THE EFFECT OF TEBUTHIURON AND 2,4,5-T ON CARBOHYDRATE LEVELS IN ROOTS OF BLACKJACK OAK AND WINGED ELM

By

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Let education be a sort of amusement;
You will then be better able to find
out the natural bent — Plato

CHAPTER I

INTRODUCTION

There are thousands of acres in Oklahoma that are covered with brush in which the production potential could be greatly enhanced if economic brush control practices were employed. The use of bulldozers has been an effective brush control practice, but the cost is prohibitive. The phenoxy herbicides, such as 2,4,5-T (chemical names for all herbicides reviewed are listed in Table I), have been the herbicides most commonly used in brush control. Immediate results in terms of canopy reduction are apparent with treatments of 2,4,5-T but they are often short-lived since resprouting soon occurs producing another canopy. Some of the problem may be that non-structural carbohydrates in the roots of treated trees are not depleted and there are adequate food reserves for the initiation of new foliar growth. If this is the case, other compounds should be explored with regards not only to their initial effectiveness as a herbicide for brush control, but also their effect on total non-structural carbohydrates (TNC) levels in the roots.

Tebuthiuron has shown promise for being a good herbicide for the control of certain brush species. Soil treatments of 2.24 kg/ha on mixed brush have given excellent control of elms (Ulmus spp.) and oaks (Quercus spp.). Tebuthiuron possess several desirable characteristics such as effective residual activity, limited lateral movement, minimum leaching, and good stability on the soil surface. There also has been

TABLE I

COMMON AND CHEMICAL NAMES OF HERBICIDES

Common Name	Chemical Name	Solubility in H_2O (ppm)	
2,4-D	(2,4-dichlorophenoxy) acetic acid	600	(20 C)
2,4,5-T	(2,4,5-trichlorophenoxy) acetic acid	238	(30 C)
Bromacil	5-bromo-3-sec-butyl-6-methyluracil	815	(25 C)
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea	42	(25 C)
Fenuron	1,1-dimethyl-3-phenylurea	3850	(25 C)
Linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea	75	(25 C)
Monuron	3-(p-chlorophenyl)-1,1-dimethylurea	18	(25 C)
Neburon	1-butyl-3-(3,4-dichlorophenyl)-1-methylurea	5	(24 C)
Picloram	4-amino-3,5,6-trichloropicolinic acid	430	(25 C)
Silvex	2-(2,4,5-trichlorophenoxy)propionic acid	140	(25 C)
Tebuthiuron	N[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N-N'-dimethylurea	2500	(25 C)

less resprouting with tebuthiuron than with 2,4,5-T treatments. This may be due to the depletion of root reserves by the trees treated with tebuthiuron. There is usually only the initial defoliation of trees treated with 2,4,5-T whereas there are several defoliations with tebuthiuron the first season and some additional defoliations have been noted into the second and third years after treatment.

The objectives of this study were; (1) to evaluate the defoliation and resprouting of blackjack oak and winged elm treated with 2,4,5-T and tebuthiuron, (2) to determine the non-structural carbohydrate levels in roots of blackjack oak and winged elm treated with 2,4,5-T and tebuthiuron, and (3) to correlate soil temperature and soil moisture with tree response and carbohydrate levels.

CHAPTER II

LITERATURE REVIEW

Properties of 2,4,5-T

The phenoxy herbicides have been used extensively in brush control. It has been found that chlorophenoxy herbicides have profound effects upon the growth and structure of plants. Epinastic bending may follow application within minutes, growth may cease within hours and over days of exposure formation of tumors, secondary roots, and fasciated structures is pronounced (Ashton and Crafts, 1973).

Wills and Basler (1971) recognized that translocation of phloem-mobile herbicide molecules occurs along with the assimilate stream through the phloem system. It seems apparent for a thorough distribution of a herbicide active movement of foods in the plant is required. Badiei et al. (1966) reported that a high sugar level in root tissue was not necessary for good translocation, but that translocation of sugars toward root tissue was essential. They also found that absorption and translocation of 2,4,5-T in blackjack oak (common and scientific names of all plant species reviewed are listed in Table II) were inversely related to soil moisture stress. Pallas (1959) reported that plants growing in soil with a moisture level near the wilting point translocated only half as much 2,4-D or plants growing in soil at field capacity. However, Wills and Basler (1971)

TABLE II

COMMON AND SCIENTIFIC NAMES OF PLANTS

Common Name	Scientific Name
Alfalfa	Medigo sativa L.
Aspen	Populus tremuloides Michx.
Bahiagrass	Paspalum notalum Flugge.
Berlandier wolfberry	Lycium berlandieri Dun.
Bermudagrass	Cynodon dactylon (L.) Pers.
Bitterbrush	Purshia tridentata (Pursch) DC.
Blackjack oak	Quercus marilandica Muenchh.
Chokeberry	Aronia melanocarpa (Michx.) Willd.
Citrus	Citrus spp.
Common groundsel	Senecio vulgaris L.
Common ragweed	Ambrosia artemisiifolia L.
Corn	Zea mays L.
Creosotebush	Larrea tridentata (DC.) Cov.
Downy brome	Bromus tectorum L.
Henbit	Lamium amplexicaule L.
Hickory	Carya texana Buckl.
Honey mesquite	Prosopis juliflora (Swartz) DC. var. glandulosa (Torr.) Cockerell
Japanese brome	Bromus japonicus Thunb.
Leatherleaf	Chamaedaphne calvculata (L.) Moench
Live oak	Quercus virginiana Mill.
Marestail	Erigeron canadensis L.
Mustard	Brassica juncea (L.) Coss.

TABLE II (Continued)

Common Name	Scientific Name
Oats	*Avena sativa* L.
Post oak	*Quercus stellata* Wangenh.
Sand shinery oak	*Quercus harvardii* Rydb.
Soybean	*Glycine Max* (L.) Merr.
Sphagnum moss	*Sphagnum magellanicum* Brid.
Sugar maple	*Acer saccharum* Marsh
Tarbush	*Flourensia cernua* DC.
Turbinella oak	*Quercus turbinella* Greene
Turkey mullein	*Eremocarpus setigerus* Benth.
Turkey oak	*Quercus laevis* Walt.
Weeping lovegrass	*Eragrostis curvula* (Schrad) Nees
Whitebrush	*Aloysia lycioides* Cham.
Whitethorn	*Acacia constricta* Benth.
Winged elm	*Ulmus alata* Michx.
Yaupon	*Ilex vomitoria* Ait.

found that with winged elm variations in soil moisture had little effect on absorption, but a decrease in soil moisture did reduce translocation from leaves to roots.

Brush Control with Auxin Type Herbicides

Eaton et al. (1970) determined that the stage of growth of blackjack oak and post oak was of primary importance with regard to first year defoliation. They found the plants were most susceptible six to eight weeks after the last killing frost when the leaves had reached full size. They also concluded that high air temperature, low relative humidity, and poor spray coverage all reduced the effectiveness of the sprays. Dahl et al. (1971) found that soil temperature at the 18 inch depth was the most important factor affecting response of honey mesquite to 2,4,5-T applications.

Elwell (1964) and Darrow and McCully (1955) indicated that two aerial applications of 2,4,5-T totaling three to four lb/A with not more than two years between treatments were required to effectively control blackjack oak and post oak. Bovey et al. (1969) also reported that single or repeated applications of 2,4,5-T did not satisfactorily control live oak. Scifres (1972) reported that applications of 2,4,5-T and silvex from May 1 to June 1 when sand shinnery oak is in full leaf and actively growing are most effective. He also found that combinations of silvex or 2,4,5-T with picloram controlled more sand shinnery oak than expected and substantially increased grass production. Elwell (1967) concluded that foliar applications of 2,4,5-T did not effectively control winged elm. Stritzke (1975) found that the addition of NH_4SCN to 2,4,5-T consistently increased control.

Properties of Tebuthiuron and Other Urea Type Herbicides

Tebuthiuron is a member of the substituted urea family of herbicides. Unlike the other substituted urea herbicides, it has a thiadiazol group substituted instead of a phenyl group (Figure 1).

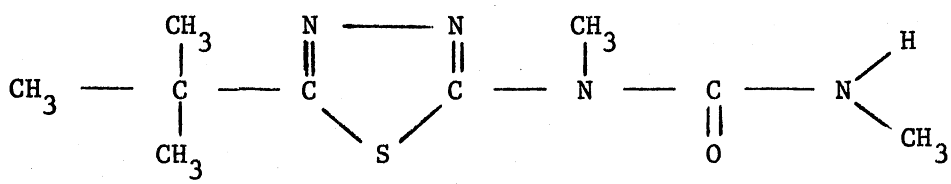

Figure 1. Chemical Structure of Tebuthiuron

Tebuthiuron has a water solubility of 2500 ppm at 25 C. It is one of the most water soluble urea herbicides. Tebuthiuron is light stable and dissipates in soil primarily by microbial degradation (Walker et al. 1973). Rainfall is necessary to move the tebuthiuron into the soil but it is very stable on the soil surface for extended periods of time (Walker et al. 1973). This stability of tebuthiuron allows pelleted surface applications to remain on the surface for a considerable length of time before rainfall without significant loss of herbicidal activity (McNeill et al. 1977). They found tebuthiuron exhibits a soil half-life of about 15 months and this persistence coupled with resistance to leaching keeps tebuthiuron active in the root zone long enough to give long-term weed and brush control.

Inhibition of the Hill reaction of photosynthesis is generally accepted to indicate the primary site of action of the urea herbicides. This involves the site of oxygen evolution in photosystem II. It also prevents the formation of ATP and NADPH which are required for carbon fixation (Ashton and Crafts 1973).

Monuron was the first herbicide known to be translocated only by the apoplastic system and its translocation pattern has been used as a standard to indicate this type of transport by other compounds (Ashton and Crafts, 1973). Bucha and Todd (1951) concluded from their original greenhouse studies with monuron that it was readily absorbed by the root system and translocated to the leaves. Baur and Bovey (1975) also found that tebuthiuron translocation was limited to the apoplast (non-living tissue). Steinert (1976) found that herbicidal activity of tebuthiuron was due primarily to root uptake and that accumulation was greatest in the tops of ragweed plants treated through the nutrient solution.

Plant Response to Urea Herbicides

At low rates urea herbicides have been widely accepted as selective preemergence and postemergence herbicides. At higher rates they have been used extensively as general soil sterilants (McWhorter 1963).

It appears that certain species of plants have an inherent resistance to some of the urea herbicides. Ashton and Crafts (1973) reported that citrus species, turkey mullein, and common groundsel are examples of plants that are resistant to monuron. Steinert (1976) found that soybeans and corn were least susceptible to tebuthiuron whereas Japanese brome, mustard, and bermudagrass were very susceptible.

It also appears that all urea herbicides are not equally phytotoxic. Sheets and Crafts (1957) reported that six times as much fenuron as diuron was required to inhibit the growth of oats by 50%, when applied via the nutrient solution, and four times as much fenuron as monuron.

Diuron at 3.36 kg/ha, as reported by Arnold and Santelmann (1970), gave satisfactory control of henbit and marestail on dormant alfalfa. With spring applications of diuron and linuron to native grass, 60% of the downy brome could be controlled without injuring the grass (Smith and Moore, 1969).

Brush Control with Urea Type Herbicides

The selective brush control with urea type herbicides was noted by Darrow and McCulley in 1959. They found that aerial application of pelleted fenuron at 4.48 kg/ha produced effective control of post oak, blackjack oak, and winged elm. Rodgers et al. (1962) found that monuron, diuron, and fenuron at rates of 11.2 kg/ha were effective in controlling turkey oak, thus allowing bahiagrass and weeping lovegrass to be established on the treated sites. Wagle and Schmutz (1963) indicated that applications of fenuron resulted in good control of turbinella oak while allowing for significant increases in grass production and quality. Schmutz (1967) stated that fenuron and monuron were both effective soil herbicidal treatments for controlling creosotebush, tarbush, and whitethorn. Bovey et al. (1969) found that bromacil and fenuron were most effective during spring and fall months.

The best results were obtained if the herbicide was leached adequately into the root area by a rain soon after treatment. Dana (1967) found that fenuron was not effective on leatherleaf and chokeberry in Sphagnum moss bogs. Fenuron also gave erratic control of winged elm (Kirby et al. 1967).

Baur and Bovey (1975) have observed control of yaupon, post oak and blackjack oak with soil applications of tebuthiuron using 2.24 to 4.48 kg/ha. Nickels and Stritzke (1977) also noted excellent tree kill of post oak, blackjack oak, hickory and winged elm with 4.48 kg/ha of tebuthiuron. Scifres and Mutz (1977) found that tebuthiuron applied at 2.24 kg/ha effectively controlled whitebrush and Berlandier wolfberry in south Texas. They also found that more than 85% of the populations were completely defoliated and not resprouting after two years.

Carbohydrate Levels in Plants

Kramer and Kozlowski (1960) state that seasonal depletion and accumulation of carbohydrate reserves reflect variations among species in demands made on foods by vegetative and reproductive growth. Trees that grow in intermittent flushes deplete small amounts of carbohydrates at each flush and often show several maxima and minima of reserves. With most deciduous forest trees of the Temperate Zone, carbohydrate reserves decrease sharply during spring growth to a minimum in early summer and they subsequently increase to an autumn peak and finally decline slightly during the winter.

Woods et al. (1960) found that carbohydrate reserves in roots of turkey oak dropped rapidly during the spring flush of growth and reached a low point around the first of May. Tew (1969) states that soluble sugar and starch of aspen was lowest immediately after leaf flush in the spring. McConnell and Garrison (1966) working with bitterbrush reported root carbohydrate reserves to be depleted during the early growing season and during seed production. Coyne and Cook (1970) also concluded that the most important factor influencing carbohydrate reserves in plants is the stage of growth.

It would be reasonable to assume that any disruption of the plant growth would alter carbohydrate reserves in a plant. Donart and Cook (1970) found that defoliation and subsequent regrowth of desert range plants during early spring caused a reduction of up to 20% in reserve carbohydrates. Trlica and Cook (1971) working with several desert range species state that reduced carbohydrate reserve levels in defoliated plants were the result of continued respiration, reduction in photosynthesis, and the use of reserves in producing regrowth. They found that there was a 5 to 28% reduction in available carbohydrates due to depletion, depending upon the species sampled. They also concluded that the more regrowth that was attained after defoliation in the current growing season by a species, the greater was the carbohydrate reserve storage by fall.

Parker and Houston (1971) showed that artificial defoliation of sugar maple trees throughout the growing season caused significant reduction in carbohydrate levels in the roots. Wargo et al. (1972) stated that severely defoliated sugar maple trees refoliated the same season, but the starch content was reduced by 80%. They also found that root starch was lowest in trees defoliated most often.

Boo and Pettit (1975) found that mechanically shredding the roots of sand shinnery oak with a power-take-off driven "flail type" shredder significantly reduced root carbohydrate reserves for six months. However, this was only a temporary effect and by December the carbohydrate levels were essentially the same as the unshredded roots.

Reductions of carbohydrates in plants by urea type herbicides have also been reported. As early as 1955 Cook showed that monuron caused a decrease in the carbohydrate content of the aerial portion of some terrestrial plants. Walsh and Grow (1977) reported that diuron, neburon, monuron and fenuron depressed carbohydrate levels of six species of marine algae.

CHAPTER III

METHODS AND MATERIALS

Winged Elm and Blackjack Oak Areas

Winged elm and blackjack oak were the two brush species selected for evaluation of total non-structural carbohydrates (TNC) in the roots. The winged elm had been planted into the area on a 3.0 x 3.0 m grid in 1971. The soil type was a Port silt loam presently classified as a fine silty, mixed, Thermic Cumulic Haplustolls. The blackjack oak were resprouts located on a Bates fine sandy loam series and had been bulldozed in 1964. The Bates series is classified as a fine loamy, siliceous, Thermic Typic Argiudolls. See Table III for the physical properties of the two soils.

Tebuthiuron (10% pellets) and the low volatile ester formulation of 2,4,5-T were applied to both the winged elm and blackjack oak. The winged elm trees were pre-selected prior to treatment by height. They were placed into five height categories; trees less than 1.2 m, 1.2 to 1.5 m, 1.5 to 1.8 m, 1.8 to 2.1 m, and those above 2.1 m tall. On February 12, 1976, 125 winged elm (25 trees per height category) were treated with 7.5 grams of tebuthiuron (10% pellets) applied on a 1.8 x 1.8 m area (equivalent to 2.24 kg/ha) around each tree. On May 28, 1976, 60 winged elm were selected by height categories and foliar treated with a solution of 2,4,5-T. The solution was a mixture

TABLE III

PHYSICAL PROPERTIES OF SOILS FROM BLACKJACK OAK AREA, WINGED ELM AREA AND BURNED AREA

Physical Properties	Location		
	Blackjack Oak	Winged Elm	Burned Area
Textural Class	sandy loam	silt loam	sandy loam
Percent Sand	58.5	27.0	58.5
Percent Clay	14.5	25.0	12.5
Percent Silt	27.0	52.0	29.0
Percent Organic Matter	1.74	0.98	1.52
Cation Exchange Capacity*	6.75	8.06	14.32

*Milliequivalent per 100 gram soil.

of 63 ml of 2,4,5-T (1,183 gms/liter) in 3.8 liters of water sprayed for nine seconds with a hand sprayer (equivalent to 2.24 kg/ha).

In the blackjack oak area on February 12, 1976 five plots (15.2 x 15.2 m) were treated with tebuthiuron (10% pellets) equivalent to 2.24 kg/ha. On May 28, 1976, three plots (15.2 x 15.2 m) were treated with a solution of 2,4,5-T. The solution was a mixture of 95 ml of 2,4,5-T (1,183 gms/liter) plus 95 ml of diesel in 18.9 liters of water foliar applied with a hand sprayer until the solution dripped from the leaves.

Sampling of the roots began for the untreated trees on February 12, 1976. Trees treated with tebuthiuron were first sampled April 26, 1976, and sampling for trees treated with 2,4,5-T began on June 8, 1976. Sampling was done twice monthly from April 12 until September 15, 1976. Root samples from five trees were collected from each treatment at each sampling date.

The roots that were dug ranged from 0.5 to 3.0 cm in diameter. The roots were placed in an oven (65 C) and dried for 48 hours. After drying, the bark was removed by scraping with a pocket knife and the roots were ground in a Wiley mill to pass through a 2.0 mm screen. The roots were then analyzed for TNC content using the Anthrone method (Yemm and Willis 1954). Results of preliminary tests indicated the 2.0 mm grinding did not differ from the 1.0 mm grinding and the TNC content of the roots did not vary drastically within the 0.5 to 3.0 cm diameter range.

On each sampling date soil temperature at 10.2 and 30.5 cm and soil moisture at 30.5 cm was determined. The defoliation of each sampled tree was visually estimated on a scale of 0 to 100%.

The analysis used to determine the effect on TNC by the treatments was a randomized block design with sampling dates used as blocks. A regression analysis was used to estimate the concentrations of TNC levels in the roots on a given sampling date using the variables, soil temperature at 10.2 cm and 30.5 cm, the height categories (winged elm), defoliation, and days since application of the treatment.

Evaluation of Fire Plus Tebuthiuron in Blackjack Oak

The area, located on the Sarkey Foundation near Lamar, Oklahoma was burned March 22, 1976. The soil is a sandy loam of the Hector-Hartsells association. See Table III for the soil properties. The area was divided into main plots (burned and unburned). Each plot was subdivided into 30.5 x 30.5 m subplots and one-half treated on April 8, 1976, with tebuthiuron (20% pellets) equivalent to 2.24 kg/ha. The study was replicated three times. Sampling dates were July 20, 1976, October 27, 1976, and March 10, 1977.

Root samples were taken from one blackjack oak in each sub-plot. The roots were placed in an oven (65 C) for 48 hours, scraped with a pocket knife to remove bark and then ground in a Wiley mill to pass through a 2 mm screen. The roots were then analyzed for TNC by using the Anthrone method.

To determine the visual effectiveness of the treatment, percent defoliation was taken during the first growing season after treatment on September 29, 1976. The experiment was analyzed as a split-plot design.

Laboratory Analysis

After the root samples were ground, 0.5 gm of the root sample was placed in a 250 ml beaker with 50 ml of 0.2 N HCl and allowed to boil slowly for one hour. The root solution was then filtered into a 100 ml volumetric flask. The beaker and filtrate were washed with 50 ml deionized water and the solution was then brought to 100 ml volume. Then 0.1 ml of the sample was placed into a 20 ml test tube with 0.9 ml of deionized water. The Anthrone reagent, as described by Yemm and Willis (1954) was used to determine the TNC content. This method was used since there are no serious interactions of hexoses and pentoses. The Anthrone reagent (5.0 ml) was then added to the root solution and agitated. The solution was then placed in a hot water bath for 15 minutes and followed by 20 minutes in a cold water bath. The samples were then read for optical density on a spectrophotometer (B and L Spectronic 20) at 620 mu.

Standards were used containing 0, 40, 80, 120, 200 μg of glucose per one ml of water to serve as a basis for comparison with the unknown TNC content of the root samples.

CHAPTER IV

RESULTS AND DISCUSSION

Winged Elm and Blackjack Oak Areas

On the first sampling date (February 12, 1976) the roots of untreated winged elm contained 22.9% TNC (Figure 2). There was a decline of TNC in early spring with leaf initiation and by April it was less than 14%. After the leaves were full size (4 to 6 cm long) TNC began to increase and by the October sampling the roots contained 32.3% TNC (Table IV).

The TNC content in the roots of untreated blackjack oak was essentially the same as that for the untreated winged elm (Figure 3). The major difference was the decline of TNC in the roots of blackjack oak was delayed resulting in a greater TNC content in late March and early April. By May 13 the leaves were essentially fully developed (Table V) and the TNC were starting to accumulate.

On April 26 winged elm treated with tebuthiuron had a TNC content in the roots of 9.9% (Figure 2). This was 4% lower than the untreated trees (13.3%). The TNC content continued to decline and by August 18 it was only 2.6%, with most of the trees completely defoliated (Table VI). All of the smaller trees ($<$ 1.2, 1.2 to 1.5 and 1.5 to 1.8 m) were considered dead by the August 18 sampling and only the larger trees (1.8 to 2.1 and $>$ 2.1 m) were sampled after that date.

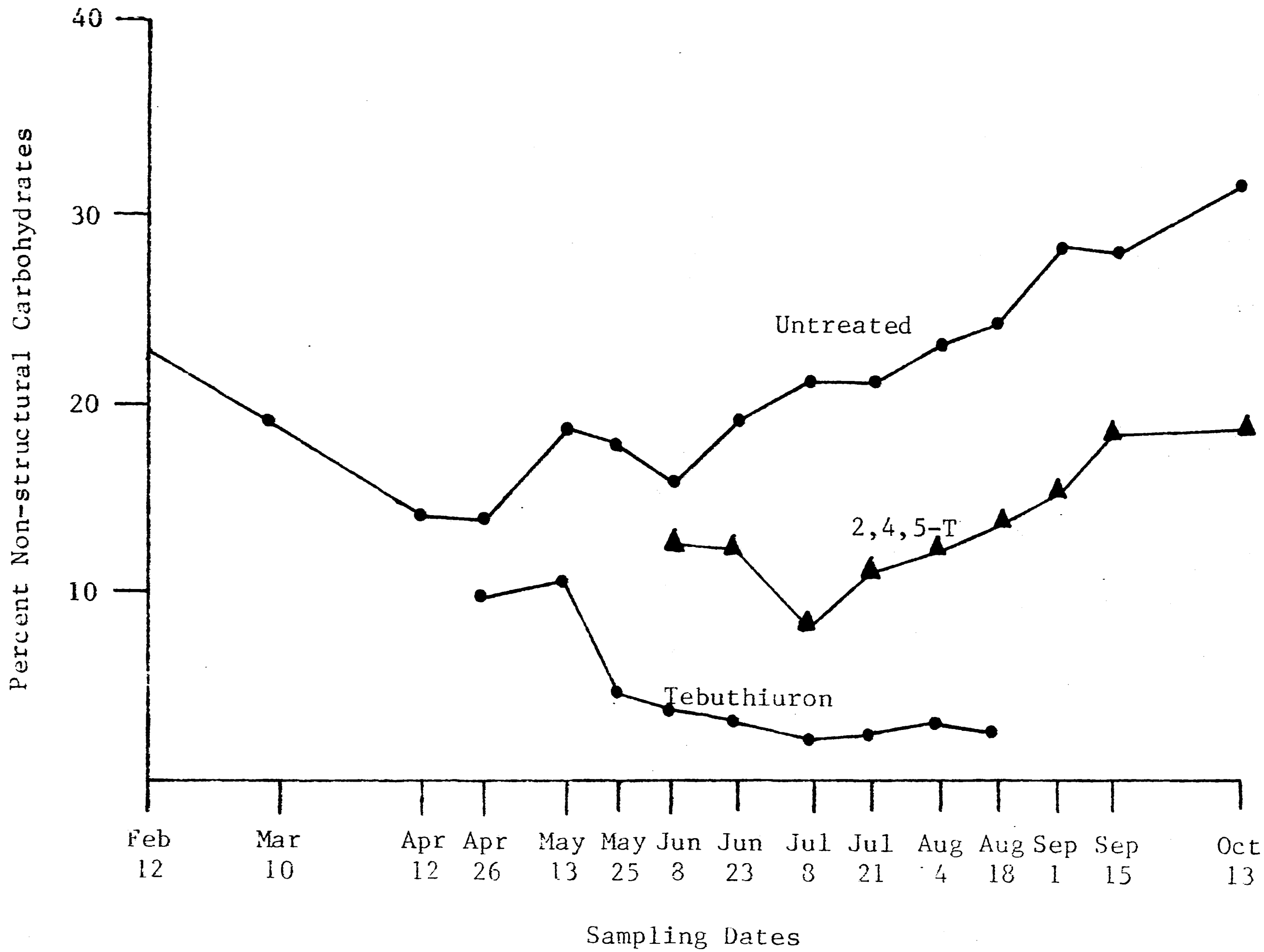

Figure 2. The Percent of Non-structural Carbohydrates in Roots of Untreated Winged Elm and in Roots of Trees Treated with Tebuthiuron and 2,4,5-T on Various Sampling Dates

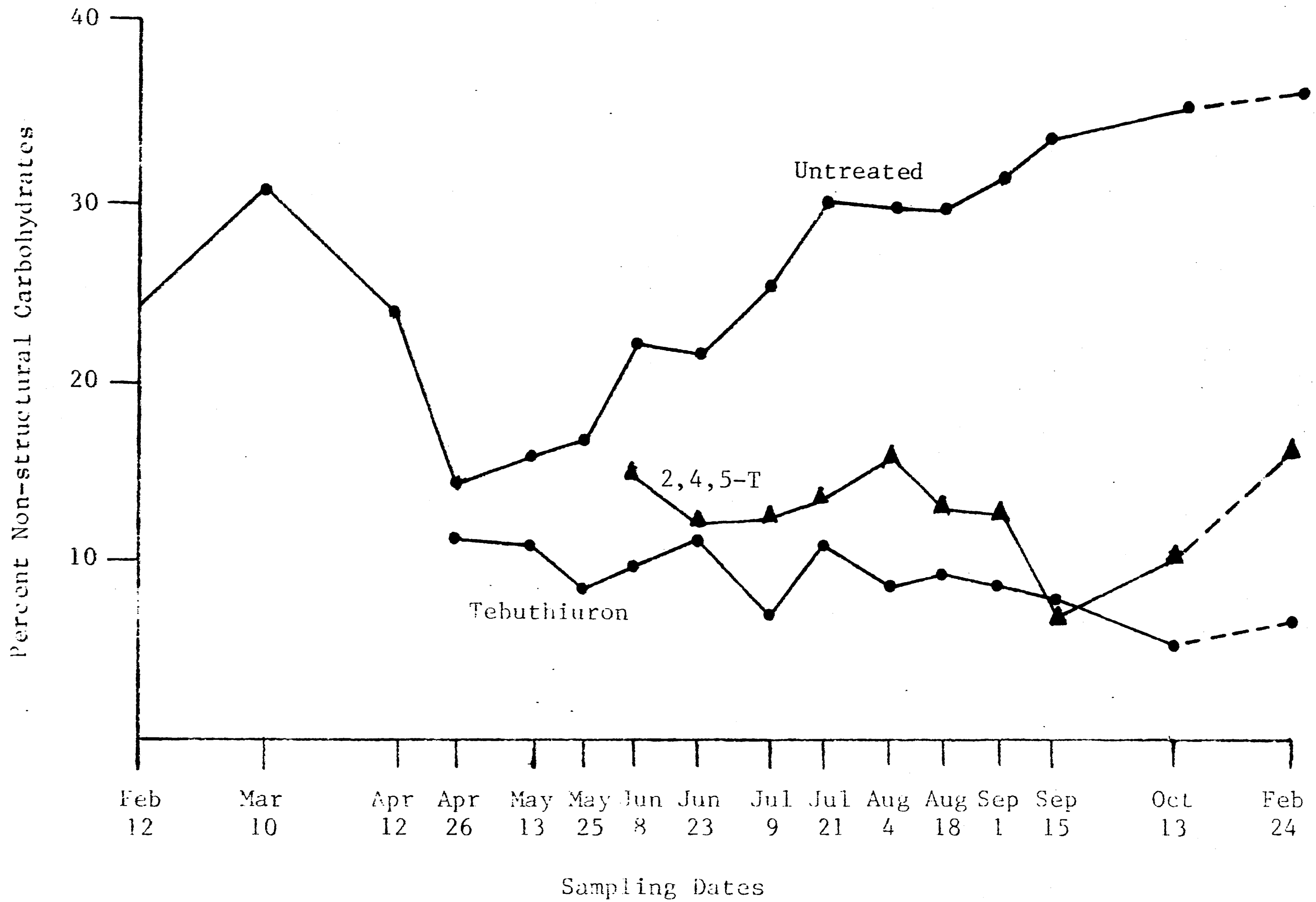

Figure 3. The Percent of Non-structural Carbohydrates in Roots of Untreated Blackjack Oak and in Roots of Trees Treated with Tebuthiuron and 2,4,5-T on Various Sampling Dates

TABLE IV

LEAF LENGTH AND PERCENT TOTAL NON-STRUCTURAL CARBOHYDRATES IN THE ROOTS OF WINGED ELM TREATED WITH TEBUTHIURON AND 2,4,5-T ON VARIOUS SAMPLING DATES

		Treatments			
Sampling Date	Leaf Length	No Herbicide %	Tebuthiuron %	2,4,5-T %	LSD Values .05 Level
February 12	Dormant	22.90	-	-	
March 10	Budding	19.18	-	-	
April 12	2-3 cm	13.79	-	-	
April 26	3-4 cm	13.37	9.99	-	4.80
May 13	4-5 cm	19.12	10.51	-	8.97
May 25	4-6 cm	18.80	4.68	-	6.22
June 8	4-6 cm	15.86	3.87	12.83	7.07
June 23	5-7 cm	19.54	3.61	12.64	4.96
July 8	4-6 cm	21.41	2.31	8.42	3.17
July 21	4-6 cm	20.99	2.92	11.11	6.27
August 4	4-6 cm	22.75	3.49	12.16	5.55
August 18	4-6 cm	24.00	2.69	13.50	8.94
September 1	4-6 cm	28.95	4.25[1]	15.09	
September 15	4-6 cm	27.26	4.85[1]	19.25	
October 13	4-6 cm	32.33	7.03[1]	19.39	

-means no observations on that date.

[1]Two observations.

TABLE V

LEAF LENGTH AND PERCENT TOTAL NON-STRUCTURAL CARBOHYDRATES IN THE ROOTS OF BLACKJACK OAK TREATED WITH TEBUTHIURON AND 2,4,5-T ON VARIOUS SAMPLING DATES

Sampling Date	Treatments				LSD Values .05 Level
	Leaf Length	No Herbicide %	Tebuthiuron %	2,4,5-T %	
February 12	Dormant	24.48	-	-	
March 10	Budding	30.84	-	-	
April 12	2 cm	24.38	-	-	
April 26	6-7 cm	14.35	11.19	-	6.10
May 13	8-10 cm	15.41	10.68	-	3.33
May 25	8-10 cm	16.53	8.53	-	4.63
June 8	10-12 cm	22.24	9.86	14.19	5.66
June 23	10-12 cm	21.02	10.92	11.46	6.63
July 9	10-12 cm	25.27	7.02	12.33	4.52
July 21	10-12 cm	30.45	10.88	13.28	8.80
August 4	10-12 cm	29.77	8.74	15.92	9.02
August 18	10-12 cm	29.68	9.10	12.79	8.28
September 1	10-12 cm	31.31	8.82	12.45	8.60
September 15	10-12 cm	33.90	8.34	6.56	5.97
October 13	10-12 cm	35.59	5.88	10.11	4.33
February 24 (1977)	Dormant	36.55	7.68	17.87	8.10

-means no observations made on that date.
LSD value .05 level are given for each date.

TABLE VI

DEFOLIATION OF BLACKJACK OAK AND WINGED ELM ON VARIOUS SAMPLING DATES WITH TREATMENTS OF TEBUTHIURON AND 2,4,5-T

Sampling Date	Blackjack Oak		Winged Elm	
	Tebuthiuron %	2,4,5-T %	Tebuthiuron %	2,4,5-T %
April 26	10	-	30	-
May 13	25	-	45	-
May 25	30	-	90	-
June 8	50	20	90	25
June 23	45	70	90	60
July 8	90	50	100	60
July 21	90	70	100	50
August 4	90	65	100	50
August 18	90	70	100	65
September 1	90	70	90[1]	50
September 15	100	90	90[1]	70
October 13	100	80	90[1]	80
May, 1977	100	70	100	50

-means no data taken on that date.

[1]Contains only two observations from the 6 to 7 and > 7 foot tall categories.

They contained 4.2% on September 1, 4.8% on September 15, and 7.0% on October 13. Defoliation for all three dates was 90%. By the following spring (May, 1977) all winged elm treated with tebuthiuron were completely defoliated and most of the trees were considered dead since no resprouts were noted. The TNC content in roots of winged elm two weeks after spraying with 2,4,5-T was 3% less than the untreated trees and declined to a low of 8.4% by the July 8 sampling. This was significantly lower than the amount of TNC in untreated trees but significantly more than in roots of trees treated with tebuthiuron (Table IV). After the July 8 sampling there was an increase in TNC which essentially paralleled the increase in untreated trees. This was evidently due to activity of leaves remaining on trees since defoliation ratings essentially increased throughout the first year with some recovery by the following spring (Table VI).

The TNC content in the roots of winged elm treated with tebuthiuron was significantly less than that of winged elm treated with 2,4,5-T on all dates sampled (Figure 2). Also, there was no recovery of TNC levels with the tebuthiuron treated trees.

When the blackjack oak treated with tebuthiuron were first sampled (April 26) the roots contained 11.1% (Figure 3). This was 3% less than the untreated trees on that same date. The percent TNC decreased gradually until October 13 when the roots contained nearly 6% and the trees were completely defoliated (Table V). In May, 1977, the defoliation was still 100%.

Two weeks after the blackjack oak had been sprayed with 2,4,5-T the TNC content was 14.1%, with a 20% defoliation (Table VI). This was 8% less than the untreated trees on that date (Figure 3). The TNC content was essentially constant until it reached a low of 6.5% on September 15. However, on October 13 and February 24, 1977, the TNC content had recovered to 10.1% and 17.8%, respectively. On all the sampling dates the TNC content in roots of blackjack oak treated with 2,4,5-T was significantly less than that of the untreated trees. There was a tendency for the TNC content of blackjack oak treated with tebuthiuron to be less than that of blackjack oak treated with 2,4,5-T, but only on July 9 and February 24, 1977, was the difference significant (Table V).

There were differences in soil moisture within the two tree species on different sampling dates. Table VII shows the rainfall pattern which accounts for the fluctuations in soil moisture on the different sampling dates. There were differences in soil moisture due to chemical treatment in both blackjack oak and winged elm (Tables VIII and IX). On five sampling dates the soil moisture of the blackjack oak area treated with tebuthiuron was significantly greater than the untreated area (Table VIII). Only on June 8 and October 13 were there differences in soil moisture between the blackjack oak treated with tebuthiuron and 2,4,5-T.

In the winged elm there was a significant difference in soil moisture between treatments on only two sampling dates (Table IX). On no sampling date was there a difference in soil moisture between the tebuthiuron treatment and the 2,4,5-T treatment.

The soil temperature at 10.2 cm and 30.5 cm in the untreated blackjack oak area tended to be higher than the two chemical treatments, but only on several sampling dates was the difference significant (Table X).

TABLE VII

STILLWATER DAILY RAINFALL RECORD, 1976

February

day	cm
12	.58
21	.10

March

day	cm
3	.15
4	1.40
5	.48
8	.76
9	1.70
11	2.41
30	.79

April

day	cm
7	1.47
13	4.37
15	.91
16	.15
17	.13
18	1.50
19	.41
20	2.24
29	1.55
30	.05

May

day	cm
1	.51
13	2.16
14	.05
16	.38
23	.18
27	.53
28	.76

June

day	cm
1	.25
18	.71
24	.89
29	.41

July

day	cm
1	.20
2	.18
15	.28
16	.51
25	.28
29	1.35

August

day	cm
2	7.00
3	.05
13	.13
14	.08
27	.08
31	.46

September

day	cm
1	.71
9	.61
17	1.04
19	.30
26	2.00

October

day	cm
5	1.42
20	.33
29	.36
30	1.98

TABLE VIII

SOIL MOISTURE AT 30.5 CM ON VARIOUS SAMPLING DATES IN BLACKJACK OAK AREA TREATED WITH TEBUTHIURON AND 2,4,5-T

Sampling Date	Treatments: No Herbicide %	Tebuthiuron %	2,4,5-T %	LSD Values .05 Level
February 12	12.66	-	-	
March 10	14.46	-	-	
April 12	9.18	-	-	
April 26	11.76	13.50	-	
May 13	14.30	14.30	-	
May 25	9.80	11.64	-	
June 8	6.52	11.28	8.08	1.99
June 23	2.98	5.34	5.58	1.42
July 9	3.72	4.14	5.72	2.67
July 21	5.62	9.26	9.44	2.59
August 4	13.76	13.02	14.04	1.30
August 18	5.56	5.96	7.34	5.07
September 1	3.72	7.28	5.08	2.47
September 15	5.10	5.64	5.02	1.37
October 13	4.40	11.92	9.20	2.64

-means no observations.
LSD values .05 level are given for each sampling date tested.

TABLE IX

SOIL MOISTURE AT 30.5 CM ON VARIOUS SAMPLING DATES IN WINGED ELM TREATED WITH TEBUTHIURON AND 2,4,5-T

Sampling Date	No Herbicide %	Tebuthiuron %	2,4,5-T %	LSD Values .05 Level
February 12	13.20	-	-	
March 10	13.82	-	-	
April 12	12.04	-	-	
April 26	13.00	13.12	-	
May 13	14.22	14.28	-	
May 25	11.76	13.68	-	
June 8	10.32	13.46	10.78	2.94
June 23	7.98	9.28	7.98	2.11
July 8	8.54	8.68	8.14	0.91
July 21	8.60	9.42	10.12	3.01
August 4	7.70	8.20	8.38	1.19
August 18	7.58	9.54	8.34	1.81
September 1	6.86	7.50[1]	7.32	
September 15	9.04	7.30[1]	7.30	
October 13	9.04	11.85[1]	13.00	

-means no observation.

[1]Only two observations taken.

TABLE X

SOIL TEMPERATURE AT 10.2 and 30.5 CM ON VARIOUS SAMPLING DATES IN BLACKJACK OAK AREA TREATED WITH TEBUTHIURON AND 2,4,5-T

	Depth							
	10.2 cm				30.5 cm			
Sampling Date	No Herbicide	Tebuthiuron	2,4,5-T	LSD Values .05 Level	No Herbicide	Tebuthiuron	2,4,5-T	LSD Values .05 Level
February 12	11.10	-	-		9.50	-	-	
March 10	10.60	-	-		10.40	-	-	
April 12	20.20	-	-		17.40	-	-	
April 26	15.00	14.00	-		14.50	14.70	-	
May 13	16.20	15.40	-		16.50	16.30	-	
May 25	22.00	24.70	-		20.60	21.50	-	
June 8	25.80	26.30	25.90	1.72	22.40	21.80	22.20	1.18
June 23	27.50	25.80	25.70	0.94	24.80	23.80	22.50	1.23
July 9	27.40	26.00	26.60	2.46	25.80	25.00	25.20	1.84
July 21	25.80	26.90	25.20	1.81	24.10	24.20	23.60	1.27
August 4	24.80	22.70	22.80	0.92	22.90	22.00	22.30	0.88
August 18	27.40	26.60	25.90	2.21	25.50	25.40	23.90	2.11
September 1	21.10	21.10	20.80	0.59	21.10	21.10	20.90	0.70
September 15	25.10	22.60	26.10	2.20	24.00	22.10	23.30	1.25
October 13	17.50	16.60	17.10	1.15	16.30	16.10	16.40	0.71

-means no observation.
LSD values at .05 level are given for each sampling date and depth.

On two sampling dates (July 8 and August 18) there was a significant difference in soil temperature at 10.2 cm between treatments in winged elm (Table XI). On August 4 and 18 there was statistical difference in soil temperature at 30.5 cm between treatments.

When regressions were run to predict the concentration of TNC in the roots of untreated blackjack oak it was found that the variables, days since treatment, days since treatment squared, and the cross product term of temperature at 30.5 cm * days since treatment were good predictors of TNC (Table XII). The TNC content of the roots of untreated winged elm could be predicted using temperature at 10.2 cm, the cross product terms of temperature at 10.2 cm * days since treatment, and height * days since treatment (Table XIII).

When trying to predict the TNC content in the roots of winged elm treated with tebuthiuron the variable, height category could not be used but temperature at 30.5 cm, defoliation, and defoliation squared were valuable predictors (Table XIII). The TNC content in roots of blackjack oak treated with tebuthiuron could be predicted using defoliation and defoliation squared (Table XII).

To predict the TNC content in roots of winged elm treated with 2,4,5-T only defoliation and defoliation squared could be used Table XIII). However, in blackjack oak treated with 2,4,5-T days since treatment and days since treatment squared could be used to predict the TNC content in the roots as well as defoliation and defoliation squared (Table XII).

TABLE XI

SOIL TEMPERATURE AT 10.2 and 30.5 CM ON VARIOUS SAMPLING DATES IN WINGED ELM AREA TREATED WITH TEBUTHIURON AND 2,4,5-T

	Depth							
	10.2 cm				30.5 cm			
Sampling Date	No Herbicide	Tebuthiuron	2,4,5-T	LSD Values .05 Level	No Herbicide	Tebuthiuron	2,4,5-T	LSD Values .05 Level
February 12	8.00	-	-		7.80	-	-	
March 10	12.10	-	-		9.60	-	-	
April 12	19.20	-	-		17.90	-	-	
April 26	21.00	20.50	-		17.20	17.90	-	
May 13	20.10	20.10	-		18.80	17.70	-	
May 25	21.30	20.20	-		21.30	20.60	-	
June 8	24.00	22.40	23.30	1.66	22.70	22.70	22.80	0.88
June 23	26.50	26.00	25.70	0.87	24.40	24.80	23.80	1.03
July 8	29.20	27.40	26.50	1.64	26.40	25.70	25.10	1.52
July 21	27.10	25.70	26.70	1.47	26.50	27.50	27.20	1.14
August 4	22.10	22.60	23.10	0.94	23.00	23.60	23.90	0.88
August 18	25.10	28.40[1]	29.40	3.31	24.90	29.30[1]	28.30	3.21
September 1	22.30	22.25[1]	22.20		23.40	22.75[1]	22.80	
September 15	23.00	22.75[1]	21.38		23.40	22.50[1]	22.25	
October 13	15.40	14.00[1]	14.50		16.30	14.50[1]	15.63	

-means no observations.

[1]Only contains two observations.

LSD values at .05 level are given for each sampling date and depth.

TABLE XII

REGRESSION EQUATIONS USED TO ESTIMATE CARBOHYDRATE CONCENTRATIONS IN BLACKJACK OAK

Treatment	Blackjack Oak		Predictor Variable	Probability > F
	R-Square	C.V. (%)		
No herbicide	0.48	22.1	Days since treatment	0.0004
			Days since treatment squared	0.0001
Tebuthiuron	0.38	44.8	Defoliation	0.0015
			Defoliation squared	0.0258
2,4,5-T	0.30	39.5	Days since treatment	0.0275
			Days since treatment squared	0.0224
			Defoliation	0.0077
			Defoliation squared	0.0220

TABLE XIII

REGRESSION EQUATIONS TO ESTIMATE CARBOHYDRATE CONCENTRATIONS IN WINGED ELM

	Winged Elm			
Treatment	R-Square	C.V. (%)	Predictor Variable	Probability > F
No herbicide	0.63	19.4	Temperature at 10.2 cm	0.0001
			Temperature at 10.2 cm x days since treatment	0.0001
			Height x day since treatment	0.0256
Tebuthiuron	0.87	29.3	Temperature at 30.5 cm	0.0019
			Defoliation	0.0001
			Defoliation squared	0.0001
2,4,5-T	0.54	35.4	Defoliation	0.0012
			Defoliation squared	0.0082

Evaluation of Fire Plus Tebuthiuron on Blackjack Oak

Burning had no significant effect on the TNC content in the roots of blackjack oak (Table XIV). There was no interaction between the burn treatments and chemical treatments. The only statistical difference was between chemical treatments. Tebuthiuron reduced the TNC levels in roots as much as 78% as compared to the untreated blackjack oak. Burning in combination with tebuthiuron did not have much effect on defoliation. In September the defoliation was 95% on the trees that had been burned and 87% on the trees that had not been burned.

TABLE XIV

EFFECT OF BURNING AND TEBUTHIURON ON CARBOHYDRATE LEVELS IN ROOTS OF BLACKJACK OAK

Treatment	Percent at Various Sampling Dates		
	July 20	October 27	March 20
	(%)	(%)	(%)
Main Plot			
Burned	14.8	22.7	14.3
Unburned	23.9	18.5	19.6
LSD Value	13.2	15.9	17.0
Subplot			
No herbicide	27.7	32.5	27.9
Tebuthiuron	11.0	8.7	6.0
LSD Value	9.4	4.8	2.8

LSD Values .05 level given for each date.

CHAPTER V

SUMMARY

Field and laboratory studies were carried out to determine the concentration of TNC in roots of blackjack oak and winged elm treated with tebuthiuron and 2,4,5-T. Roots were sampled from February, 1976 to October, 1976 and analyzed using the Anthrone method.

The TNC in the roots of untreated blackjack oak and winged elm trees followed a similar pattern. Generally there was a sharp decrease in TNC of roots in early spring until the leaves reached full size and then there was a gradual increase until fall dormancy.

Tebuthiuron depleted TNC in the roots of winged elm to a greater extent than 2,4,5-T. The winged elm treated with tebuthiuron showed the largest decrease in TNC whereas the winged elm treated with 2,4,5-T reached their lowest level in early July and then accumulated TNC until sampling ceased. Although the roots of winged elm treated with 2,4,5-T accumulated TNC they did not attain the levels reached by the untreated trees. One year after treatment with tebuthiuron the winged elm were completely defoliated, whereas trees treated with 2,4,5-T were 50% defoliated.

The TNC in roots of blackjack oak treated with tebuthiuron decreased gradually during the study, but they were not reduced to the extent the TNC in the roots of winged elm were reduced. The blackjack oak treated with 2,4,5-T also showed a reduction of TNC in the roots,

but they appeared to be intermediate between the untreated trees and trees treated with tebuthiuron. Blackjack oak treated with 2,4,5-T the following year were 70% defoliated. Regression analysis procedures were used to predict the TNC content in the roots of the two tree species. The variables, temperature at 10.2 cm, and the cross product terms of temperature at 10.2 cm * days since treatment, and height * days since treatment could be used to predict the TNC content of untreated winged elm. For untreated blackjack oak the variables, days since treatment, days since treatment squared and the cross product term of temperature at 30.5 cm * days since treatment were valuable as predictors of the TNC content in the roots.

The variables, temperature at 30.5 cm, defoliation and defoliation squared were the best predictors of TNC in roots of winged elm treated with tebuthiuron. For blackjack oak treated with tebuthiuron only tree response and defoliation squared were effective predictors of TNC content.

Defoliation and defoliation squared were the only effective predictors of TNC content in roots of winged elm treated with 2,4,5-T. The predictors that could be used for blackjack oak treated with 2,4,5-T were defoliation, defoliation squared, days since treatment and days since treatment squared.

Burning did not affect TNC content in the roots of blackjack oak, but treatment with tebuthiuron reduced the TNC content in the roots of trees from both unburned and burned areas.

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