus harvardii Rydb.). Wardlaw (1968) found that leaves are normally mature before they export reserves. Hull et al. (1974) also cited development of leaf surface wax as a negative factor influencing control of woody species.

Adverse environmental conditions can influence herbicide effectiveness, even though phenological and physiological conditions are conducive to control (Sosebee 1983). Since translocation of growth-regulating herbicides is closely associated with the translocation of organic food materials, any environmental factor such as light, water, temperature and nutrients which influence translocation of food reserves would probably influence systemic herbicide translocation (Muzik 1976).

Plant water stress, caused by inadequate or excessive amounts of water can result in ineffective control (Sosebee 1983). Soil temperatures also influence herbicide effectiveness in some species (Cords 1966, Dahl et al. 1971, Muzik 1976 and Dahl et al. 1978).

ABSORPTION AND TRANSLOCATION

Gross morphology is an important factor influencing foliar penetration of herbicides (Blackman et al. 1958). Ashton and Crafts (1981) consider absorption and translocation primarily dependent on a plant's molecular configuration, which determines its chemical and physical properties. The site of application is also an important factor influencing absorption and translocation of herbicides (Wardlaw 1974, Bukovac 1976 and Evert 1977). Foliar-applied herbicides must pass through cuticular layers, the cell wall, and the plasmalemma before reaching the symplast (Ashton and Crafts 1981). Aerial plant parts (leaves, stems, flowers, fruits, etc.) are covered by cuticle, which presents the major barrier to absorption (Bukovac 1976). The morphology of the waxy leaf cuticle varies with species influencing chemical interception and retention (Blackman et al. 1958, Ashton and Crafts 1981).

Once the herbicide is absorbed by leaves and stems, translocation in lethal amounts to the base and roots is imperative for mortality of a plant (Bovey and Meyer 1983). Ashton and Crafts (1973) have associated translocation of herbicides with carbohydrate movement. Crafts and Crisp (1971) reported on a number of studies showing that 2,4-D is translocated with assimilates in the phloem.

Muzik (1970) reported that translocation out of the leaf does not occur in the absence of photosynthesis. Rapid translocation of carbohydrates is necessary to move herbicides throughout the plant (Crafts and Crisp 1971). Ashton and Crafts (1981) stated that symplastically mobile herbicides, once absorbed by leaves, follow along with photosynthate via the same pathway. These authors present a revised concept of the mass flow hypothesis discussed by Crafts and Crisp (1971) as follows: the transport is along a physical turgor or osmotic gradient in the phloem maintained by a source-sink relationship.

HERBICIDE MIXTURES

Herbicide mixtures are often more active than individual chemicals for plant control without changing the total quantity of pesticide (Meyer and Bovey 1973). Bovey et al. (1970) reported that picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid) was more effective than dicamba (3,6-dichloro-o-anisic acid), 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid], or 2,4-D [2,4 dichlorophenoxy) acetic acid] on huisache (*Acacia farnesiana* (L.) Willd.) but some picloram could be replaced by a 1:1 ratio of picloram + 2,4,5-T mixture. Bovey et al. (1969) also reported this combination to be effective on live oak

(*Quercus virginiana* Mill.). Haas et al (1970) showed 2,4-D + picloram to be the more effective mixture for control of Macartney rose (*Rosa bracteata* Wendl.) than any other individual chemical tested. Scifres and Hoffman (1972) found that dicamba applied at equivalent rates as 2,4,5-T, controlled the same percentage of honey mesquite. The authors also effectively substituted dicamba for 2,4,5-T in combination with picloram for honey mesquite control.

HERBICIDE EFFICACY

Picloram has been found by numerous researchers to be an effective herbicide on sprouting plant species (Bovey et al. 1970, Bovey et al. 1972, Meyer and Bovey 1973). Meyer and Bovey (1984) reported a 100% reduction of Macartney rose canopy cover initially and maintained 73% mortality after 3 years. Meyer et al. (1976) earlier reported an 86% reduction of Macartney rose canopy with 52% mortality after 2 years when sprayed with picloram in April at a rate of 2.2 kg/ha. Bovey et al. (1968, 1970) showed that picloram was more effective than dicamba or 2,4,5-T on huisache. Haas et al. (1970) found that sprays of picloram were more effective on Macartney rose in late April and early May than later in the growing season. However, 2,4-D applications were more effective when made later in the growing season. Several authors have reported that spring treatments with picloram +

2,4-D is an effective control measure. Scifres (1972) noted a synergistic effect on sand shinnery oak with sprays of picloram + 2,4,5-T which substancially increased grass production.

Dicamba, is an effective growth regulator herbicide (Whitworth and Tolman 1968). Meyer and Bovey (1973) reported that mixtures of picloram + dicamba at 0.56 + 0.56 and 1.12 + 1.12 kg/ha were more effective for defoliation and mortality of honey mesquite than picloram, dicamba, picloram + 2,4,5-T, dicamba + 2,4,5-T or 2,4,5-T alone. Scifres and Hoffman (1972) have shown that dicamba could be substituted for 2,4,5-T without reducing percent honey mesquite mortality. Scifres (1972) observed a reduction of sand shinnery oak densities in additive effect when silvex or 2,4,5-T was combined with dicamba. Bovey et al. (1981) found triclopyr ester {[(3,5,6-trichloro-2-pyridinyl)oxy] acetic acid} at 0.56 kg/ha and dicamba + triclopyr ester at 0.28 + 0.28 kg/ha effectively reduced canopies of white brush (Aloysia lycioides Cham.), honey mesquite and huisache in greenhouse studies. Bovey and Mayeux (1980) reported 70% and 90% mortality of honey mesquite stem tissue with the ester and amine formulations of triclopyr. However, Jacoby et al. (1982) reported only 9% and 8% honey mesquite plant mortality 30 months post-spraying with triclopyr ester and amine, respectively.

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TABLE A-1 ROOT AND STEM TOTAL NONSTRUCTURAL CARBOHYDRATE CONCENTRATION ANALYSIS OF VARIANCE FOR THE KEATS LOCATION IN 1983.

DEPENDENT VARIABLE: BURNED vs UNBURNED ROOT TNC

SOURCE	DF	S.S.	F VALUE	PR > F
TRTMT	1	38.41	33.45	0.0001
DATE	14	209.31	13.02	0.0001
TRTMT*DATE	14	88.89	5.53	0.0001
ERROR	90	103.34		

DEPENDENT VARIABLE: BURNED ROOT TNC

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	14	162.12	16.01	0.0001
ERROR	45	32.55		

DEPENDENT VARIABLE: UNBURNED ROOT TNC

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	14	136.08	6.18	0.0001
ERROR	45	70.78		

DEPENDENT VARIABLE: STEM TNC

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	14	89.84	18.52	0.0001
ERROR	45	15.59		

TABLE A-2 ROOT AND STEM TOTAL NONSTRUCTURAL CARBOHYDRATE CONCENTRATION ANALYSIS OF VARIANCE FOR THE KEATS LOCATION IN 1984.

DEPENDENT VARIABLE: UNBURNED vs BURNED ROOT TNC

SOURCE	DF	S.S.	F VALUE	PR > F
TRTMT	2	29.84	14.04	0.0001
DATE	12	429.77	33.71	0.0001
TRTMT*DATE	21	104.72	4.69	0.0001
ERROR	108	114.75		

DEPENDENT VARIABLE: BURNED ROOTS

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	12	240.91	20.53	0.0001
ERROR	39	38.14		

DEPENDENT VARIABLE: 2-YR BURNED ROOTS

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	9	199.61	15.38	0.0001
ERROR	30	43.25		

DEPENDENT VARIABLE: UNBURNED ROOTS

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	12	45.63	6.74	0.0001
ERROR	39	22.00		

TABLE A-4 ROOT AND STEM TOTAL NONSTRUCTURAL CARBOHYDRATE CONCENTRATION ANALYSIS OF VARIANCE FOR SMITH LOCATION IN 1983.

DEPENDENT VARIABLE: BURNED vs UNBURNED ROOT TNC

SOURCE	DF	S.S.	F VALUE	PR > F
TRTMT	1	31.10	45.26	0.0001
DATE	11	161.65	21.39	0.0001
TRTMT*DATE	11	34.48	4.56	0.0001
ERROR	72	49.48		

DEPENDENT VARIABLE: ROOT TNC

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	11	83.46	20.85	0.0001
ERROR	36	13.10		

DEPENDENT VARIABLE: UNBURNED ROOTS

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	11	112.67	10.14	0.0001
ERROR	36	36.37		

DEPENDENT VARIABLE: STEM TNC

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	11	86.05	36.39	0.0001
ERROR	36	7.74		

TABLE A-5 ROOT AND STEM TOTAL NONSTRUCTURAL CARBOHYDRATE CONCENTRATION ANALYSIS OF VARIANCE FOR THE SMITH LOCATION IN 1984.

DEPENDENT VARIABLE: BURNED vs UNBURNED ROOT TNC

SOURCE	DF	S.S.	F VALUE	PR > F
TRTMT	1	22.10	21.47	0.0001
DATE	12	420.40	34.03	0.0001
TRTMT*DATE	12	24.64	1.99	0.0357
ERROR	78	80.29		

DEPENDENT VARIABLE: BURNED ROOT TNC

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	12	172.96	12.32	0.0001
ERROR	39	45.64		

DEPENDENT VARIABLE: UNBURNED ROOT TNC

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	12	272.08	25.52	0.0001
ERROR	39	34.65		

DEPENDENT VARIABLE: STEM TNC

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	12	83.99	12.92	0.0001
ERROR	39	21.13		

TABLE A-6 HERBICIDAL CONTROL TREATMENTS (14 MONTH EVALUATION) ANALYSIS OF VARIANCE FOR THE SMITH LOCATION IN 1983.

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	1	467.51	3.06	0.0975
REP(DATE)	2	1363.32		
TRTMT	9	10721.34	7.79	0.0001
DATE*TRTMT	9	1777.87	1.29	0.3069
ERROR	18	2753.82		

TABLE A- HERBICIDAL CONTROL TREATMENT (14 MONTH EVALUATION) ANALYSIS OF VARIANCE FOR THE KEATS LOCATION IN 1983.

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	1	473.07	1.57	0.2257
REP(DATE)	2	401.47		
TRTMT	9	12985.57	4.80	0.0023
DATE*TRTMT	9	2639.81	0.98	0.4907
ERROR	18	54.1053		

TABLE A-7 HERBICIDAL CONTROL TREATMENT (2 MONTH EVALUATION)

ANALYSIS OF VARIANCE FOR THE SMITH LOCATION IN 1983.

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	1	4.96	0.13	0.7500
REP(DATE)	2	78.59		
TRTMT	9	10527.78	5.49	0.0012
DATE*TRTMT	9	1000.83	0.52	0.7500
ERROR	18	3838.51		

TABLE A-8 HERBICIDAL CONTROL TREATMENT (2 MONTH EVALUATION)

ANALYSIS OF VARIANCE FOR THE KEATS LOCATION IN 1983.

SOURCE	DF	S.S.	F VALUE	PR > F
DATE	1	110.92	0.85	0.2500
REP(DATE)	2	2612.00		
TRTMT	9	13172.58	9.99	0.0010
DATE*TRTMT	9	1973.95	1.50	0.2500
ERROR	18	2636.09		

I - PRESCRIBED BURNING EFFECTS ON THE SEASONAL CARBOHYDRATE LEVELS OF ROUGHLEAF DOGWOOD IN THE KANSAS FLINT HILLS

II - CHEMICAL CONTROL OF ROUGHLEAF DOGWOOD IN THE KANSAS FLINT HILLS

by

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B.S., Kansas State University, 1982

AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Roughleaf dogwood (Cornus drummondii Meyer) is a major invading shrub of the bluestem prairie decreasing production and availability of desirable forage species. Total nonstructural carbohydrate (TNC) reserves as related to phenological development were determined in the roots and stems of roughleaf dogwood during the 1983 and 1984 growing seasons. The effect of late-spring burning on TNC levels was determined to provide information for development of an integrated (burning + herbicide) control method. Root TNC concentrations were the best indicator of phenological changes as stem materials showed little or no fluctuation to changes in plant development. Unburned root TNC levels rapidly decreased in the spring to the full leaf stage of development then rapidly increased to higher concentrations during floral development. The low-point in TNC concentration for the burned plants was extended 4 to 6 weeks later into the growing season. The greatest reduction of root TNC occurred during mid-June to mid-July in the burned samples. Burning for two consecutive years reduced TNC significantly compared to the one-year burned samples, extending the low-point into August.

Roughleaf dogwood was treated with several foliar-applied herbicides at 2 locations in the Flint Hills of Kansas to find a replacement for 2,4,5-T. Triclopyr ester [3,5,6-trichloro-2-pyridinlyoxy) acetic acid] at 2.2 kg/ha or in

combination with 2,4-D (1 + 1 kg/ha), triclopyr amine alone (2.2 kg/ha) or in combination with 2,4-D (1 + 1 kg/ha) and picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid) (0.56 kg/ha) were all equally effective ($p<0.05$) at controlling roughleaf dogwood at both locations providing greater than 62% canopy cover reduction. Sunlight intensity differences between the 2 plot locations affected the amount of defoliation. Triclopyr formulations unaffected by light intensity whereas 2,4-D + 2,4,5-T, picloram + 2,4-D, or dicamba + 2,4-D provided less control under reduced light intensity.