THE EVALUATION OF VARIOUS HERBICIDES FOR THE CONTROL OF WINGED ELM (ULMUS ALATA, MICHX.)

By

PHILLIP GENE STRYKER

Bachelor of Science

Purdue University

Lafayette, Indiana

1964

Submitted to the faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
July, 1966

THE EVALUATION OF VARIOUS HERBICIDES FOR THE CONTROL OF WINGED ELM (ULMUS ALATA, MICHX.)

Thesis Approved:

Thesis Adviser

Dean of the Graduate College

ACKNOWLEDGMENTS

The author is deeply indebted to his wife, Sharon, for her encouragement and assistance during the course of this study. I thank my parents, Mr. and Mrs. Paul F. Stryker, for their encouragement throughout my scholastic career. The author also appreciates the kind interest and encouragement shown by his wife's parents, Mr. and Mrs. Loyd E. Harvey, and especially for their assistance in time of need.

Appreciation is extended to Mr. Leland Tripp, Mr. George Seals, Mr. Charles Scifres, Mr. Wildon Schmidt, Mr. Gary Gerloff, Mr. Boyd Montgomery, and Mr. Lee Six for their services while establishing these experiments. Also gratitude is extended to Mr. W. C. Calhoun of Quinton, Oklahoma, and Mr. G. W. Packnett of Sulpher, Oklahoma, who consented to allow use of their property for the experiments.

Also, appreciation is extended to Dr. W. McMurphy, Mr. H. M. Elwell, and Mr. B. J. Eaton for their suggestions and assistance in evaluation of the experiments.

Thanks to Dr. P. W. Santelmann, adviser and chairman of my graduate committee, Dr. J. Q. Lynd, and Dr. Eddie Basler for their suggestions during this study.

The author extends appreciation to Mrs. Gary Roach for typing the final copy of this thesis.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

The control of invading woody plants on Oklahoma rangeland has been a problem to the rancher for many years. The economics of control methods have often been a limiting factor to their use. The introduction of 2,4,5-T proved to be a useful tool, as it provided an economical control many woody plants.

However, when one dominant or association of dominant species is removed, the area is susceptible to invasion by a new species. This is the case with winged elm (Ulmus alata, Michx.). Winged elm is not typically a dominant species, but may temporarily become dominant when the post oak-blackjack oak (Quercus spp.) overstory is removed by the use of herbicides. Winged elm exhibits resistance to aerial treatment with 2,4,5-T. Therefore, another method of control or another herbicide must be found to control this species.

The purpose of this study was to find the best way to chemically control this species. This included the timing of treatment as well as the best chemical and the best method of application in an effort to find the most practical combination.

LITERATURE REVIEW

The growth habits and the habitat of winged elm have been reviewed by Kirby (11). The competitive ability and the abundance of seed produced make winged elm a problem when vegetation of the same association is removed. Winged elm produces great quantities of seed of which as much as 96 percent are viable soon after maturity (12). Gould (9) states that winged elm is a native perennial typical to the cross timbers and the post oak savannah.

Many herbicides are being tried for winged elm control, but most are not giving satisfactory results. The method of control will often limit some of the chemicals being used. The stage of annual growth will often affect the methods being used. Injection and basal bark spray treatments would be more effective during the dormant period whereas the foliar treatments would have to be used during the growing season. Peevy (18) and Elwell (6) state that foliar treatment should be made when the leaves are fully developed. Spurrier et. al. (22) state that the basal bark method will control larger woody plants than a foliage spray.

Another problem in brush control is how to get the chemical into the plant. Winged elm has a heavy cuticle when the leaf is fully developed. Dennis (5) states that the cuticle is the main barrier to herbicides. This layer becomes thicker when the plant is grown in sunlight. Oils move freely through the cuticle whereas

herbicides are somewhat restricted and must be absorbed into the stomates. This is the reason that recommendations for aerial spraying include oil as the carrier for the herbicide.

Foliage Treatment

The recommended treatment for control of the blackjack and post oak is two pounds of 2,4,5-T in one-half gallon of diesel oil and four gallons of water. Ray (20) reports that 80% control was achieved with the same treatment on winged elm. Darrow (2) found that a retreatment with one pound of 2,4,5-T was necessary. Klingman and Shaw (13) state that elm is fairly susceptible to 2,4,5-T or silvex. However, winged elm does not appear to be controlled by this treatment in all areas of the United States.

When control of a species is not achieved with a single herbicide often other herbicides are used or combinations are used. Spurrier et. al. (22) suggest that where 2,4,5-T will not give complete control that a mixture of 2,4-D and 2,4,5-T should be used. However, Elwell (7) has found that this combination is not satisfactory on winged elm in a nursery near Perkins, Oklahoma. Some of the newer combinations are often a material which either acts as a penetrant or a herbicide that is rapidly translocated in combination with 2,4,5-T. One of the combinations being tried is picloram (4-amino-3,5,6-trichloro picolinic acid) with 2,4,5-T (7).

When numbers of woody plants are not sufficient to warrant aerial treatment, a ground foliage wetting treatment can be used. The recommendation for this method is four pounds of 2,4,5-T in 100 gallons of water. The solution is sprayed on the plant until

the leaves are dripping. Kirby (11) reports that winged elm were 95% controlled by this method. Watson and Wiltse (24) and Gantz and Laning (8) did not get as good control. Instead picloram was used at one-half to two pounds per 100 gallons of water. This treatment gave 100% control. Lichy et. al. (17) achieved complete control with the recommended treatment and needed 1.4 pounds picloram to give comparable results.

This leads to the economics of brush control. Aerial treatment is by far the cheapest method according to Darrow and McCully (4), but it also gives the poorest results. The foliage wetting treatment is more costly but does give better control. Still a better and surer method is needed. However, the cost of the operation should not be restrictive.

Injection

This method involves cutting one notch at the base of the tree for every inch DBH (diameter breast height) and placing the herbicide in the notch. Little (14) states that the cost of this method will be about $16 per acre. Darrow and McCully (4) state that the cost will be 3 to 7 cents per tree whereas the foliage wetting treatment is 1½ to 4 cents per tree and the aerial spraying will range from $3 to 7 per acre.

Many new herbicides on the market have caused a change in recommendations for injection treatment. The recommendation of one gallon of 2,4,5-T in nine gallons of diesel oil has been changed to the use of undiluted materials. Peevy (19) found that undiluted amine form of 2,4-D and 2,4,5-T gave complete control of several hardwoods.

Watson et. al. (23) used undiluted picloram at 0.25 ml per cut to get complete control of American elm (Ulmus americana) and several of the oaks. Smith (21) has found that undiluted cacodylic acid will give rapid crown kill at 1.0 ml per injection on hardwood species in Wisconsin. This is due to dessication of the meristematic tissue of the buds and new twigs.

The timing of injection appears to be critical with the use of undiluted herbicides. McGee (15) found that control was not satisfactory when injected in April. Peevy (18) suggests that winged elm may be controlled if injected in May or in September.

Soil Treatment

This method employs the use of a granular form of herbicide. The material is placed around the base of the tree. This method is very effective when the density of the brush is low. Otherwise, the cost of this method would prevent its utility.

Darrow and McCully (3) found that the urea herbicides would stunt grass when applied at a rate high enough to control winged elm. Merrifield et. al. (16) found that the urea herbicides gave little to no control of hardwoods. Hoffman (10) suggests that spring treatment gives better results.

Wiltse (25) reported that picloram will work effectively as a granular treatment. Satisfactory control was obtained on hardwoods at seven and fourteen pounds per acre on a complete coverage treatment. This herbicide moves into the soil rapidly and is taken up rapidly by the plant.

Basal Bark Treatment

The commonly applied mixture of one gallon of 2,4,5-T in twenty-four gallons of diesel oil is sprayed on the lower portion of the trunk until runoff is noticed. This should completely encircle the tree. Behrens et. al. (1) found that resprouting occurred on winged elm. This method is restricted to trees less than six inches in diameter.

Kirby (11) reported that 2,4,5-T ester and 2,4,5-T amine did not give satisfactory control on trees taller than ten feet. However, 2,4,5-T ester gave good control on trees less than six feet in height.

MATERIALS AND METHODS

Experiment 1. The Use of Simulated Aerial Treatments.

To determine the most desirable time of treatment for aerial application, three year old winged elm plants were treated at two different stages of leaf development. These were when the leaves were about one-half developed or half leaf stage and at full leaf development. The stages of development were approximate as the dates of spraying were April 22, 1965, and June 21, 1965, respectively.

Five treatments were applied in five gallons of carrier per acre. These treatments were made using an 8001 fan type nozzle at 3 miles per hour under 20 pounds pressure per square inch. The trees treated were potted in five gallon cans and had been watered regularly. The air temperatures were 84°F and 91°F respectively. Wind was calm.

The treatments used were as follows:

1. 2,4-D ester (butoxy ethanol ester of 2,4-dichlorophenoxy-acetic acid) at four pounds a.e. (acid equivalent) in one-half gallon of diesel oil and three and one-half gallons of water/A.
2. 2,4,5-T ester (butoxy ethanol ester of 2,4,5-trichlorophenoxy-acetic acid) at three pounds a.e. in one-half gallon diesel oil and four gallons of water/A.
3. Tordon 101 [commercial formulation of 0.5 pounds of picloram

(4 amino 3,5,6-trichloropicolinic acid) plus two pounds of 2,4-D amine/ in four gallons water/A.

4. Picloram plus 2,4,5-T mixture at one pound picloram plus two pounds 2,4,5-T ester in four gallons water/A.
5. Picloram (potassium salt of 4-amino-3,5,6-trichloropicolinic acid) at two pounds in four gallons of water/A.

Experiment 2. Foliage Wetting Treatments

To carry the time of application further, the foliage wetting treatments were likewise set up on a one-half leaf and full leaf stage as described in experiment 1. This was conducted at two locations. A study was set up at Stillwater whereby each treatment was replicated three times. Another study was located near Sulphur, Oklahoma, in Murray County which was replicated ten times.

At Stillwater, the tree size was approximately five feet with a DBH (diameter measured at breast height) of 3/4" to 1½". At Sulphur the trees were eight to twelve feet in height with a DBH of 1½" to 2". The trees at Stillwater were transplants that had been in place for three years. The trees at Sulphur were found in an almost pure stand in an undisturbed habitat.

The first five foliage treatments were used at Stillwater and at the half leaf stage at Sulphur. The five additional treatments were used at the full leaf stage at Sulphur. They were as follows:

1. 2,4,5-T ester was applied at the rate of four pounds aihg (active ingredient per one hundred gallons water).
2. 2,4,5-T ester plus picloram was applied at the rate of two pounds 2,4,5-T and one pound picloram aihg.

3. Picloram was applied at two pounds aihg.
4. Tordon 101 was applied at the rate of one-half pound picloram and two pounds 2,4-D amine aihg.
5. 2,4-D ester was applied at four pounds aihg.
6. GS14260 (2-tert. butylamino-4-ethylamino-6-methylthio-s-triazine furnished by Geigy Chemical Company) was applied at two pounds aihg.
7. Paraquat (1,1-dimethyl-4,4-dipyridilium dichloride) + 2,4,5-T ester was applied at the rate of one-fourth pound paraquat plus three and three-fourths pound 2,4,5-T ester aihg.
8. Picloram plus 2,4,5-T ester was applied at the rate of one pound picloram and one-half pound 2,4,5-T ester aihg.
9. GC7887 (hexaflouracetone trihydrate furnished by Allied Chemical Company) + 2,4,5-T ester at the rate of one pound GC7887 plus three pounds 2,4,5-T ester aihg.
10. NH_4CNS (ammonium thiocyanate) + 2,4,5-T ester was applied at the rate of four tenths pound ammonium thiocyanate and three and six tenths pounds 2,4,5-T ester aihg.

The 2,4-D and 2,4,5-T esters were the butoxy ethanol formulation and were furnished by Amchem Chemical Company. Each contained four pounds acid per gallon. The treatments were applied until the foliage was wet and dripping.

The one-half leaf stage treatments were made at Sulphur on April 24, 1965 and at Stillwater April 28, 1965. The air temperatures were 80°F and 76°F, respectively, at time of treatment. Wind speed at Sulphur was four mph. A plastic screen was used at Stillwater to prevent drift.

The full leaf stage was treated at Sulphur on June 2, 1965, and at Stillwater on June 9, 1965. The air temperatures were 78°F and 88°F, respectively. Wind speed was eight to ten mph at Sulphur. The plastic screen was again used at Stillwater to prevent drift.

Experiment 3. Basal Bark and Soil Treatments.

This experiment was designed to compare several herbicides for use as a basal bark spray or as granular soil applied materials. All the basal bark treatments were applied with diesel oil as a carrier. The mixture was sprayed on the lower ten to twelve inches of the trunks of trees approximately two inches DBH until runoff was noticed.

The treatments were applied December 29, 1964. The location was southwest of Quinton, Oklahoma, in Pittsburg County. The air temperature was 74°F and the soil was moist and 60°F. Each treatment was replicated ten times. The concentrations used in the basal bark treatments were:

1. Sixteen pounds of 2,4,5-T ester aihg applied to a tree about six feet in height.
2. Sixteen pounds of 2,4,5-T ester aihg applied to the larger tree mentioned above.
3. Six pounds of picloram aihg.
4. Eight pounds of picloram aihg.
5. One and one-half pounds of picloram plus six pounds of 2,4-D amine aihg.
6. Two pounds of picloram plus eight pounds of 2,4-D amine aihg.

7. Six pounds of 2,4,5-T ester plus one and one-half pounds of picloram aihg.
8. Eight pounds of 2,4,5-T ester plus two pounds of picloram aihg.
9. Sixteen pounds of 2,4,5-T amine aihg.
10. Sixteen pounds of Dacamine T (oleyl-1,3-propylene diamine salt of 2,4,5-T) aihg.

The soil applied herbicides were placed evenly around the base of the tree. The picloram treatments were spread on an area four feet square. Dicamba was placed at the base of the trunk rather than over a given area. The treatments were as follows:

1. Fenuron (3-phenyl-1,1-dimethylurea) pellets at 1279 pounds/A. or one tablespoon per stem in one square foot.
2. Dicamba (dimethylamine salt of 2-methoxy-3,6-dichlorobenzoic acid) at two tablespoons per inch DBH.
3. Picloram 10K pellets at five pounds/A.
4. Picloram 10K pellets at ten pounds/A.

Experiment 4. Winter Injection Treatments.

This experiment was designed to test the influence of the carrier on the activity of a herbicide when injected into the base of the tree. A commercial injector developed by R. W. Little was used to make the notch. One notch was made for each inch DBH and the herbicide was placed in the notch by the use of an automatic syringe. The carriers used were water and diesel oil. Different dilutions were used to determine the point at which a herbicide no longer gives

control. Dilutions were gallons of herbicide to gallons of carrier.

Trees of 2 to 3½ inches DBH were selected for treatment. The locations was southwest of Quinton, Oklahoma. Each treatment was replicated ten times. Five milliliters of the mixture was placed in each notch. The treatments were made December 30, 1964, where the air temperature was 60°F and the soil was moist at 48°F. The treatments were as follows:

Herbicide	Tree Size	Carrier	Dilution (aihg)	
2,4,5-T ester	6'	oil	1:9	44
2,4,5-T ester	12'	oil	1:9	44
Picloram	12'	oil	1:9	22
Picloram	12'	oil	1:18	11
Picloram + 2,4-D amine	12'	oil	1:9	5.5+22
Picloram + 2,4-D amine	12'	oil	1:18	2.8+11
Picloram + 2,4,5-T ester	12'	oil	¼:½:9	5.5+22
Picloram + 2,4,5-T ester	12'	oil	¼:½:18	2.8+11
2,4,5-T ester	12'	oil	1:18	22
2,4,5-T ester	12'	oil	1:27	14:7
2,4,5-T ester	12'	water	1:9	44
2,4,5-T ester	12'	water	1:18	22
2,4,5-T ester	12'	water	1:27	14.7
2,4,5-T amine	12'	oil	1:9	44
2,4,5-T amine	12'	water	1:9	44
2,4-D Dacamine	12'	oil	1:9	44
2,4-D amine	12'	water	1:9	44
2,4-D ester	12'	oil	1:9	44

Herbicide	Tree Size	Carrier	Dilution (aihg)	
2,4-D ester	12'	water	1:9	44
2,4,5-T Dacamine	12'	oil	1:9	44

The dacamine formulations are oleyl-1,3-propylene diamine salts of 2,4-D and 2,4,5-T. These were furnished by Diamond Alkali Corporation.

Experiment 5. Spring Injection and Soil Treatments.

To further study the affects of the carrier on a herbicide, a study was located near Sulphur, Oklahoma, in Murray County. Here many aspects of herbicidal injection were considered. The experiment, as a spring injection, was treated March 26, 1965. The herbicides were applied undiluted, diluted in water, or diluted in diesel oil. The notches were made with the Little injector. Different rates of chemical were applied to the notch with an automatic syringe without a needle. A new method called the bore hole technique was used with undiluted cacodylic acid. A one-half inch hole was drilled to the center of the tree. The chemical was then injected into the hole. The technique was developed by R. W. Smith (21).

The experiment was located in an almost pure stand of winged elm rather than being located in an area of mixed brush as the understory as was the experiment at Quinton. This area was an undisturbed area located on the northern edge of the Arbuckle Mountain range.

Also included in this experiment were five soil treatments using the granular form of the herbicide. All treatments were applied to trees two to three and one-half inches DBH. All heights were twelve

to fifteen feet. Each treatment was replicated ten times. At the time of treatment the temperatures varied from 30°F to 39°F. The wind was from the north at 25 mph and brought in an ice cover within eight hours. The treatments were as follows:

Chemical	Carrier	Dilution (aihg)		Quantity/cut
2,4,5-T ester	water	1:9	44#	5 ml
2,4,5-T ester	water	1:18	22#	5 ml
2,4,5-T ester	water	1:27	14.7#	5 ml
2,4,5-T ester	oil	1:9	44#	5 ml
2,4,5-T ester	undiluted		4#/gal.	1 ml
2,4,5-T ester	undiluted		4#/gal.	2 ml
2,4,5-T amine	water	1:9	44#	5 ml
2,4,5-T amine	undiluted		4#/gal.	0.6 ml
2,4-D amine	water	1:9	44#	5 ml
2,4-D amine	undiluted		4#/gal.	1 ml
2,4-D amine	undiluted		4#/gal.	2 ml
2,4-D ester	water	1:9	44#	5 ml
2,4-D ester	water	1:18	22#	5 ml
2,4-D ester	undiluted		4#/gal.	1 ml
2,4-D ester	undiluted		4#/gal.	2 ml
Picloram	water	1:9	22#	5 ml
Picloram	water	1:18	11#	5 ml
Picloram	undiluted		2#/gal.	0.15 ml
Picloram	undiluted		2#/gal.	0.30 ml
Cacodylic acid	water	1:9	62.7#	5 ml
Cacodylic acid	undiluted	"bore hole"	5.7#/gal.	2 ml

Chemical	Carrier	Dilution (aihq)		Quantity/Cut
Cacodylic acid	undiluted		5.7#/gal.	1 ml
Cacodylic acid	undiluted		5.7#/gal.	2 ml
Dicamba	water	1:9	44#	5 ml
Dicamba	water	1:18	22#	5 ml
Paraquat	water	2:9	44#	5 ml
Paraquat	water	4:9	88#	5 ml
Picloram + 2,4-D amine	undiluted		0.5#+2#/gal.	1 ml
Picloram + 2,4-D amine	undiluted		0.5#+2#/gal.	2 ml
Picloram	granules		2.5#/A.	
Picloram	granules		5#/A.	
Dicamba	granules		1 tablespoon/inch DBH	
Dicamba	granules		2 tablespoons/inch DBH	
Dicamba	granules		4 tablespoons/inch DBH	

The 2,4-D and 2,4,5-T esters were the butoxy ethanol formulation furnished by Amchem Products Inc. The picloram and the picloram + 2,4-D amine mixture was furnished by Dow Chemical Company, cacodylic acid by Ansul Chemical Company, dicamba by Velsicol Chemical Company, 2,4-D and 2,4,5-T dimethyl amines by Amchem Products Inc., and paraquat by Chevron Chemical Company.

Experiment 6. A Bioassay Method for Tracing Picloram

One of the more promising new herbicides tested on winged elm has been picloram. In an effort to try to determine the movement and speed in the plant an experiment was designed to bioassay for the

herbicide in woody plant material.

To test the movement of the herbicide, the leaves on nine small winged elm seedlings in pots were wetted with a small quantity of solution made to the ratio of one pound picloram in one hundred gallons of water. Three plants were then harvested on each of the three succeeding days. Each plant was sectioned into 6 portions in an effort to trace movement. The leaves were removed, then the stems from which they came were removed. The remaining stem and root was each divided into two equal portions.

Each section was ground in 20 ml water in a mortar and placed in the upper one-half inch of four hundred grams of sterilized soil. Five safflower seeds were then planted as a test plant for picloram. The pots were top watered daily. Symptoms were noted and the plants harvested at twenty-five days. Dry weights of the safflower plants were taken.

To further test this method a series was run without crushing the plant material. The rest of the procedure remained the same. This was used to test the movement of the herbicide out of the plant material into the soil.

RESULTS AND DISCUSSION

In order to evaluate the treatments used to control winged elm, each individual tree was rated by estimating defoliation. Each tree was compared to an untreated tree. Percent defoliation was estimated by the number of buds which failed to break dormancy or by leaf removal due to the effect of the herbicide.

Experiment 1. The Use of Simulated Aerial Treatments.

Table I shows there is an indication that treatments containing 2,4,5-T gave better control when applied at the full leaf stage. It can also be noted that picloram seems more active when used at the earlier leaf stage.

This was an attempt to simulate aerial spraying. A pressure of 20 psi was used in order to reduce the volume. By using this low pressure, larger droplets were produced. This may have resulted in poorer coverage of the plants.

The trees in this experiment were attacked by elm leaf beetle one week following the full leaf stage treatment. This attack may have reduced the resistance of the plant to the herbicide.

Experiment 2. Foliage Wetting Treatments.

The results of this experiment are found in Table II. The half-leaf stage treatment at Sulphur may be a bit misleading as the check

TABLE I

THE EFFECT OF HERBICIDES SPRAYED ON WINGED ELM AT TWO INTERVALS AFTER TREATMENT*

		Half Leaf Stage		Full Leaf Stage	
Chemical	Rate#/A.	12 wk.	54 wk.	4 wk.	47 wk.
2,4-D	4	23	10	40	23
2,4,5-T	3	60	33	90	80
Picloram + 2,4-D amine	½ + 2	86	60	40	63
Picloram + 2,4,5-T	1 + 2	46	43	80	100
Picloram	2	100	100	60	100
Check	-	0	10	0	0

*% defoliation is average of three replications.

TABLE II

THE EFFECT OF FOLIAGE WETTING SPRAYS ON WINGED ELM

AT VARYING INTERVALS AFTER TREATMENT*

Chemical	aihg	Sulphur				Stillwater			
		Half Leaf Stage		Full Leaf Stage		Half Leaf Stage		Full Leaf Stage	
		8 wks.	51 wks.	7 wks.	46 wks.	5 wks.	53 wks.	5 wks.	46 wks.
2,4,5-T	4#	100	100	61	65	93	97	76	76
Picloram	2#	100	100	92	88	70	93	67	90
Picloram + 2,4,5-T	1#+2#	100	100	96	85	97	97	90	90
2,4-D ester	4#	97	100	65	78	77	70	35	60
Picloram + 2,4-D amine	½+2	100	100	58	65	80	73	50	70
GS 14260	2	---	---	27	21	--	--	--	--
Paraquat + 2,4,5-T	¼+3 3/4	---	---	66	85	--	--	--	--
Picloram + 2,4,5-T	1+½	---	---	96	85	--	--	--	--
GC 7887 + 2,4,5-T	1+3	---	---	72	80	--	--	--	--
NH_4CNS + 2,4,5-T	.4=3.6	---	---	88	44	--	--	--	--
Check		62	65	0	0	0	0	0	0

*% defoliation measured as average of three replications at Stillwater and ten replications at Sulphur.

plants were severely defoliated by herbicide. This was partly due to the fact that spacing between treatments was only ten to fifteen feet. Drift may have been slight even though the wind was not a problem. Also, an increase of 35°F was noted from the time of treatment until the warmest portion of the day. Low volatile materials were used, but this increase in temperature may have volatilized some of the herbicides. The vapors may have then caused the damage to the untreated check plants.

A trend was developed from the half leaf stage in comparison to the full leaf stage. Better control was achieved with all herbicides at the earlier treatment date. This is an exception to recommendations by Elwell (6).

The mixtures of 2,4,5-T and picloram as well as picloram alone seem to have given the best results. The ammonium thiocyanate (NH_4CNS) gave satisfactory defoliation the first season, but regrowth was prolific during the second season. Paraquat and hexaflouracetone trihydrate (GC7887) were added to enhance penetration and translocation. It appears that these chemicals were successful in increasing translocation of 2,4,5-T as measured by defoliation. The ammonium thiocyanate did not give satisfactory enhancement of translocation at 46 weeks.

Another problem encountered with the late stage treatment at Sulphur was that of complete coverage. This was taken into account when ratings were made.

The percent defoliation of each tree was rated against the untreated check plants. The average of all replications appear in the tables.

Experiment 3. Basal Bark and Soil Treatments.

The results of the basal bark treatments are found in Table III. Regrowth was considered when visual ratings were given for defoliation even though there is a physiological difference between normal growth and the regrowth forced by herbicidal treatment.

It appears that the 6' trees are more susceptible to this type of treatment than the 12' trees. However, it was observed that picloram had a tendency to settle out of diesel oil which may account for the lack of activity. When placed in solution with 2,4,5-T, the picloram did not settle so readily. As can be seen, the plants were more susceptible to this mixture. This mixture of picloram and 2,4,5-T was prepared by the author to test the additive affects of the two compounds. The settling of the chemical in the oil may have been a problem in all the treatments except those using 2,4,5-T. The only basal bark treatments that gave satisfactory results were those containing 2,4,5-T, and 2,4,5-T alone was the best treatment.

The granular herbicide treatments indicate that high rates of picloram are necessary for control. Fenuron and dicamba did not provide a satisfactory job of control at the rates used.

Experiment 4. Winter Injection Treatments.

The results of the winter injection treatments are shown in Table IV. The treated trees were located in a wet, low area which may have explained the regrowth on some of the treatments. Most all treatments were giving satisfactory control at 28 weeks with the exception of 2,4-D ester in water and 2,4,5-T ester at 1:18 in water. This

TABLE III

THE EFFECT OF BASAL BARK AND SOIL TREATMENTS ON WINGED ELM 28 AND 71 WEEKS AFTER TREATMENT*

Chemical	Tree Size	Rate aihg	28 wks.	71 wks.
2,4,5-T	12'	16#	100	100
2,4,5-T	12'	16#	67	89
Picloram	12'	6#	34	41
Picloram	12'	8#	65	67
Picloram + 2,4-D amine	12'	1½#+6#	24	33
Picloram + 2,4-D amine	12'	2#+8#	43	56
Picloram + 2,4,5-T	12'	1½#+6#	63	80
Picloram + 2,4,5-T	12'	2#+8#	89	98
2,4,5-T amine	12'	16#	11	18
Dacamine 2,4,5-T	12'	16#	28	35
Fenuron pellets	12'	1279#/A.	41	39
Dicamba granules	12'	2 tablespoons/in DBH	40	35
Picloram granules	12'	5#/A.	67	69
Picloram granules	12'	10#/A.	90	100
Check			0	0

*% defoliation expressed as average of ten replications.

TABLE IV

THE EFFECTS OF WINTER INJECTION TREATMENTS FOR WINGED ELM CONTROL MEASURED AT 28 AND 71 WEEKS AFTER TREATMENT*

Chemical	Tree Height	Dilution (aihg)		Carrier	28 wks.	71 wks
2,4,5-T ester	6'	1:9	44#	oil	100	100
2,4,5-T ester	12'	1:9	44#	oil	100	100
2,4,5-T ester	12'	1:18	22#	oil	100	100
2,4,5-T ester	12'	1:27	14.7#	oil	100	100
2,4,5-T ester	12'	1:9	44#	water	99	100
2,4,5-T ester	12'	1:18	22#	water	37	65
2,4,5-T ester	12'	1:27	14.7#	water	100	92
2,4,5-T amine	12'	1:9	44#	oil	88	97
2,4,5-T amine	12'	1:9	44#	water	100	100
2,4,5-T dacamine	12'	1:9	44#	oil	100	100
2,4-D ester	12'	1:9	44#	oil	100	100
2,4-D ester	12'	1:9	44#	water	53	67
2,4-D amine	12'	1:9	44#	water	95	100
2,4-D dacamine	12'	1:9	44#	oil	90	92
Picloram	12'	1:9	22#	oil	100	100
Picloram	12'	1:18	11#	oil	92	88
Picloram + 2,4,5-T ester	12'	1:9	5.5+22#	oil	100	89
Picloram + 2,4,5-T ester	12'	1:18	2.8+11#	oil	100	100
Picloram + 2,4-D amine	12'	1:9	5.5+22#	oil	95	91
Picloram + 2,4-D amine	12'	1:18	2.8+11#	oil	100	100
Check					0	0

*% defoliation measured as average of ten replications.

remained true at 71 weeks with slight regrowth on the treatments mentioned above.

The extreme dilution of 2,4,5-T ester indicates that a cheaper method can be recommended. The results indicated that dilutions on many of these chemicals was not high enough.

Experiment 5. Spring Injection and Soil Treatments.

The results of this experiment are shown in Table V. One problem encountered in this experiment was the sleet storm which may have diluted the different herbicides beyond the effective concentration.

Probably the most outstanding effect observed was the control by undiluted herbicides. Picloram gave excellent control either diluted or injected undiluted at 0.15 ml per notch. This treatment was much cheaper than any other used when compared at present market prices.

The bore-hole method was not satisfactory on trees of this size. The use of undiluted cacodylic acid was satisfactory when injected at the base of the tree. Considerable regrowth was noted on the lower portions of the trees treated with diluted cacodylic acid.

The most practical treatment general use by the rancher or by the commercial brush control specialist would appear to be the use of undiluted 2,4-D ester or 2,4-D amine. The herbicides were inexpensive and did not require the accuracy used in applying picloram.

The addition of 2,4-D ester or 2,4,5-T ester to water was not satisfactory in any of the treatments. However, the recommended 2,4,5-T in oil was the standard to compare economics and control.

TABLE V

THE EFFECT OF SPRING INJECTION TREATMENTS ON WINGED ELM AT TWO INTERVALS AFTER TREATMENT*

Herbicide	Carrier	Dilution (aihg)		4 wks.	56 wks.
2,4,5-T ester	water	1:9	44#	0	2
2,4,5-T ester	water	1:18	22#	0	7
2,4,5-T ester	water	1:27	14.7#	0	3
2,4,5-T ester	oil	1:9	44#	53	92
2,4,5-T ester	undiluted	1 ml	4#/gal.	30	82
2,4,5-T ester	undiluted	2 ml	4#/gal.	38	84
2,4-D amine	water	1:9	44#	83	90
2,4-D ester	water	1:9	44#	35	35
2,4-D amine	undiluted	1 ml	4#/gal.	88	100
2,4-D amine	undiluted	2 ml	4#/gal.	98	100
2,4-D ester	undiluted	1 ml	4#/gal.	76	94
2,4-D ester	undiluted	2 ml	4#/gal.	82	100
Picloram	undiluted	.15 ml	2#/gal.	96	100
Picloram	undiluted	.3 ml	2#/gal.	100	100
Picloram	water	1:9	22#	100	100
Picloram	water	1:18	11#	98	100
Cacodylic acid	undiluted	1 ml	5.7#/gal.	100	100
Cacodylic acid	undiluted	2 ml	5.7#/gal.	100	100
Cacodylic acid	undiluted	"bore hole"	1 ml	77	62
Cacodylic acid	water	1:9	62.7#	86	71
2,4,5-T amine	water	1:9	44#	73	96
2,4,5-T amine	undiluted	1 ml	4#/gal.	84	100
Dicamba	water	1:9	44#	88	99
Dicamba	water	1:18	22#	86	97
Paraquat	water	2:9	44#	8	43
Paraquat	water	4:9	88#	7	57
2,4-D ester	water	1:18	22#	7	4
Picloram + 2,4-D amine	undiluted	1 ml	½+2#/gal.	95	100
Picloram + 2,4-D amine	undiluted	2 ml	½+2/gal.	95	100
Picloram (granules)			2½/A.	55	34
Picloram (granules)			5#/A.	62	82
Dicamba (granules)		1 tbsp./stem		10	9
Dicamba (granules)		2 tbsp./stem		14	14
Dicamba (granules)		4 tbsp./stem		22	21
Check				0	0

*% defoliation expressed as average of ten replications.

The granular treatments were comparable to those in experiment 3. The only satisfactory treatment was picloram at five pounds per acre. Dicamba was not satisfactory as a granular material at any of the rates even though the liquid form gave good control when injected.

Another comparison worth noting was the increase in control by 2,4,5-T amine over 2,4,5-T ester. This was evident in the 2,4-D treatments also.

Experiment 6. A Bioassay Method for Tracing Picloram.

This experiment was designed as an attempt to trace the herbicide in the plant without the assistance of a radioactive chemical. At the time labled picloram was not available. This method seemed a logical alternative since safflower was suggested as a bioassay test plant for picloram in soil.

Dry weights were taken from each treatment combination since seedling disease presented problems to other methods of evaluation. The results were weighed in grams and are shown in Table VI.

The data suggests that picloram moves into the plant rapidly. The movement of the material within the plant was not linear with time. However, the weights of all treatment combinations were less than of the untreated check. The data from the uncrushed portion was more consistent since disease had not damaged the safflower plants. The downward movement of picloram in the plant was shown by the significant difference between treatment combinations.

Visual observations indicated that picloram had moved into the root zone during the first day. This was suggested by the "onion

TABLE VI

THE TRANSLOCATION OF PICLORAM IN WINGED ELM TISSUE AS MEASURED BY EFFECTS ON DRY WEIGHT OF 25 DAY OLD SAFFLOWER PLANTS

Position on plant	Number of days following treatment			
	Untreated	1 day	2 days	3 days
Crushed plant material				
Leaves	.149a	.128b	.022d	.019c
Stems from which leaves were removed	.091d	.057b	.048c	.042b
4-8" above soil surface	.096c	.059ab	.043c	.069a
0-4" above soil surface	.130b	.057b	.081a	.075a
Upper 4" of root	.104c	.069a	.065b	.074a
Lower 4" of root	.091d	.072a	.079a	.071a
Uncrushed plant material				
Leaves	.157a	.036d	.028d	.025c
Stems from which leaves were removed	.118b	.061c	.041c	.030c
4-8" above soil surface	.103d	.072b	.057b	.054b
0-4" above soil surface	.121b	.071b	.062b	.061b
Upper 4" of root	.112c	.083a	.077a	.065b
Lower 4" of root	.114bc	.085a	.079a	.078a

Any two figures within the same group followed by the same letter are not significantly different tested at .01 level.

leaf" shape of the leaves of the safflower plants. Further increases in concentration of the herbicide in the roots and stems were noted with time.

The entire experiment was watered daily. The problem of disease may have been lessened if the plants had been watered only every other day.

SUMMARY AND CONCLUSIONS

Studies were conducted to determine the most satisfactory herbicide and treatment method to control winged elm. Also considered in this study was timing of treatment.

The only basal bark treatment that was satisfactory was 2,4,5-T on a 6' tree. The other treatments were erratic and did not give control. Picloram at ten pounds per acre was the only soil treatment that resulted in good control.

The injection method of treatment was the most consistent method of control. The ester formulations of 2,4-D and 2,4,5-T were less effective when diluted in water. The potassium salt of picloram loses effectiveness when diluted in diesel oil. The time of year may affect the effectiveness of 2,4,5-T, but was not a factor in the other treatments. The use of water or oil may have been the success or failure of some of the treatments. However, the season should not affect the treatments using undiluted herbicides. Undiluted herbicides, in general, gave good control regardless of the chemical used. However, the bore hole method is not satisfactory for winged elm control.

There is an indication that foliar treatments on winged elm should be applied earlier than full leaf development. Better control was achieved in both locations when treated during the half-leaf stage. This suggests that further research should be done in this area.

The addition of picloram, paraquat, and hexaflouracetone trihydrate to 2,4,5-T may have enhanced the activity of 2,4,5-T. However, the addition of ammonium thiocyanate did not prove satisfactory at the rate used.

Picloram can be traced in a plant by use of a bioassay technique. Picloram was one of the most effective herbicides in all methods of treatment. Picloram showed considerable promise as a new herbicide for control of winged elm.

LITERATURE CITED

1. Behrens, R., H. M. Elwell, W. A. Gentner, H. M. Hull, D. L. Klingman, F. A. Peevy, F. L. Timmons and F. H. Tschirley. 1961. Chemical control of brush and trees. U. S. D. A. Farmers Bul. 2158.

2. Darrow, R. A. 1960. Aerial application of herbicides for brush and weed control. Texas Agr. Progress. Vol. 62: 19-23.

3. Darrow, R. A. and W. C. McCully. 1957. Comparison of granular forms of urea herbicides in aerial and hand broadcast application for control of Post oak and blackjack oat. Proc. S. Weed Conf. 10: 124-129.

4. Darrow, R. A. and W. C. McCully. 1959. Brush control and range improvement in post-oak and blackjack oak areas of Texas. Texas Agr. Exp. Sta. Bul. 942: 1-16.

5. Dennis, R. 1964. The fascinating story of herbicide action. Nat. Ag. Chem. Assoc. News 22-6: 4-5.

6. Elwell, H. M. 1958. Control of brush on rangeland and pastures. NC Weed Conf. Proc. 15: 73-74.

7. Elwell, H. M. 1965. Unpublished research data.

8. Gantz, R. L. and E. R. Laning, Jr. 1964. Tordon for control of woody rangeland species in Western United States. Down to Earth 19-3: 10-13.

9. Gould, F. W. 1962. Texas plants, a check list and ecological summary. Texas Agr. Exp. Sta. College Station, Texas.

10. Hoffman, G. O. 1959. Controlling brush and weeds on Texas rangelands. Proc. S. Weed Conf. 12: 167-170.

11. Kirby, B. W. 1965. Responses of winged elm (Ulmus alata Michx.) to various methods and times of herbicide treatment. M. S. Thesis. Okla. State Univ., Stillwater, Oklahoma.

12. Kirby, B. W. and P. W. Santelmann. 1964. Germination and emergence of winged elm seed. Weeds 12 (4).

13. Klingman, D. L. and W. E. Shaw. 1962. Using phenoxy herbicides effectively. U. S. Dept. Agr. Farmers Bul. 2183: 1-24.

14. Little, R. W. 1963. Reclaiming native grass from brush and tree infestation. Proc. S. Weed Conf. 16: 199.

15. McGee, C. E. 1966. Spring injection fails. Proc. S. Weed Conf. 19: 267.

16. Merrifield, R. G. and T. Hansbrough. 1961. Substituted urea herbicides in the control of undesirable hardwoods. Weeds 9: 85.

17. Nation, H. A. and C. T. Lichy. 1964. Tordon herbicide for brush control in Southern U.S. Proc. S. Weed Conf. 17: 287.

18. Peevy, F. A. 1961. Killing woody plants with herbicides. Proc. S. Weed Conf. 14: 208.

19. Peevy, F. A. 1964. Reducing hardwood control costs by injecting undiluted 2,4-D amine. Proc. S. Weed Conf. 17: 232-239.

20. Ray, H. C. 1958. Aerial chemical reduction of hardwoods brush as a range improvement practice in Ark. Jour. of Range Management 11(6): 284-290.2.

21. Smith, R. W. 1966. Progress report on cacodylic acid as a silvicide. Proc. S. Weed Conf. 19: 263.

22. Spurrier, E. C., W. O. Scott, and F. W. Slife. 1957. Chemical control of weeds and brush. Ill. Agr. Exp. Sta. Circular 771.

23. Watson, A. J. and R. J. Mesler, Jr. 1964. Effect of tordon herbicide as basal frill and tree injection of certain hardwood trees. Down to Earth 19-4: 20-23.

24. Watson, R. J. and M. G. Wiltse. 1964. Tordon for brush control on utility rights of way in the eastern United States. Down to Earth 19-1: 11-14.

25. Wiltse, M. G. 1964. Tordon herbicide as a soil treatment for brush control. Down to Earth 19-4: 3-6.

VITA

Phillip Gene Stryker

Candidate for the Degree of

Master of Science

Thesis: THE EVALUATION OF VARIOUS HERBICIDES FOR THE CONTROL OF WINGED ELM (Ulmus alata Michx.)

Major Field: Agronomy

Biographical:

Personal Data: Born April 5, 1941, at Clinton, Indiana, the son of Paul F. and Mary K. Stryker.

Education: Attended grade school in Rockville and Greene Township, Judson, Indiana; graduated from Turkey Run High School, Marshall, Indiana in 1959; received Bachelor of Science from Purdue University with a major in Agronomy in January 1964; graduate study at Oklahoma State University completing requirements for the Master of Science degree in July, 1966.

Experience: Reared on a grain farm in Indiana, worked there until 1960; worked for Agronomy and Botany Departments at Purdue University 1960-1964; served as graduate teaching assistant in Biology Department at Purdue University 1964; served as a graduate research assistant while completing requirements for the Master of Science degree from Oklahoma State University.

Member of: Agronomy Club, American Society of Range Management, American Grassland Council, and Weed Society of America.