FACTORS INFLUENCING THE EFFECTIVENESS OF COMMERCIAL AERIAL APPLICATIONS OF 2,4,5-TRICHLOROPHENOXYACETIC ACID FOR CONTROL OF BLACKJACK AND POST OAKS

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CHAPTER I

INTRODUCTION

There are approximately 390 million acres of brush infested land in the United States. Nearly 240 million acres of this area have suitable climate, soil, and topography to support livestock of some type if the woody vegetation could be effectively controlled.

The introduction of 2,4,5-trichlorophenoxyacetic acid, (2,4,5-T), in the early 1950's was a revolutionary development in the control of woody plants. Commercial application of this herbicide rapidly became the most economical and effective method of controlling undesirable woody plants. This placed increased emphasis on reclamation of marginal land with aerial application of 2,4,5-T being an integral key to progress in controlling brush on large areas.

Despite considerable progress in the field of aerial application for brush control, many problems still prevail. A major problem is the erratic response of a given brush species to commercial herbicide application. This is particularly true with aerial application of 2,4,5-T for control of blackjack, post oak, and other undesirable hardwoods.

The objective of this study was to investigate commercial aerial application of 2,4,5-T for control of blackjack and post oaks and determine the factors adversely influencing herbicide activity.

CHAPTER II

LITERATURE REVIEW

Plant Growth Conditions

Date of Treatment Herbicidal effectiveness has been reported to be primarily dependent on species susceptibility, physiological condition of the plant and other factors affecting plant growth (33). It has been reported that the most important factor governing 2,4,5-T effectiveness in mesquite was the season of treatment, and during the proper season, plant condition was the greatest single factor influencing translocation (53). Susceptibility of shinnery oak to 2(2,4,5-trichlorophenoxy) propionic acid, (2,4,5-TP), was low in early spring, increased rapidly to a point of maximum susceptibility in late spring and early summer, and then declined as active plant growth ceased later in the summer (49).

Blackjack and post oaks were most susceptible to ground and aerial 2,4,5-T sprays in May when trees had just reached full leaf, with best results being obtained from that time to mid-July when plants were still growing actively (26,27,29,59). Red oaks were most effectively controlled with foliar applied 2,4,5-T in May and susceptibility decreased as the growing season progressed to September, with fewer resprouts observed from May treatments than any other date (16).

Basler et al. (7, 8, 20) indicated the seasonal variation in absorption, translocation, and metabolism of 2,4,5-T generally corresponded to the seasonal susceptibility of blackjack oak to foliar applied sprays. He stated herbicidal effectiveness of 2,4,5-T was partially due to the physiological condition of the plant and not necessarily due to immediate environmental conditions, although these could be critical in obtaining a high degree of translocation and ultimate control.

Frost Severe late frost drastically reduced the susceptibility of shinnery oak to 2,4,5-TP at early and mid-spring treatment dates and reduced kill for optimum spray dates 15-35% (49, 50). These workers also found that light frost reduced the effectiveness of early season treatments but increased the effectiveness of late season treatments.

Cuticle According to Leopold (47) herbicide absorption was influenced by a waxy cuticle, immediate environmental conditions, and the nature of the spray solution. He further stated that the cuticle was formed by an oxidative drying process which increased with leaf age and light intensity. This suggests that cuticle thickness should increase from spring to summer as leaves age and the amount of sunlight radiation increases. Wax ester and acid cuticular components were found to increase in quantity with leaf age in a number of plants (46). Velvet mesquite was found to be more susceptible to 2,4,5-T foliar sprays before a waxy cuticle developed (68).

Burning A spring burn prior to spraying shinnery oak with 2,4,5-TP in the same season decreased defoliation and root kill in early season treatments with the burn effect becoming less pronounced as the spray season progressed (49, 51, 52). However, herbicidal effectiveness was greatly enhanced by spraying the year following a burn. The number of blackjack and post oak sprouts increased on sprayed and unsprayed areas when burned, as compared to unburned areas (30).

Retreatment Interval Satisfactory control of small oaks and low density scattered oak stands was obtained with a single aerial application of 2,4,5-T, but dense mature oak stands required two or more applications for adequate canopy reduction (23, 25). These workers found retreatment in successive years was more effective than comparable treatments in alternate years. Shinnery oak was found to be susceptible to successive applications of 2,4,5-TP with no decrease in response to later treatments (49). These workers also found a comparison of single year and consecutive year spraying showed the advantage of multiple sprayings lengthening the susceptibility period within a spray season.

Tree Size Several workers have generally found low volatile 2,4,5-T esters to be equally effective on all sizes of blackjack and post oaks (27, 59). Darrow and McCully (23) reported some variation in response of blackjack and post oaks to 2,4,5-T, could be due to tree size and character of the plants. Small mesquite trees were found to be more easily controlled with 2,4,5-T foliar sprays than larger trees (53). These workers accredited this to the greater distance required for translocation from the foliage to basal tissues in addition to less vigor in both roots and shoots of older plants.

In a four gallon per acre aerial application it was found that 19-22 percent of the total volume penetrated the upper canopy of a two story post oak and yaupon brush stand, but only 4-6 percent of the total spray penetrated both canopies (14).

Environmental Conditions

Air Temperature Higher air temperatures in a 65°-90° F. range were found to increase absorption and translocation of phenoxy herbicides in a wide range of test plants (5, 15, 37, 48, 58, 67). Morton (55) reported translocation of 2,4,5-T in mesquite seedlings was higher at 85° F. than at 70° or 100° F., but absorption was greatest at 100 degrees. Other workers found translocation of phenoxy herbicides was impeded by air temperatures above 86°-90° F. in a number of plant species. Air temperature between 60°-80° F. was reported to be optimum for application of 2,4,5-T foliar sprays for control of blackjack and post oaks (24). Higher air temperatures increased the volatility of 2,4,5-T esters and low volatile esters were volatile at 90°-120° F. (6, 45). Other workers stated volatility and herbicide evaporation may be the primary effect of air temperature (68). Currier and Dybing (19) showed that excessive air temperature may increase penetration and translocation of foliar applied herbicides, but effectiveness was lowered due to evaporation of spray droplets.

<u>Humidity and Dew</u> In field experiments, relative humidity at spray time had no effect on control of velvet mesquite with foliar applied 2,4,5-T (15). In contrast, three times more 2,4,5-T was absorbed by the foliage of mesquite seedlings at 95% relative humidity than at 35% (68). Control of purslane with foliar applied herbicides increased from 49% to 100% with a 70% increase in relative humidity (3). Kidney beans were reported to have absorbed and translocated larger amounts of 2,4,-D at 70-75% relative humidity than at 30-40% relative humidity (58). Elwell (24) reported higher relative humidity at spray time could lead to more satisfactory control of blackjack and post oaks with aerially applied 2,4,5-T. According to Currier and Dybing (19), higher humidity prevents moisture stress, delays drying of spray droplets, and may favor

cuticular permeability of foliar applied herbicide sprays. The cuticle has been found to often be porous in nature, and during conditions of high humidity, dew or rain these pores become filled with water. Upon application of aqueous sprays at this time, droplets immediately become in contiunuum with moisture in the leaf and should be able to easily transverse the cuticle (19). Control of mesquite and oaks with foliar 2,4,5-T sprays was found to be more effective when precipitation occurred immediately before spraying (21).

Wind Velocity and Direction Wind at spray time had no specific effect on control of mesquite with foliar applied 2,4,5-T (32). Wind up to 15 mph did not appear to adversely affect control of blackjack and post oaks with aerially applied 2,4,5-T, but wind in excess of ten mph created excessive drift problems (21). Elwell and Elder (29) stated the optimum time to apply aerial sprays of 2,4,5-T was when wind was at a minimum. Wind velocity at spray time was found to be inversely correlated to control of four hardwood species with aerial 2,4,5-T sprays (54). Halstead (35, 36) stated plant coverage was dependent on atmospheric turbulence and not strictly wind velocity at spray time. Roth (63) reported the effect of crosswind or wind in general to be one of the greatest and least controllable factors influencing the distribution of aerially applied sprays.

Application Factors

Droplet Size In work with 2,4,5-T foliar sprays on mesquite and cotton, it was reported that droplet spacing was of major importance in spray coverage, and a maximum droplet spacing of 3.1 millimeters was required for maximum herbicidal effectiveness. Results of this work further indicated drop size, spray volume, and herbicide concentration had little direct influence on response of the test plants. In contrast, it was reported that herbicidal effectiveness decreased with increased drop sizes in a range of 100 to 300 microns diameter (31). These workers stated that larger droplets became physiologically isolated and smaller drops increased the number of contact points per unit area on susceptible tissues. In wind tunnel studies, it was found that distilled water droplets evaporated 35 times faster than diesel oil at 59° F. and 40% relative humidity (65). It was further reported that water droplets less than 200 microns in diameter completely evaporated before falling 20 feet after being dispersed. In studies on droplet size, it was reported that 80 micron diameter droplets gave the most uniform coverage of aerially applied insecticides, but ten percent more total spray volume was lost to drift, convection, and evaporation as compared to 150-300 micron diameter droplets (42).

Aerodynamic Forces Isler and Yuill (43) stated that aerodynamic forces created by movement of fixed wing aircraft had a very marked effect on spray droplet distribution. Other workers found sprays or dusts dispersed from fixed wing aircraft generally followed the airflow and smaller particles were most affected (69). Swath width was generally found to be widened and sprays were more evenly distributed as nozzles on trailing edge booms were spread out from the fuselage (63). These workers also found when nozzle placement was too close to the wingtip, droplets were caught in the wingtip vortex and the spray patterns became concentrated in parts of the swath. Akesson and Yates (1) found spray released from the mid-portion of the wing, spread out evenly and moved downward, but spray released three feet from the wingtip moved into the vortex. Reed (60) calculated the path of various sized spray droplets released from 25%, 50%, and 75% of the distance from the fuselage to the wingtip. He concluded particles less than 210 microns diameter were greatly affected by the wingtip vortex and were most severely affected when released 75% the distance of the wing from the fuselage.

Aircraft type Yates and Akesson (73) found helicopters produced less variance in spray deposit patterns than fixed wing aircraft. No difference in the effectiveness of 2,4,5-T for control of oaks was found when sprays were applied with high or low wing monoplanes, or biwing aircraft (27, 70).

Airspeed In studies on spray atomization, it was found that a 250% increase in airpseed reduced mean drop diameter 60% (63). It was also reported that drop size was more influenced by orifice size and the angle of the discharging nozzle in relation to the line of thrust of the aircraft than by airspeed. Other workers found drop size was not influenced by airspeed using small orifices, but was affected when larger orifices were used (71). Other workers reported that atomization of sprays released from aircraft was mainly affected by airspeed and the horizontal component of the liquid velocity dispersed from the nozzle (41).

Boom Pressure Most workers agree that boom pressure had no great effect on atomization of aerially applied sprays as a 100-500% increase in boom pressure decreased mean droplet diameter only 16-20% (41, 71)

Herbicide Rate Several workers have found oaks were satisfactorily controlled with aerial 2,4,5-T sprays applied at the rate of 1.5-2.0 lbs. per acre in 4-5 gallons total volume (20, 24, 34, 58). Elwell (27) reported no difference in single aerial applications of 2 or 3 lbs. per acre of 2,4,5-T for control of oaks but found a 1 lb. rate less effective. Adequate suppression of oaks was obtained with a 1-2 lb. retreatment the year following the initial treatment, but when retreatment was delayed two years 2 lbs. per acre was more effective (27). The 2 lb. rate of 2,4,5-T in initial treatments and retreatments was generally more effective, with higher or lower rates resulting in less control.

Formulation Aerial applications of butoxy ethanol and propylene glycol butyl ether esters of 2,4,5-T have been reported to be slightly more effective than alkyl esters for control of undesirable hardwoods, but amine formulations were usually found to be less effective than esters (25, 27, 30, 56, 59). Other workers reported the difference in effectiveness of amine and ester formulations could be attributed to the fact that esters remain in aqueous state longer than amines when dispersed in sprays (24).

Nature of Spray Solution Leopold (47) stated absorption of herbicides was strongly influenced by a number of factors including pH of the spray solution. Weak acids were found to penetrate cells more readily and cuticular absorption was greater at pH 4 than at pH 7 (19). 2,4-D spray solutions were more toxic to soybean and corn plants at pH 5 and pH 7 than at pH 9 (38). P^{32} translocation in bean plants was unaffected by pH of the root medium from pH 2 to pH 5 but was decreased considerably at pH 7 (69). Phenoxy herbicides were found to be more toxic to mesquite when pH of the spray solution was lowered from pH 8 to pH 6 (11). However, lowering the pH of the root bathing solution did not influence the degree of root inhibition by cotyledon application. Growth of lemma minor, which had an optimum pH of 5.1, was greatly restricted by

2,4-D spray solutions of pH 4 but was unaffected by spray solutions of pH 4.6-6.1 (12).

Toxicity of aromatic herbicides to sorghum plants was increased when applied in water carriers with higher proportions of sodium ions (64). Borgen (13) reports calcium in excess of 20 ppm in spray water was a definite factor in the differential response of brush species to foliar sprays of 2,4-D and 2,4,5-T esters. He reported a direct ratio existed between calcium concentration in the spray water and the resurgence rate of 28 brush species after treatment. He postulated that hydrogenated fatty acids of the cutin and tomentose cover of the foliage were permeable to pure water solutions of 2,4-D and 2,4,5-T esters but were converted to impermeable precipitates by excess calcium. The calcium effect was alleviated somewhat by addition of adjuvants containing sodium ions.

Edaphic Conditions

Soil Type Topography Hurlon (39) stated soil type may be one of many factors influencing the effectiveness of aerially applied 2,4,5-T for control of hardwoods in Arkansas. Mesquite was reported to be more susceptible to foliar applied herbicides on upland sandy soils than on bottomland clay soils (32). Blackjack and post oaks were more susceptible to 2,4,5-T foliar sprays in valley sites than on shallow upland ridges (21, 26). However, associated hardwood species in valley sites were most resistant to 2,4,5-T and the overall control was consistently lower.

Soil Temperature The susceptibility of big sage brush, rabbitbush, and Canada thistle to 2,4-D foliar sprays was significantly correlated to soil temperature (17, 40). Herbicides were more toxic to these plants at soil temperatures of 75° F. than at 45° F. Ketellapper (44), indicated restricted plant growth at suboptimum temperatures is due to deficiencies of certain metabolites. Plant growth and herbicidal effectiveness were increased when certain metabolites were supplied to plants at suboptimum temperatures.

Soil Moisture Absorption and toxicity of 2,4,-D decreased in corn and soybean plants sprayed under moisture stress (37). Translocation of 2,4-D in bean plants, near the permanent wilting point was decreased 50% as compared to plants not under stress (9, 57). These data indicate 2,4-D translocation may be drastically reduced with only moderate decreases in soil moisture. Control of mesquite was improved by spraying 2,4,5-T in time of adequate soil moisture (32). Excessive resprouts occurred after treatments during prolonged drought or moisture stress (32). Translocation and defoliation of winged elm and blackjack oak increased when plants sprayed with 2,4,5-T under moisture stress were subjected to high soil moisture immediately after treatment (30, 72). It has been reported that soil moisture prior to application and precipitation immediately following are of considerable importance in obtaining maximum control of oaks with 2,4,5-T foliar sprays (21, 27). A high correlation was found between the number of days since precipitation of 0.5 inches or more, and inches of available soil moisture at spray time and the response of four hardwood species to 2,4,5-T foliar sprays (54).

CHAPTER III

METHODS AND PROCEDURES

Research was conducted in ten eastern Oklahoma counties in the summers of 1965, 1966, and 1967. Locations were chosen which had brush stands composed primarily of post oak, (Quercus stellata Wang), and blackjack oak, (Quercus marilandica Muench.), with minor amounts of hickory, (Carya laciniosa Michx., tomentosa Nutt.), winged elm, (Ulmus alata minch.), red oak, (Quercus borealis Michx. f., shumardii var. schneckii Brit. Sarg., falcata Michx.) and black oak, (Quercus velutina Lam.). The 79 locations used in the study were under commercial contract by private landowners and were treated by commercial aerial applicators as a part of their regular work. The test areas were aerially sprayed with approximately the recommended rate of two pounds of 2,4,5-T per acre in five gallons oil-in-water emulsion.

All factors suspected of having an effect on the defoliation of brush with 2,4,5-T were assigned an evaluation system and included in the study. All information that could be completed at the time of application was recorded on a field form with information on other factors being completed in the laboratory.

The following field form lists the factors investigated during this study. Each factor was investigated in detail and categorized in a rating by dividing the range of variability encountered into subunits.

FIELD FORM FOR AERIAL APPLICATION SURVEY

I. Land Owner, Description, and County

II. Plant Condition at Spray Time

A. Application date (1) May 21-28 (2) May 29-June 4 (3) June 5-11 (4) June 12-18 (5) June 19-25 (6) June 26-July 2 (7) July 3-9 (8) July 10-16 (9) after July 16

B. Frost free interval prior to application, (time in weeks) (1) 4-6 (2) 6-8 (3) 8-10 (4) 10-12 (5) 12-14 (6) 14-16 (7) $>$16

C. Previous chemical treatment (1) no previous treatment (2) previous treatment

D. Retreatment interval (time in years) (1) 0 (2) 1 (3) 2-3 (4) $>$3

E. Foliage leaf condition (1) clean (2) dusty (3) waxy

F. Foliage damage by insects (1) none (2) light (3) moderate

G. Previous fire history (years since previous burn) (1) no fire known (2) 1 year or less (3) over 1 year

H. Range condition at spray time (1) excellent (2) good (3) fair (4) poor

III. Edaphic Conditions

A. Soil type (1) sand (2) sandy loam (3) sandy clay loam

B. Soil depth (inches) (1) 0-15 (2) 15-30 (3) $>$ 30

C. Topography (1) upland (2) bottomland (3) slope

D. Soil temperature, degrees Fahrenheit, (F), at 4 inch depth (1) 65-69 (2) 70-74 (3) 75-79 (4) 80-84 (5) 85-89 (6) $>$ 90

E. Soil moisture (percent oven dry weight at 6-12 inch soil depth) (1) 0-5% (2) 10-15% (3) 15-20% (4) 20-25% (5) 25-30%

IV. Environmental Conditions at Spray Time

A. Air temperature (F^{o} 3 feet above ground level) (1) 50-60 (2) 61-70 (3) 71-80 (4) 81-90 (5) $>$ 90

B. Percent relative humidity (3 feet above ground level) (1) 40-60% (2) 60-80% (3) 80-100%

C. Dew condition on foliage (1) dry (2) moist (3) wet

D. Wind velocity in miles per hour, (mph), (1) 0-1 (2) 1-3 (3) 3-6 (4) 6-10 (5) $>$ 10

E. Wind direction in relation to plane flight (1) with plane flight (2) diagonal to flight (3) across flight

F. Rain and cloud cover at spray time (1) raining (2) misting (3) no clouds (4) high clouds (5) low clouds (6) partly cloudy

G. Total inches rainfall during previous 6 month dormant season (Oct.-Mar.) (1) 0-4 (2) 4-8 (3) 8-12 (4) 12-16 (5) $>$ 16

H. Total inches rainfall 3 months prior to application (1) 0-4 (2) 4-8 (3) 8-12 (4) 12-16 (5) $>$ 16

I. Total inches rainfall 1 month prior to application (1) 0-2.0 (2) 2.01-4.0 (3) 4.01-6.0 (4) 6.01-8.0

J. Total rainfall 3 months following application (1) 0-4 (2) 4-8 (3) 8-12 (4) 12-16 (5) $>$ 16

V. Application Factors

A. Plane type (1) Stearman (2) Snow (3) Piper Cub (4) Pawnee (5) Call Air (6) Other

B. Airspeed mph (1) 80-100 (2) 100-120

C. Swath width in feet (1) 33 (2) 40 (3) 50 (4) 65

D. Boom pressure in pounds per square inch, (psi), (1) 8-12 (2) 12-15 (3) 15-20 (4) $>$20

E. Percent spray coverage (1) 10-12.9% (2) 13-15.9% (3) 16-18.9% (4) 19-21.9% (5) $\geq$ 22%

F. Herbicide brand (1) Amchem (2) Dow (3) Thompson Hayward (4) Diamond Alkali (5) Hercules (6) Woodbury (7) Spencer and Gulf (8) Other

G. Product concentration, pounds active ingredients, (a i), per gallon (1) 4 lb. (2) 6 lb.

H. Rate of 2,4,5-T per acre (1) 2 lb. (2) 3 lb.

I. Conductivity of water used in spray mix (1) 0-2000 (2) 2000-4000 (3) $>$ 4000

J. Total cations, (ppm), of water used in spray mix (1) $<$10 (2) 10-20 (3) $>$ 20

K. Total anions, (ppm), of water used in spray mix (1) $<$10 (2) 10-20 (3) $>$20

L. Sodium absorption ratio, (SAR), of water used in spray mix (1) 0-1 (2) 1-3 (3) 10-18

M. pH of water used in spray mix (1) $<$ 6.5 (2) 6.5-7.5 (3) $>$ 7.5

VI. Percent Defoliation of Blackjack and Post Oaks

A. Average post oak defoliation, (av. of all tree sizes)

(1) 95-100% (2) 90-94% (3) 85-89% (4) 80-84% (5) 75-79%
(6) 70-74% (7) 65-69% (8) 60-64% (9) 55-59% (10) < 55%

B. Small post oak defoliation- same as in A. (1)-(10)

C. Medium post oak defoliation- same as in A. (1)-(10)

D. Large post oak defoliation- same as in A. (1)-(10)

E. Average blackjack defoliation, (av. of all tree sizes) same as in A. (1)-(10)

F. Small blackjack defoliation- same as in A. (1)-(10)

G. Medium blackjack defoliation- same as in A. (1)-(10)

H. Large blackjack defoliation- same as in A. (1)-(10)

I. Average defoliation of all oaks, (av. all sizes of blackjack and post oaks)- same as in A. (1)-(10)

Commercial aerial applicators were contacted before they began spraying in randomly chosen areas, and the locations being treated were used for test sites in the study. Landowners were interviewed to obtain exact information concerning previous chemical treatment, retreatment interval and fire history of the sprayed area.

Wind velocity, wind direction, relative humidity, dew condition, soil temperature, air temperature, and swath width were recorded during the actual spraying near the same site within the spray perimeter, where coverage samples were taken. Wind velocity was measured with a pocket atmometer and air temperature was determined with a Fahrenheit thermometer. Relative humidity was determined with a sling psychrometer and two or more readings were usually taken during the spray operation. Swath width was estimated by measuring the distance stepped off by the flagmen as the spraying was in process. This was checked several times at both ends of the spray perimeter when possible.

Information concerning foliage condition, insect damage, range condition, topography, and cloud cover was recorded by visually surveying the surrounding area. During this time soil type, soil depth, and soil temperature were recorded. Two soil moisture samples were collected from each sprayed area, one at a 6-12 inch depth, and the other at a 12-24 inch depth. Each sample for analysis was a composite of two or more samples taken with a hand auger at different sites within the sprayed area. Soil samples were placed in waterproof cans, transported to the laboratory and dried at approximately 105° C. for 48 hours, to determine soil moisture as percent oven dry weight. Soil temperature was determined with a brass pointed Fahrenheit soil thermometer at a 2-4 inch soil depth near the same sites soil moisture samples were collected. Soil depth was determined by measuring the distance from the soil surface to the underlying parent material at several sites in the sprayed area.

Data on plane type, airspeed, boom pressure, herbicide rate per acre, and total volume per acre were obtained through personal interview with the applicator. Estimates of airspeed and boom pressure were only approximate at best, because all aircraft were not properly equipped with pressure gauges and airspeed indicators. However, the rate and volume per acre were reasonably correct as aircraft were usually well calibrated.

In 1965 coverage data were obtained by making counts of the number of visible droplets on the foliage of treated plants during application. Difficulty was encountered in selecting uniform samples for valid comparisons between locations, and this system was not used after 1965. In 1966 coverage samples were taken on four inch square cards of white cardboard treated with a five percent acetone solution of Dupont commercial oil red powder dye. Spray droplets did not imprint permanent stains on red dye cards and this system was discontinued after 1966. In 1967 coverage samples were taken on four inch squares of Kodak 480 linographic paper taped to cardboard squares the same size. This paper was not sensitive to oil, very sensitive to water, and responded well to oil-in-water emulsions. Spray drops were permanently stained and coverage could be evaluated for considerable time periods after spraying. However, the paper was sensitive to light with droplet visibility being impaired and eventually lost if exposed to strong light for excessive time periods. This necessitated collection of cards immediately after spraying and placement in dark storage until evaluation.

Sites for sampling coverage were selected in open areas inside the spray perimeter before the spray operation began. Cards were placed on metal stands two feet above ground level, and spaced 10 to 20 feet apart, perpendicular to the direction of plane flight. Cards were collected after the aircraft had worked several swaths away and ten replications were taken at each location.

Actual evaluations for percent coverage were completed in the laboratory using a transparent grid twelve centimeters square, marked in millimeters. A random sample was selected from each card collected in the field. The grid was placed over cards and read under low magnification. The percent of total area covered by spray droplets was estimated in each square.

At the time of application, the herbicide brand, formulation concentration, water source, and equipment used to prepare the herbicide field mix were inspected. Spray water, herbicide mix and concentrate were sampled at all locations shortly after spraying.

Water samples used in the herbicide mix were collected and analyzed for pH, conductivity, total cations, total anions, and sodium absorption ratio (SAR). SAR is the ratio of the sodium content to one-half the square root of the sum of calcium and magnesium in milliequivalents per liter. pH determinations were made on a Beckman model H-2 pH meter. Conductivity was measured on a model RC-1B conductivity bridge. Cations were determined with a Perkin Elmer model 303 atomic absorption spectrophotometer. Calcium and magnesium were measured after diluting ten times with five percent lanthanum solution (La_2O_3) and distilled water. Sodium analysis required no reagents other than a water dilution.

All anion concentrations except sulfates were determined by titration methods. Carbonate and bicarbonate ppm were determined by titrating with 0.0999 normal (N) hydrochloric acid after addition of phenolphthalein and methyl orange indicators. Chlorides were determined by using potassium dichromate as the indiactor and 0.01 N silver nitrate as the titrant. Sulfate analysis was made with a Bausch and Lomb colorimeter at 700 millimicrons, (mu), after adding 0.5 milliters, (ml), of one percent gum arabic and 0.25 teaspoon barium chloride to 25 ml acetate buffer plus a 25 ml aliquot of the water sample.

The concentration of 2,4,5-T in field mixes prepared by applicators was determined on a Beckman DU-2 ultraviolet spectrophotometer. Analyses were made at 283 mu and ethanol was used as a diluent. 2,4,5-T concentrate from the same lot of chemical used to prepare field mixes was used to prepare standards.

Rainfall data and frost free period prior to treatment were compiled from climalogical records of the nearest meteorological recording station. Frost free period prior to treatment was based on the last day having a minimum temperature of 32° F. or lower.

Evaluations for percent defoliation were made in the fall of the same year treatments were applied. Transects 12 X 1000 feet or 12 X 500 feet were evaluated in the same general area coverage samples and other data had previously been collected. All tree species in the transect were divided into three size classes; small trees less than three inches in trunk diameter, medium trees three to six inches in trunk diameter, and large trees greater than six inches in trunk diameter. Every tree was rated as to defoliation with a rating from zero to ten, with zero being no defoliation and ten being 100 percent defoliated. The average defoliation for all blackjack and post oaks was used to express the results of the experiment. These two species constituted the majority of the woody plants on the test areas and other hardwoods were encountered only in minor amounts.

Defoliation was selected as the criterion to measure plant response because of limited time to conduct the study. Evaluations could be made the following fall after summer treatments prior to frost and natural leaf drop. This criterion has been used by other workers as an indication of susceptibility of brush species to foliar applied herbicides with adequate success. High defoliation of blackjack and post oaks is an indication of good susceptibility to foliar herbicide application. A defoliation level of 70% or more the fall following an early summer herbicide application is considered successful.

Following collection of defoliation data, two way frequency distribution tables were compiled for each factor in the study, using defoliation as the independent variable. Distribution tables were used to illustrate the variability in plant response, the range of extremes encountered with each factor, and conditions under which spray applications most frequently occurred. Average defoliation of each factor subunit was used to construct two-way graphs and establish the effect of each factor on oak response to 2,4,5-T treatment. Following this procedure, linear regression was used to establish correlations for all factors appearing to be linearlly correlated to defoliation.

CHAPTER IV

RESULTS AND DISCUSSION

Plant Growth Conditions: Oak response to 2,4,5-T at various application dates is shown in Figure 1 for the times applicators made their treatments through the spray season. Defoliation of oaks with 2,4,5-T averaged 73% for the initial application period between May 21-28, but sharply increased to a maximum of 87% for applications made one week later. Following June 4 treatments, oak defoliation by 2,4,5-T slowly declined to a minimum after July 16.

The influence of the interval between the last killing frost and 2,4,5-T application (Figure 2) closely paralled the pattern of application date. Average defoliation 4-6 weeks after the last killing frost was 70% and a maximum defoliation of 89% was attained with 2,4,5-T treatments during the next two week period. Following the period of maximum oak susceptibility to 2,4,5-T at 6-8 weeks after the last frost, defoliation steadily declined to 66% for a frost free interval of 16 weeks or more prior to spray application.

The seasonal susceptibility trend of blackjack and post oaks to aerially applied 2,4,5-T is shown in Figures 1 and 2. Susceptibility of 2,4,5-T is most likely determined by growth stage and physiological condition of the plants at spray time. Other workers have found maximum suppression of oaks with 2,4,5-T sprays shortly after full leaf expansion with susceptibility steadily declining from this time through late

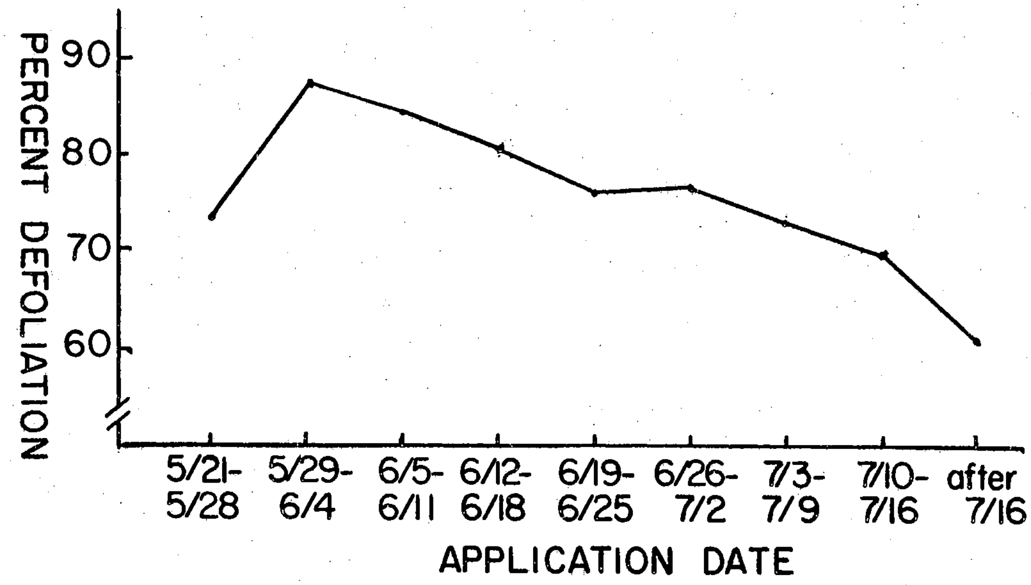

Figure 1. The Relationship Between Application Date and Defoliation of Blackjack and Post Oaks with 2,4,5-T

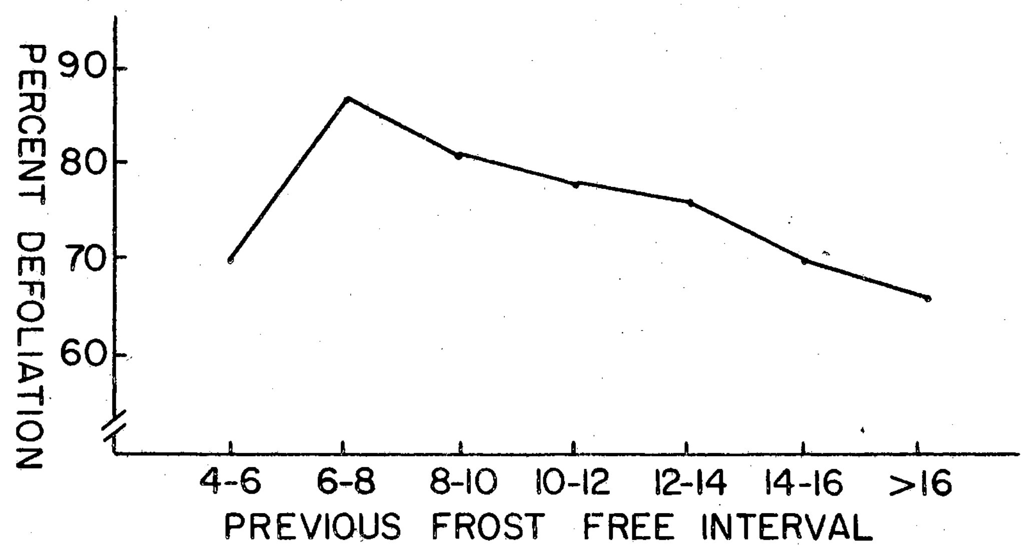

Figure 2. The Relationship Between Frost Free Interval Prior to Treatment and Defoliation of Blackjack and Post Oaks with 2,4,5-T

summer (16, 24, 25, 29, 39). Lower defoliation following 2,4,5-T applications before May 29 and during a frost free interval of 4-6 weeks (Figures 1 and 2) could be a result of spraying before oak leaves were fully expanded. It was observed in 1966, after severe frost in late April, that some oak leaves were not yet fully expanded during treatments applied before June 1. The date of 2,4,5-T application is apparently critical in obtaining maximum effectiveness of 2,4,5-T. The period of maximum susceptibility appears to last about two weeks but satisfactory results from aerially applied sprays can be obtained for about 1½-2 months after mid-May. Oak response to aerial application of 2,4,5-T during periods of low susceptibility may often be a major factor contributing to poor brush control.

A clean or dusty leaf condition at spray time did not influence herbicidal effectiveness with defoliation being 79% and 80% respectively (Figure 3). A noticeable amount of dust on oak foliage at spray time was encountered only twice and this was in small confined areas.

A thick cuticle and excessive leaf wax decreased defoliation with 2,4,5-T 13%. A waxy leaf condition was designated only when excessive amounts of leaf wax and cuticle became visibly apparent on oak foliage. Estimation of a clean or waxy condition was arbitrarily rated in the field at spray time in view of the fact that some leaf wax and cuticle were present on oak leaves throughout the spray season. An excessive amount of leaf wax and cuticle occurred late in the spray season, usually after early July when daily air temperatures were high and oaks were apparently not growing actively. Other workers have reported increased cuticle thickness with increased air temperatures, light intensities, and leaf age (46, 47). A thick cuticular barrier inevitably leads to less absorption of foliar applied herbicides.

Moderate insect damage on oak foliage at spray time adversely influenced herbicidal effectiveness (Figure 4). Moderate insect damage was not frequently encountered and was found at only four locations. Severe damage was not encountered. Light foliar insect damage did not influence defoliation by 2,4,5-T but occurred at 60 of the 79 locations investigated. Insect damage was one of several factors which became more prominent late in the spray season. After insect numbers increased in the summer, damage became more apparent.

The susceptibility of oak brush to retreatments of 2,4,5-T in years following an initial treatment is of considerable importance. The phenomenon of oaks becoming resistant to succeeding applications of 2,4,5-T has been suspected, although evidence is lacking. In sampling 52 initial treatments and 27 retreatments, there was very little difference in oak response to 2,4,5-T (Figure 5). In analyzing the retreatment interval, there was only five percent difference in oak defoliation following a second application of 2,4,5-T one, two, three or more years after the initial treatment (Figure 6). These results are expressed in defoliation and actual percent kill after one or two years would be a better measure of retreatment susceptibility.

Fire may be used to control some types of brush, but a burn and herbicide application in the same year were detrimental to defoliation of blackjack and post oaks with 2,4,5-T. Applications of 2,4,5-T two or more years after a burn were equally effective to applications on unburned areas (Figure 7). The locations which were burned and then sprayed within one year were a consequence of uncontrolled accidental fires, often severe in nature. The burn effect was usually evident on

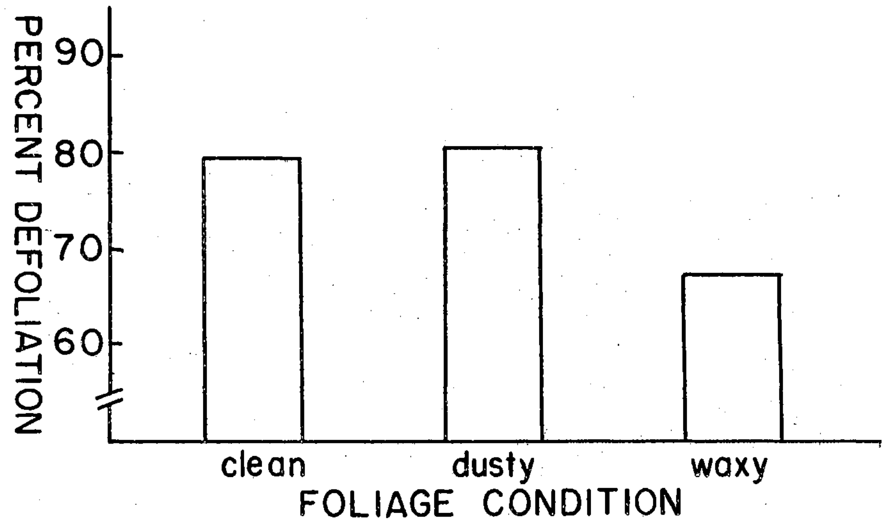

Figure 3. The Relationship Between Foliage Condition at Spray Time and Defoliation of Blackjack and Post Oaks with 2,4,5-T

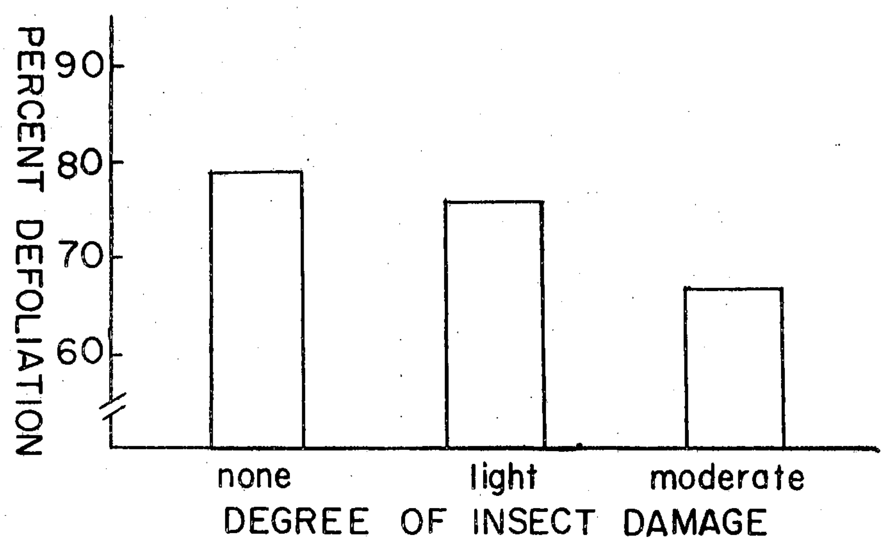

Figure 4. The Relationship Between Foliar Insect Damage and Defoliation of Blackjack and Post Oaks with 2,4,5-T

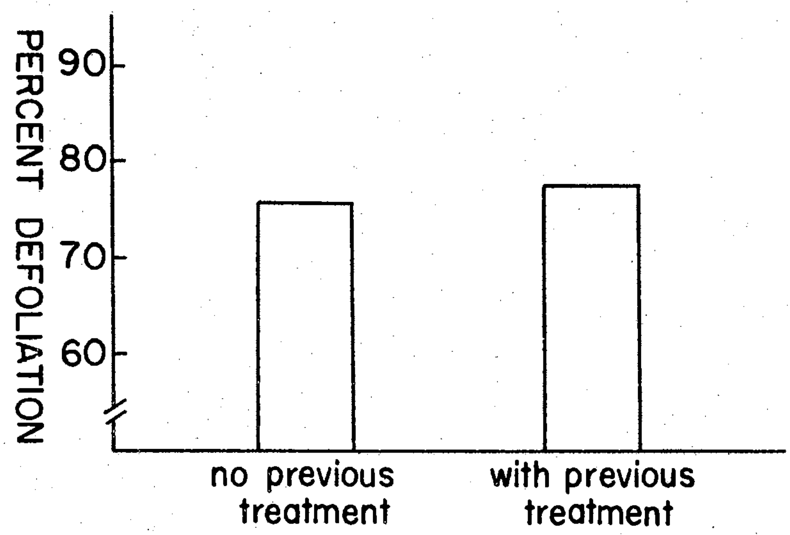

Figure 5. The Relationship Between a Previous 2,4,5-T Treatment and Defoliation of Blackjack and Post Oaks by Retreatments

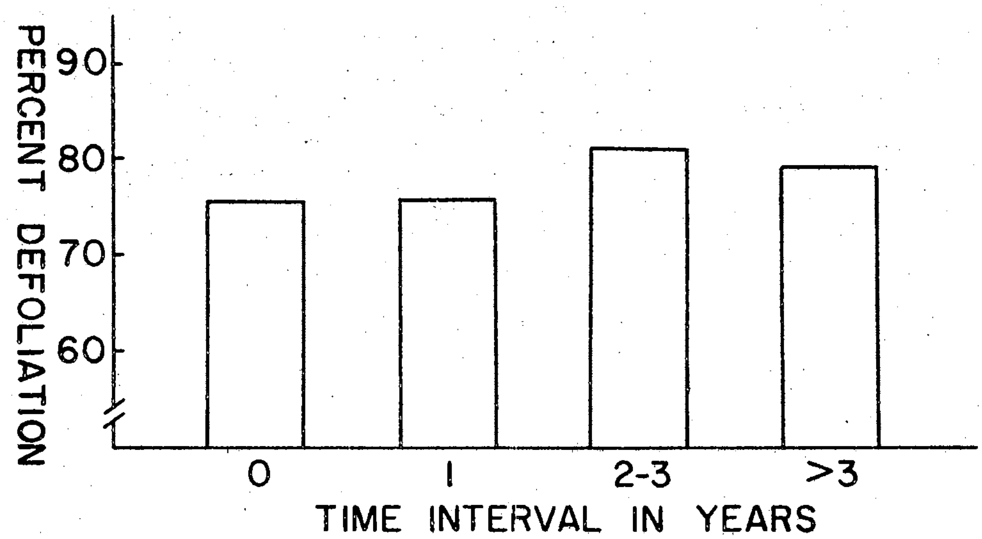

Figure 6. The Relationship Between Retreatment Interval and Defoliation of Blackjack and Post Oaks with 2,4,5-T

charred tree trunks at spray time. The majority of these fires had occurred in the spring prior to spraying, often within two-three months of 2,4,5-T application.

Range condition at spray time had no significant effect on oak defoliation by 2,4,5-T (Figure 8). Only one site was found to be in excellent range condition with 11, 37 and 30 sites being encountered in good, fair, and poor range condition respectively. A dense stand of native grass would be expected to compete with brush for moisture and nutrients, and sites with better range conditions consistently had lower density brush stands. A less dense brush stand enables more complete spray coverage, normally resulting in higher defoliation. Density of woody vegetation was not included in this study, but locations with dense brush stands inevitably had the poorest range conditions. To obtain satisfactory grass release, some workers have reported dense brush stands required repeated applications of 2,4,5-T while thin scattered stands were adequately suppressed with single applications (23).

Tree size did not appear to affect the susceptibility of blackjack and post oaks to 2,4,5-T (Table 1). Defoliation of large and medium blackjack and post oaks greater than three inches in basal trunk diameter was only 4-5% higher than defoliation of small trees less than three inches in trunk diameter. A differential response of various sized trees within a species could be partially attributed to spray coverage, particularly in a two story vegetative cover. Smaller trees may compose a majority of tree numbers in such brush stands and receive only a small amount of the total spray dispersed. Some workers have found understory plants in similar brush stands received 22.5% or less of a four gallon per acre aerial treatment (14).

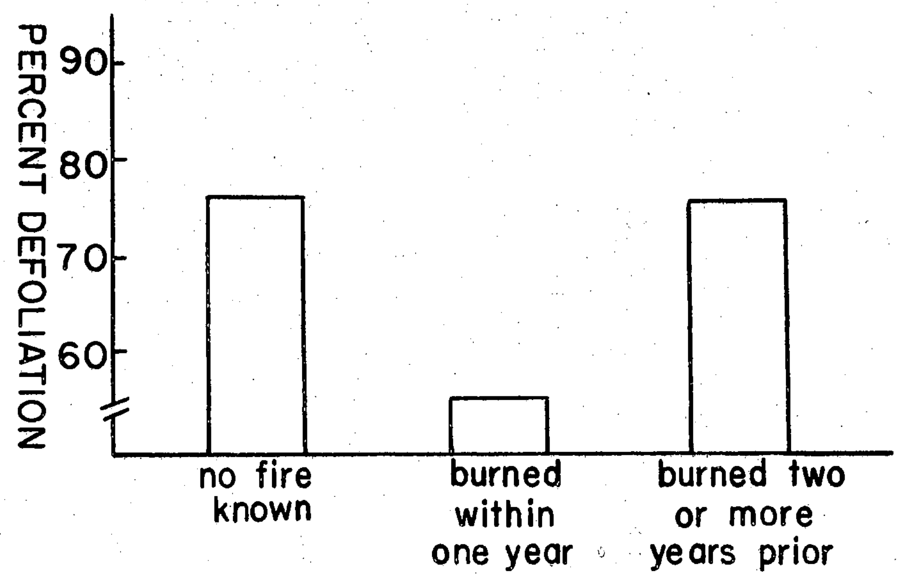

Figure 7. The Relationship Between Fire Prior to 2,4,5-T Treatment and Defoliation of Blackjack and Post Oaks

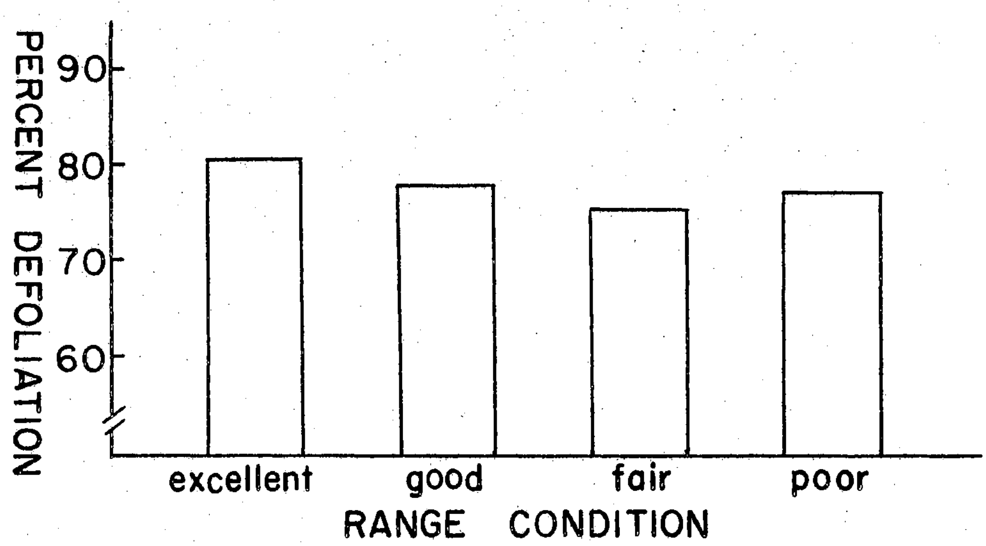

Figure 8. The Relationship Between Range Condition at Spray Time and Defoliation of Blackjack and Post Oaks with 2,4,5-T

TABLE I

PERCENT DEFOLIATION OF ALL SIZES OF TWO HARDWOOD SPECIES WITH AERIALLY APPLIED 2,4,5-T

Tree Species	Tree Size			
	small	medium	large	average
Post Oak	75	78	80	78
Blackjack	68	72	72	71
Av. of all Oaks	71	75	76	75

Environmental Conditions at Spray Time: Higher air temperatures at spray time were significantly correlated with reduced defoliation of oaks by 2,4,5-T (Figure 9). Air temperature had a regression coefficient of -0.785 and a correlation coefficient of 0.76 with defoliation. An increase in air temperature from a 50-60° F. range to a 61-70° F. range decreased defoliation with 2,4,5-T approximately ten percent. A temperature increase from 61-80° F. showed a slight increase in defoliation with 2,4,5-T. Increases in temperature above 80° F. continued to reduce 2,4,5-T phytotoxicity. Other workers have shown that plant growth and herbicide absorption generally increase directly with air temperatures below 100° F. (5, 15, 37, 48, 67). Herbicide volatility and evaporation of spray droplets increase with a rise in air temperature and may be the primary factors reducing the effectiveness of 2,4,5-T foliar sprays at higher air temperatures (6, 45, 68). Some workers have found that even low volatile 2,4,5-T esters may become volatile above 90° F. (6, 45). In this study, air temperature was one of the most critical factors influencing the effectiveness of aerially applied 2,4,5-T.

Wind velocity up to six mph had no influence on 2,4,5-T effectiveness but wind above this limit caused a slight reduction in oak defoliation by 2,4,5-T (Figure 10). Applicators were reluctant to apply 2,4,5-T in wind in excess of six mph as 67 of 79 locations sampled were treated in wind below this range. Twelve locations were treated with wind in the six to ten mph range but no treatments were applied when wind was greater than ten mph. When applicators began spraying at 4 or 5 A.M., wind was usually at a minimum, but generally increased in mid-morning. Air temperature usually increased concurrently with wind velocity during this same time. This indicates a number of factors become increasingly adverse shortly after early morning which could reduce the effectiveness of aerially applied 2,4,5-T. A constant wind at spray time is much less disadvantageous than a gusty wind of varying velocity (63). This could be due to displacement of the dispersed spray from the intended swath path. A steady wind would be expected to displace sprays approximately the same distance in each proceeding swath but a gusty wind would cause erratic displacement of sprays resulting in spotty coverage. Wind is extremely unpredictable, uncontrollable, and is often the limiting factor in aerial application of many phenoxy herbicides.

Wind direction across the plane flight path resulted in 2,4,5-T causing slightly higher defoliation than wind diagonal to or with plane flight path (Figure 11). This particular aspect of wind usually received little attention as brush infested rangelands normally have only one convenient direction to be sprayed. It is logical to assume a slight crosswind of constant velocity would be more advantageous than wind with plane flight path. A slight crosswind could aid in even spray distribution and enable more complete coverage of the entire foliage,

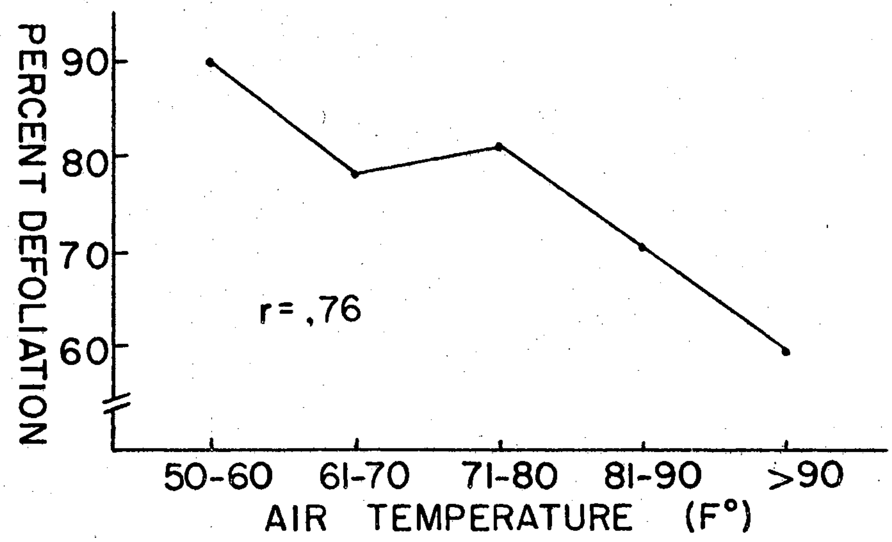

Figure 9. The Relationship Between Air Temperature and Defoliation of Blackjack and Post Oaks with 2,4,5-T

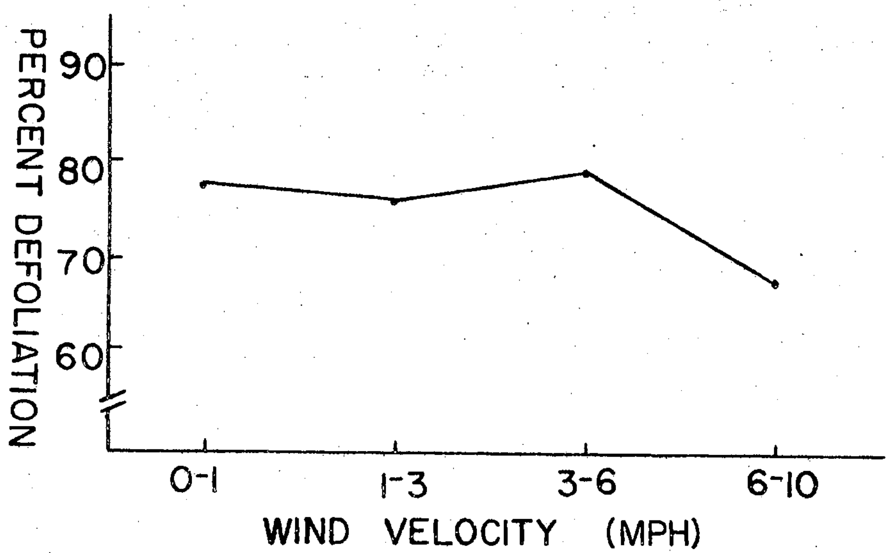

Figure 10. The Relationship Between Wind Velocity and Defoliation of Blackjack and Post Oaks with 2,4,5-T

while wind with plane flight could tend to concentrate spray on certain parts of the swath at the expense of the remaining portions. This phenomenon is perhaps evident from the data in Figure 11 but is not of strategic importance with the differences in defoliation due to wind direction.

Relative humidity at spray time was significantly correlated with defoliation by 2,4,5-T (Figure 12). This factor had a regression coefficient of 0.525 and an r value of 0.472 with defoliation. A 20% decrease in humidity reduced the effectiveness of 2,4,5-T approximately 10%. Relative humidity should be considered of moderate importance in aerial application of 2,4,5-T but the majority of spray treatments were applied when humidity was greater than 60%. In sampling 79 locations, 30 and 44 were treated when humidity was in ranges of 80-100% and 60-80% respectively, while only five locations were treated in a 40-60% range of relative humidity. Results of this study generally agree with previous studies on application of phenoxy herbicides in various ranges of relative humidity (18, 19, 47, 58).

A wet dew condition on foliage at spray time resulted in higher defoliation of blackjack and post oaks with aerially applied 2,4,5-T (Figure 13). Defoliation for dry, moist and wet conditions on the foliage at spray time was 69%, 74% and 77% respectively. A wet leaf condition was encountered only nine times while dry and moist conditions were encountered 21 and 49 times respectively. Dew at spray time could increase defoliation as a wet foliage would allow droplets to remain in aqueous solution on the foliage longer, reduce the rate of spray evaporation, and extend absorption time. However, the differences in defoliation resulting from dew on foliage at spray time were small and

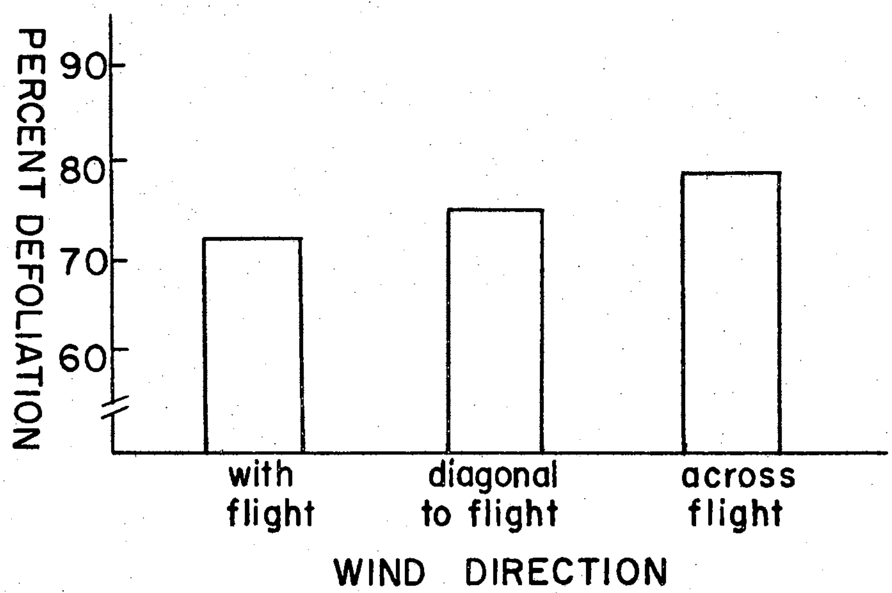

Figure 11. The Relationship Between Wind Direction in Relation to Plane Flight and Defoliation of Blackjack and Post Oaks with 2,4,5-T

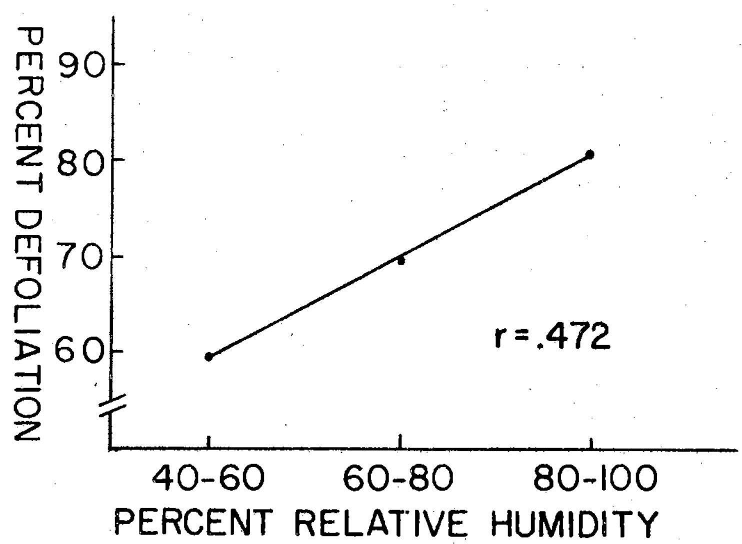

Figure 12. The Relationship Between Relative Humidity and Defoliation of Blackjack and Post Oaks with 2,4,5-T

should not be considered of major importance.

Rain and cloud cover at spray time did not influence oak response to 2,4,5-T as only seven percent difference in defoliation occurred between the extremes of all categories (Figure 14). Conditions of high humidity have been shown to increase herbicidal effectiveness (3, 18, 19, 58, 61). However, rain or mist may alleviate the favorable aspect of high humidity by creating excessive runoff of the applied herbicide spray from the foliage. Rain and mist conditions during the actual spraying were not frequent, and accounted for only three of 79 samples. Clear skies and cloud cover were about equally encountered with 36 locations treated under cloud cover and 40 locations treated during time of no clouds.

Total rainfall during the previous six month dormant season from approximately October to March prior to 2,4,5-T application had no effect on oak defoliation (Figure 15). Regression analysis with defoliation and total inches of rainfall resulted in an r value of 0.054.

Total rainfall three months prior to application did not have a significant effect on defoliation with 2,4,5-T (Figure 16). The r value for this factor was 0.193.

Total rainfall one month prior to application was significantly correlated with defoliation of oaks with 2,4,5-T (Figure 17). An increase in total rainfall from less than 2.0 to over 4.0 inches was correlated with a ten percent increase in defoliation by 2,4,5-T. Further increases in rainfall did not increase oak response to 2,4,5-T. Two or more total inches rainfall one month prior to 2,4,5-T application may be an indication of the amount required for oaks to grow actively and be in a physiological condition necessary to maintain a high degree of

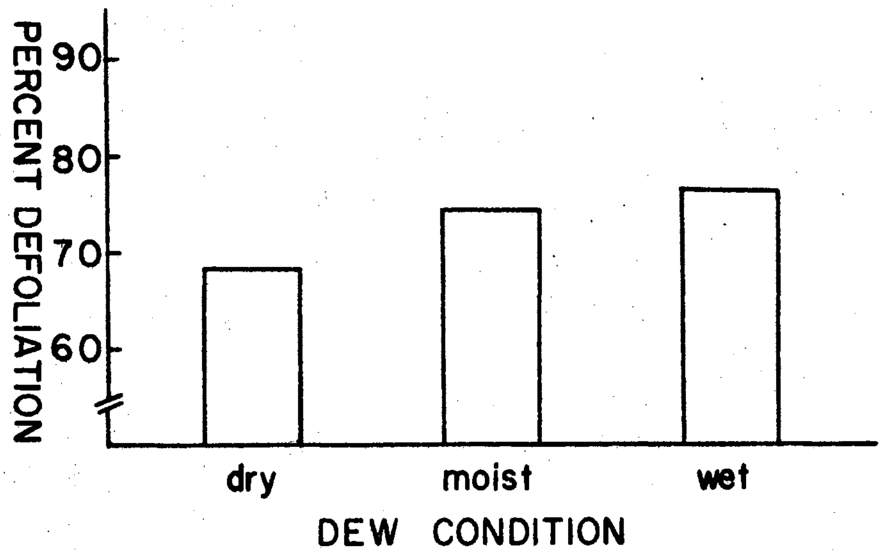

Figure 13. The Relationship Between Dew Condition on Foliage at Spray Time and Defoliation of Blackjack and Post Oaks with 2,4,5-T

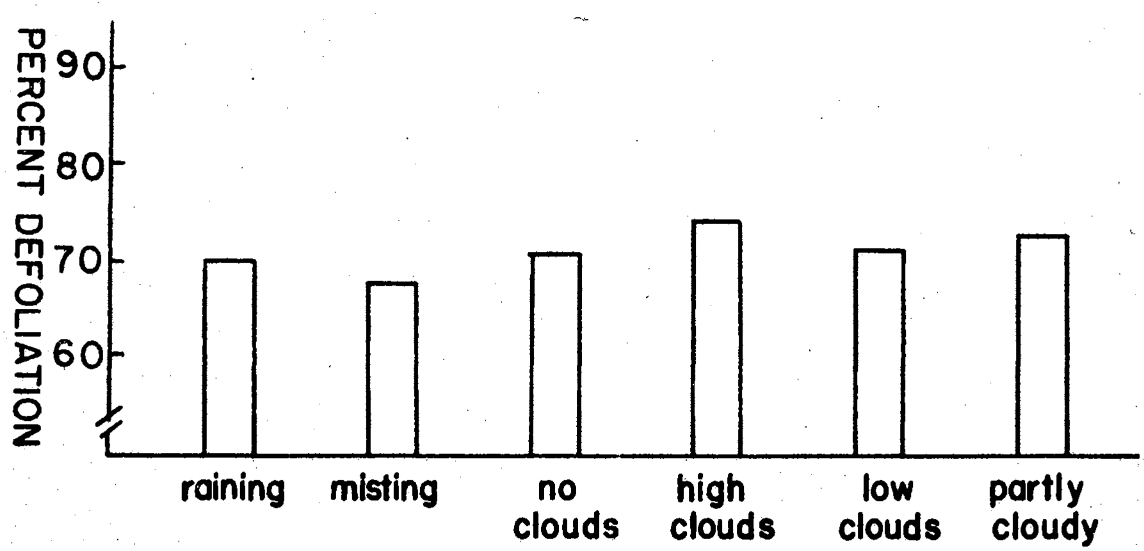

Figure 14. The Relationship Between Rain and Cloud Cover at Spray Time and Defoliation of Blackjack and Post Oaks with 2,4,5-T

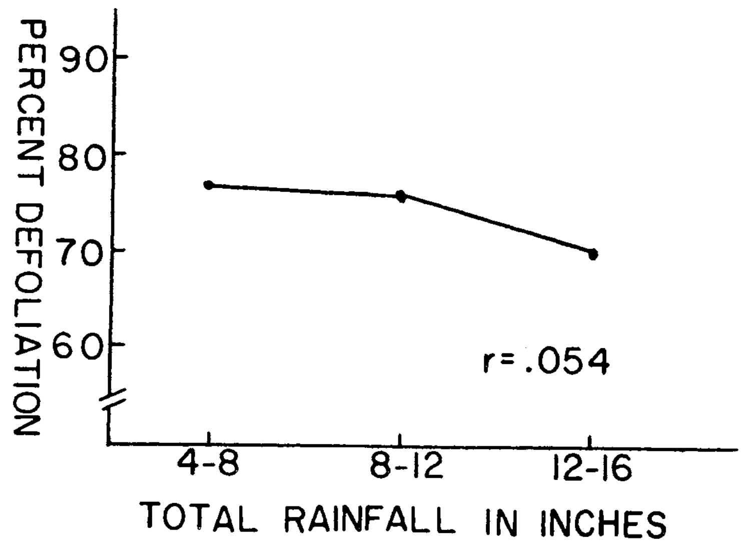

Figure 15. The Relationship Between Total Rainfall During the Previous Six Month Winter Dormant Season and Defoliation of Blackjack and Post Oaks with 2,4,5-T

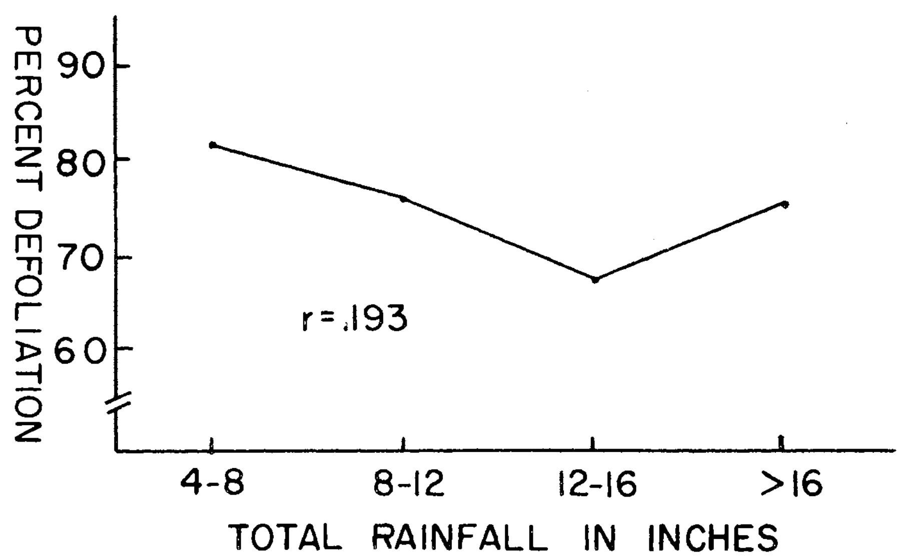

Figure 16. The Relationship Between Total Rainfall Three Months Prior to Application and Defoliation of Blackjack and Post Oaks with 2,4,5-T

susceptibility to foliar applied 2,4,5-T sprays. The data indicate rainfall one month prior to 2,4,5-T application is more critical than total rainfall for other time periods prior to or following spray application.

Total rainfall three months following 2,4,5-T application was not significantly correlated with defoliation of oaks following 2,4,5-T application (Figure 18). The r value for this factor as 0.013. Low correlations with rainfall may be partially due to methods used to collect data. Rainfall data was compiled from weather bureau records of the nearest recording stations which were often several miles from the sprayed area. Rains are seldom uniform over large areas and low correlations with total rainfall could be partially due to variation in rainfall between recording stations and the actual sprayed areas.

Application Factors: The effect of 2,4,5-T formulation on defoliation of oaks is shown in Figure 19. Average differences in defoliation were less than five percent for applications of butoxy ethanol, propylene glycol butyl ether, and isooctyl ester formulations of 2,4,5-T. Defoliation of blackjack and post oaks with amine formulations was ten percent lower than the average for low volatile esters. Amine formulations were applied at only two locations and more data is needed to adequately test their effectiveness. These results are in agreement with other workers who reported little or no difference in the effectiveness of aerially applied low volatile ester formulations of 2,4,5-T but found amine salts less effective for control of undesirable hardwoods (27, 30, 59). Defoliation for eight herbicide brands is shown in Table II. Differences in defoliation accredited to respective brands of low volatile ester formulations were considered non-significant as all brands resulted in defoliation with five percent of the average for all esters

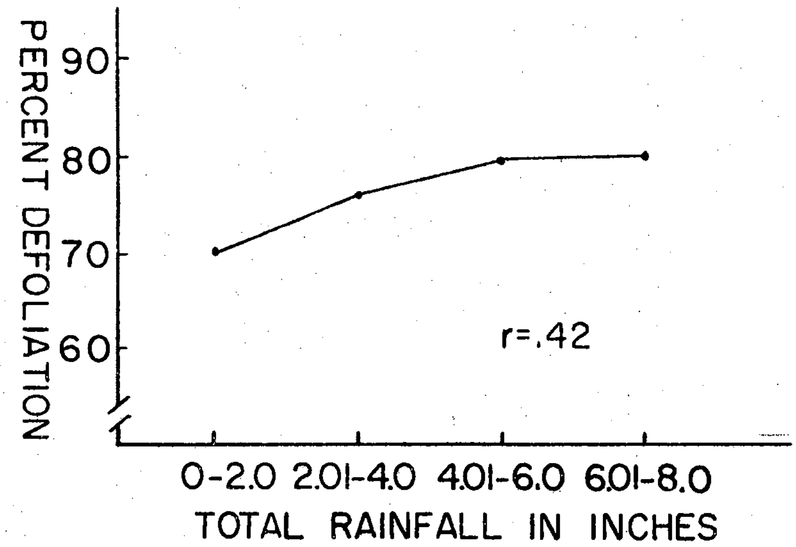

Figure 17. The Relationship Between Total Rainfall One Month Prior to Application and Defoliation of Blackjack and Post Oaks with 2,4,5-T

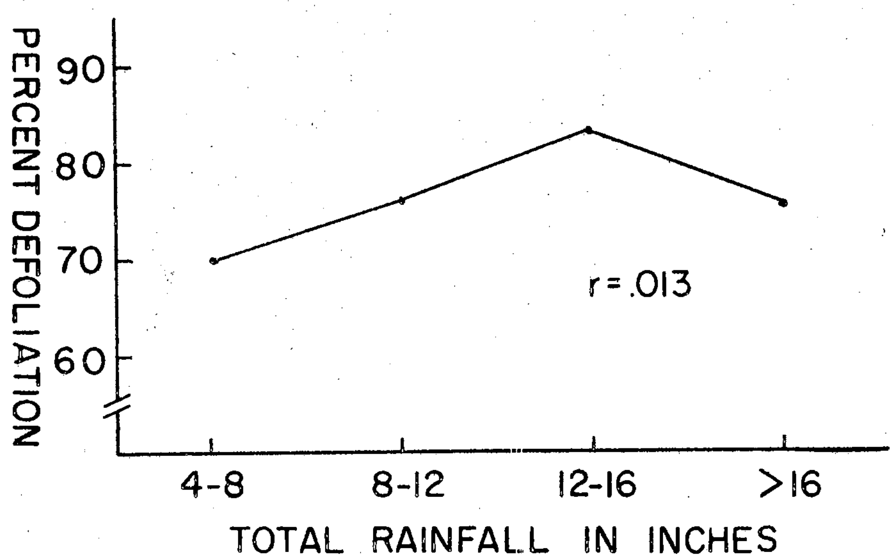

Figure 18. The Relationship Between Total Rainfall Three Months Following Application and Defoliation of Blackjack and Post Oaks with 2,4,5-T

tested.

TABLE II

THE EFFECT OF BRAND OF 2,4,5-T ON DEFOLIATION OF BLACKJACK AND POST OAKS

Brand of 2,4,5-T	Number of Samples	Percent Defoliation
A	24	73
B	14	69
C	7	72
D*	2	63
E	2	75
F	15	77
G	11	67
H	4	73
Av. of all Esters	77	72

*Amine Formulations

A rate of approximately two pounds per acre of 2,4,5-T was as effective as a three pound rate (Figure 20). The three pound rate was applied at two locations where total volume was increased from 5.0 to 7.5 gallons per acre.

Analysis of the 2,4,5-T field mixes which were applied to test areas showed 55 of 65 samples to be within 0.25 lbs. of the designated two pounds per five gallons (Table III). Eight samples contained more than 2.25 pounds of 2,4,5-T and only two samples were extremely low which contained 1.34 and .88 pounds of 2,4,5-T per five gallons. Oak defoliation for locations treated with field mixes containing 1.34

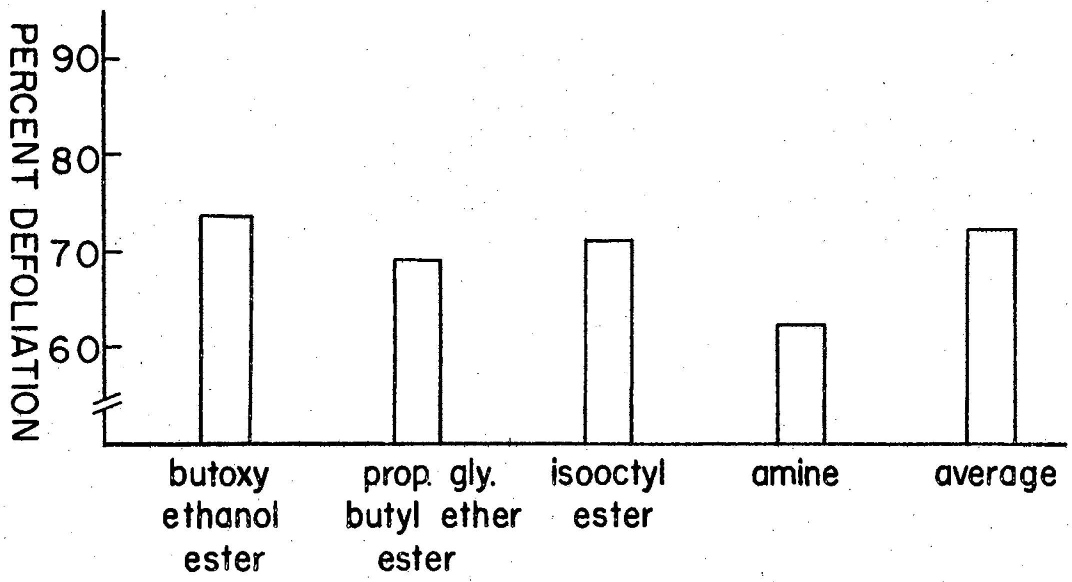

Figure 19. The Relationship Between 2,4,5-T Formulation and Defoliation of Blackjack and Post Oaks

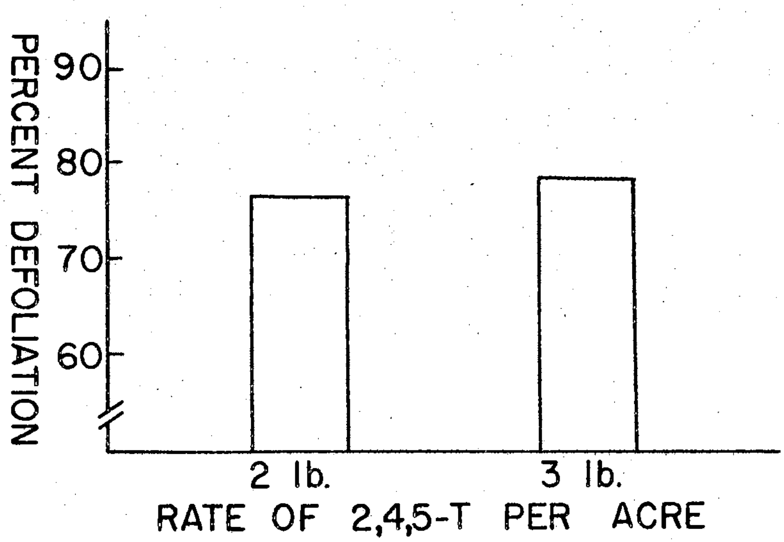

Figure 20. The Relationship Between Two Rates of 2,4,5-T and Defoliation of Blackjack and Post Oaks

TABLE III

CONCENTRATION OF 2,4,5-T IN COMMERCIALLY PREPARED SPRAY MIXES AND FREQUENCY OF CORRESPONDING DEFOLIATION OF BLACKJACK AND POST OAKS AFTER TREATMENT

lbs. of 2,4,5-T per 5 gal. field mix	Percent Defoliation and Frequency					Av.
	40-49%	50-59%	60-69%	70-79%	80-89%	
.88	1					43
1.34	1					44
1.76		1		1	2	75
1.78					1	82
1.80					6	71
1.82					1	88
1.84			1			67
1.86			1	1	2	77
1.90				4	6	79
1.92		3	3			58
1.94			2	2	1	72
1.98	2	1	1	4	1	65
2.04		1			1	72
2.06	1					58
2.08				1	2	79
2.12					1	84
2.18				1		78
2.32			1	1	2	75
2.36				2		77
2.46					1	80
2.62				1		75

pounds of 2,4,5-T or less was extremely low at 44-43%. Low defoliation for locations treated with field mix containing less than 1.76 pounds of 2,4,5-T per five gallons can be attributed to this factor alone. Low defoliation for locations treated with field mix containing 1.76 pounds or more of 2,4,5-T per five gallons could in some instances be attributed to some other factor such as poor coverage, high air temperature, fire, or date of application.

Pounds of 2,4,5-T per five gallons is a good indication of the rate and volume applied per acre. Aircraft were calibrated to apply five gallons volume per acre. Applicators frequently checked calibration to insure a five gallon volume per acre because a small error could be very costly. It is apparent from the data that the optimum rate of 2,4,5-T for control of oaks is above 1.34 pounds per acre but an increase from 1.76 to 2.62 pounds gave no further increase in oak defoliation.

Product concentration of 2,4,5-T had no effect on defoliation of blackjack and post oaks after treatment (Figure 21). Four and six pound concentrates were found to be equally effective for defoliation of blackjack and post oak when applied at approximately 2lb./A. Fifty-two locations were treated with four pound concentrates and 27 were treated with six pound concentrates.

General classes of fixed wing aircraft used for application of 2,4,5-T had no significant effect on defoliation of blackjack and post oaks (Figure 22). Previous investigations of various aircraft used for application of phenoxy herbicides on native rangelands have found no difference in effectiveness due to plane type (27, 70). Actual plane types were categorized from general classes in Figure 22 and illustrated in Table IV. Average defoliation ranged from a low of 68% to a high of

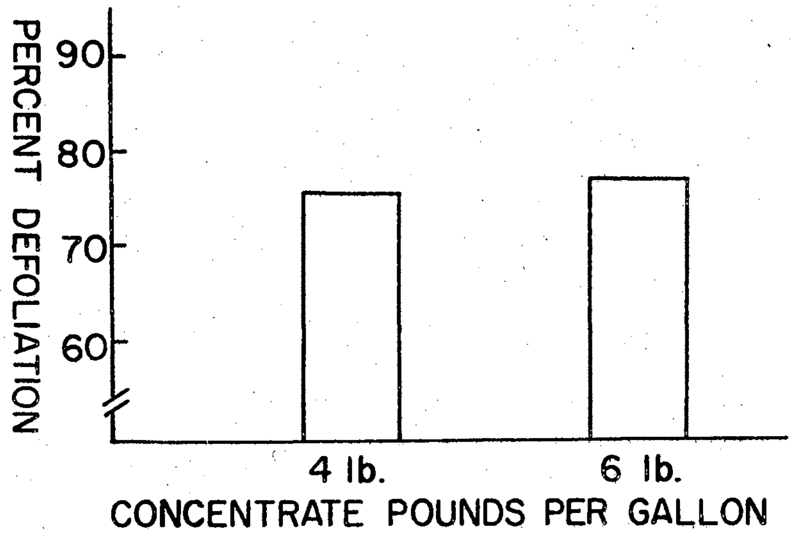

Figure 21. The Relationship Between 2,4,5-T Product Concentration and Defoliation of Blackjack and Post Oaks

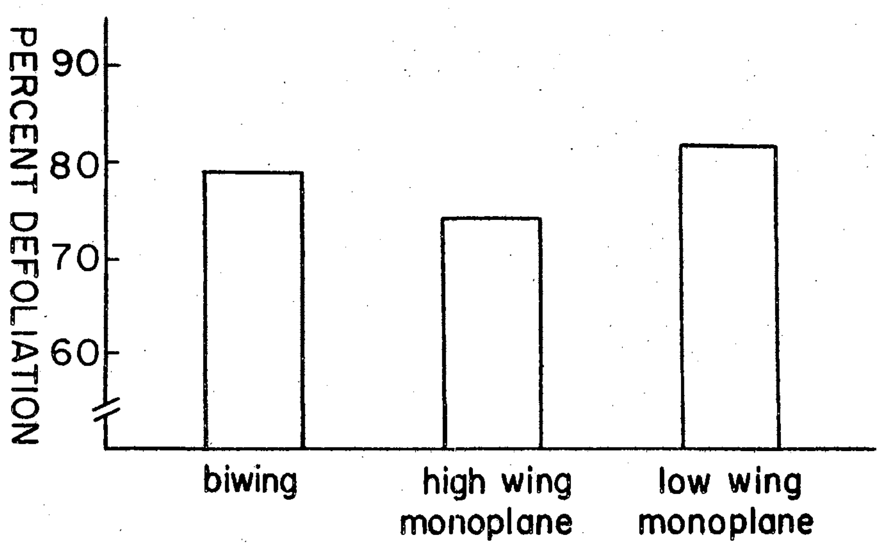

Figure 22. The Relationship Between Aircraft Design and Defoliation of Blackjack and Post Oaks with 2,4,5-T

83% with the overall average for all plane types being 77%. Defoliation following application of 2,4,5-T for all plane types except one was within six percent of the overall average. Small differences in defoliation due to plane type are regarded to be non-significant as substantial sample numbers were available only for Stearman aircraft.

TABLE IV

THE EFFECT OF PLANE TYPE USED FOR APPLICATION OF 2,4,5-T ON DEFOLIATION OF BLACKJACK AND POST OAKS

Plane Type	Number of Samples	Percent Defoliation
Stearman	53	77
Snow	6	83
Piper Pawnee	5	74
Piper Cub	9	68
Call Air	1	80
Others	5	77
Av. of all plane types	79	77

Airspeed in a range of 80 to 120 mph had no significant effect on defoliation of blackjack and post oaks with 2,4,5-T (Figure 23). Defoliation by 2,4,5-T was 75% and 78% for 80-100 and 100-120 mph ranges of airspeed respectively. This factor was subject to error in measurement as aircraft were seldom equipped with airpseed indicators. Previous workers have found that great increases in airspeed significantly reduced droplet size (63, 71). Fixed wing aircraft have a relatively narrow working range of airspeed, and this greatly restricts the use of airspeed in regulating droplet size, or spray distribution which are not seriously influenced by small changes in airspeed (71).

An increase in boom pressure caused a consistent decline in oak defoliation by 2,4,5-T (Figure 24). An increase in pressure from eight to 22 psi or more decreased defoliation by 2,4,5-T about 13%. All aircraft were not equipped with pressure gauges and accurate readings of boom pressure during spray dispersal were not obtained. Therefore, the data for boom pressure may not be a true indication of the effect of this factor and differences in defoliation should not be considered important. Other workers report the increase in boom pressure required to significantly reduce droplet size was far in excess of the range encountered in this study (41, 71). Applicators generally gave this factor little consideration in spraying brush.

The degree of spray coverage was significantly correlated with defoliation of blackjack and post oaks with 2,4,5-T (Figure 25). This factor resulted in an R value of 0.74 and a regression coefficient of 0.998 with defoliation. An increase in spray coverage up to 18.9% showed increased defoliation following treatment. Further increases in spray coverage did not influence defoliation. The data indicate that 16% spray coverage may be the minimum required for maximum effectiveness of aerially applied 2,4,5-T for control of blackjack and post oaks. Behrens (10) reported droplet spacing was the most critical aspect of spray coverage, and a minimum droplet spacing of 3.1 mm. (72 droplets/in.^{2}), was required for obtaining maximum herbicidal effectiveness of 2,4,5-T in mesquite. Ennis and Williamson (31) report greater phytotoxicity of 2,4-D esters and amines in low volume applications with spray droplets in a range of 100 microns diameter as compared to 300 micron diameter

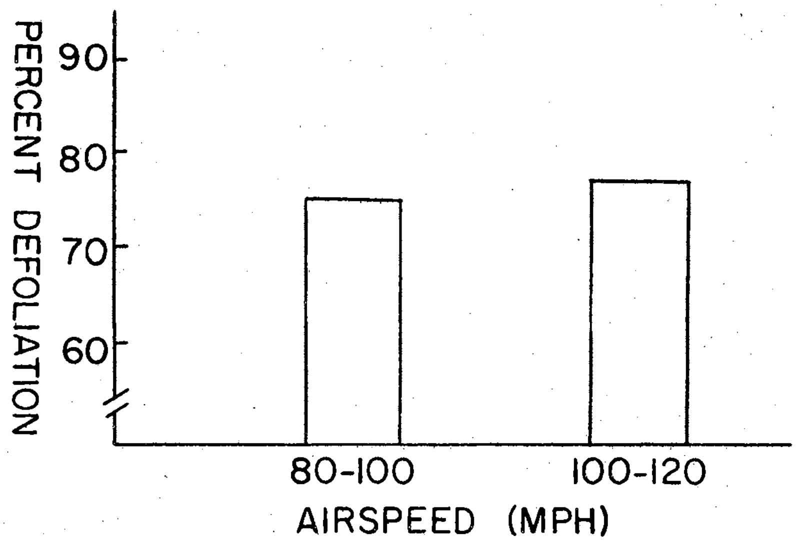

Figure 23. The Relationship Between Airspeed and Defoliation of Blackjack and Post Oaks with 2,4,5-T

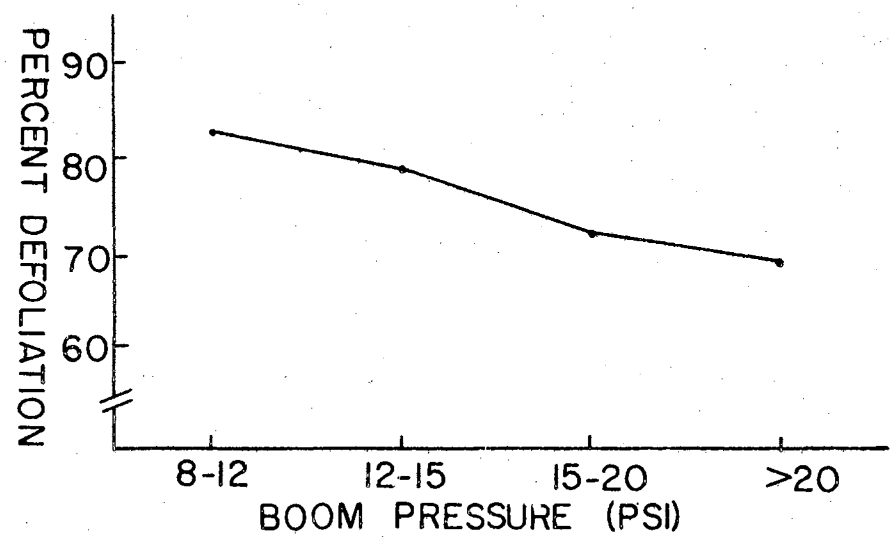

Figure 24. The Relationship Between Boom Pressure and Defoliation of Blackjack and Post Oaks with 2,4,5-T

droplets. Adequate coverage is critical in obtaining a high degree of 2,4,5-T effectiveness as indicated by previous workers and the results of this study. Spray coverage is probably influenced by other factors and a number of interactions may exist with other factors. Evaporation of dispersed sprays, herbicide volatility, and drift are of considerable importance in spray coverage and have been indicated to be primarily influenced by air temperature, relative humidity, and wind velocity (3, 65, 68).

Swath width had a definite influence on 2,4,5-T effectiveness. Defoliation of blackjack and post oaks by 2,4,5-T decreased with increased swath widths (Figure 26). Application of 2,4,5-T sprays in a 33 foot swath resulted in 85% defoliation with 40 and 50 foot swaths giving about 75% defoliation by 2,4,5-T. An increase in swath width to 65 feet lowered defoliation by 2,4,5-T to 55%. The number of locations treated with 33, 40, 50 and 65 foot swaths was 9, 65, 4, and 1 respectively. A 33 foot swath was slightly more effective than a 40 foot swath but 40 and 50 foot swaths were equally effective. Aircraft flying time could be reduced up to 25% if a 50 foot swath could be used with equal effectiveness of a 40 foot swath.

The effect of spray water pH on defoliation of blackjack and post oaks by 2,4,5-T is shown in Figure 27. The r value of 0.211 for pH was near the significant value of 0.225 at the 95% level. The pH values of samples tested were between pH 3.7 and pH 8.4. Fifty of 76 samples were in the range of pH 6.5-7.5. Thirteen and twelve samples had pH values below 6.5 and above 7.5 respectively. Extremely high pH of spray water may slightly reduce the effectiveness of 2,4,5-T for control of blackjack and post oaks. Sixteen percent of the samples tested

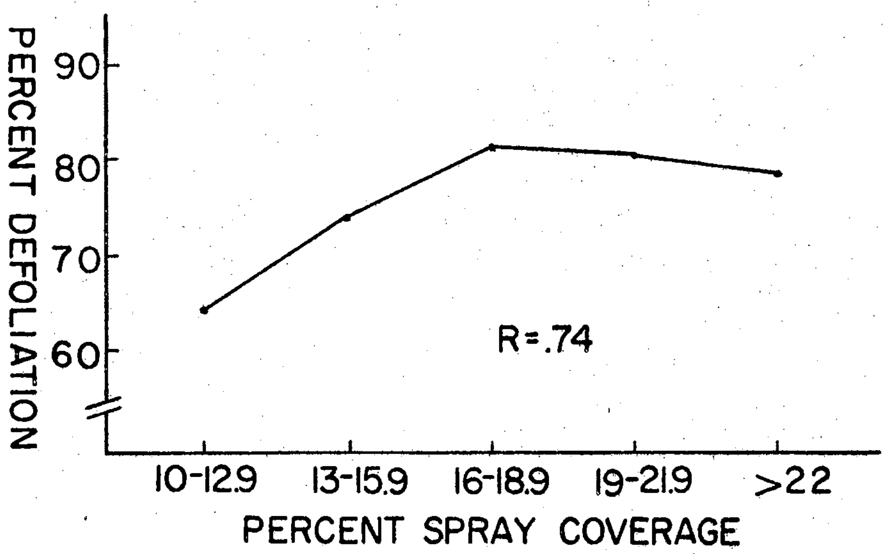

Figure 25. The Relationship Between Degree of Spray Coverage and Defoliation of Blackjack and Post Oaks with 2,4,5-T

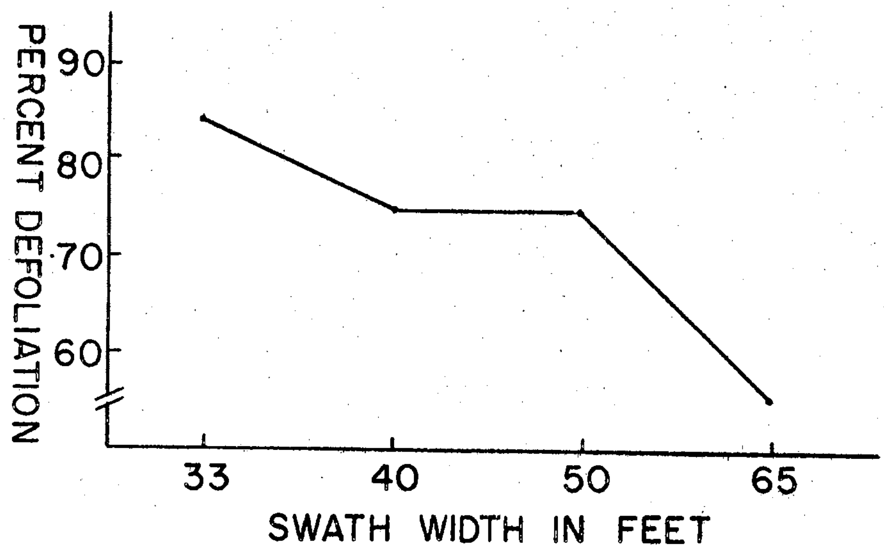

Figure 26. The Relationship Between Swath Width and Defoliation of Blackjack and Post Oaks with 2,4,5-T

had pH values above 7.5 but the reduction in defoliation after treatment was less than 10%. The results of this study indicate spray water pH should be considered a minor factor in aerial application of 2,4,5-T for control of blackjack and post oaks.

Conductivity of spray water had no effect on defoliation of oaks by aerially applied 2,4,5-T (Figure 28). Conductivity is a reciprocal of the electrical charge of a fluid substance and is expressed in micro mhos/cm^2 in this study. Conductivity is primarily influenced by ionic charge and increases in direct proportion to ion content. The effect of this factor was not significant and the difference in defoliation was only eight percent for samples with a range of conductivity from 92-4100. The majority of samples had lower conductivity values with 60 to 76 samples being in a 92-1000 range.

Total cation concentration of water used in preparing spray mixes had no significant effect on defoliation of blackjack and post oaks with 2,4,5-T (Figure 29). The r value of this factor was 0.136. Water which has a higher concentration of calcium and magnesium salts often creates compatibility problems in mixing and applying certain herbicides. Some workers have reported decreased effectiveness of foliar applied phenoxy herbicides for control of undesirable hardwoods when water used in mixing sprays contained calcium ions in excess of 20 ppm (13). The range of total cations in waters analyzed was 12-570 ppm. Calcium and magnesium were as high as 88 and 45 ppm respectively with no apparent influence on defoliation following 2,4,5-T application.

Total anion concentration of water used to prepare spray mixes had no significant effect on defoliation of blackjack and post oaks by 2,4,5-T (Figure 30). The difference in average defoliation was only

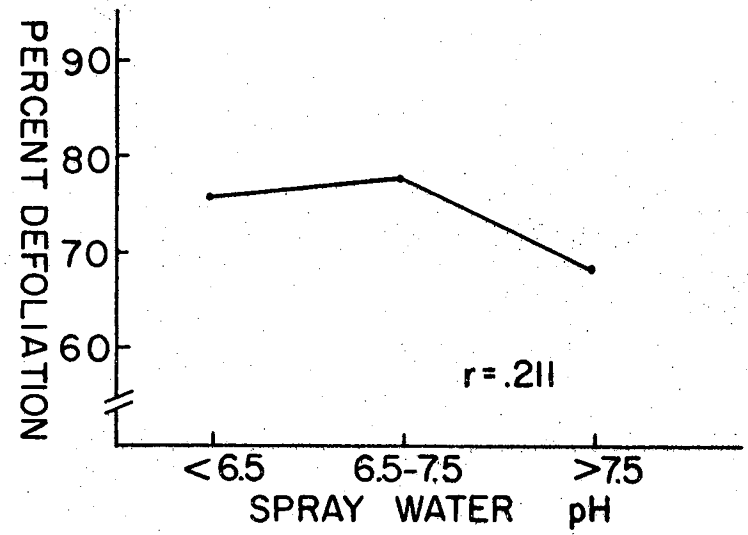

Figure 27. The Relationship Between Spray Water pH and Defoliation of Blackjack and Post Oaks with 2,4,5-T

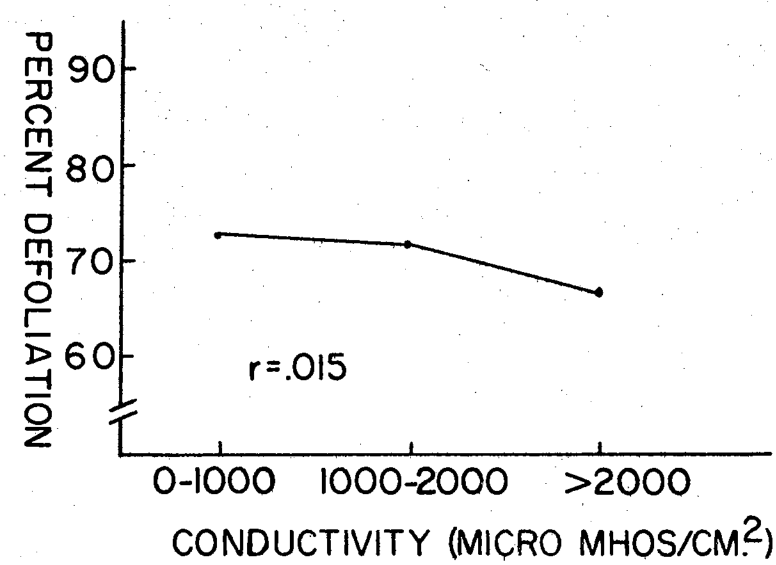

Figure 28. The Relationship Between Spray Water Conductivity and Defoliation of Blackjack and Post Oaks with 2,4,5-T

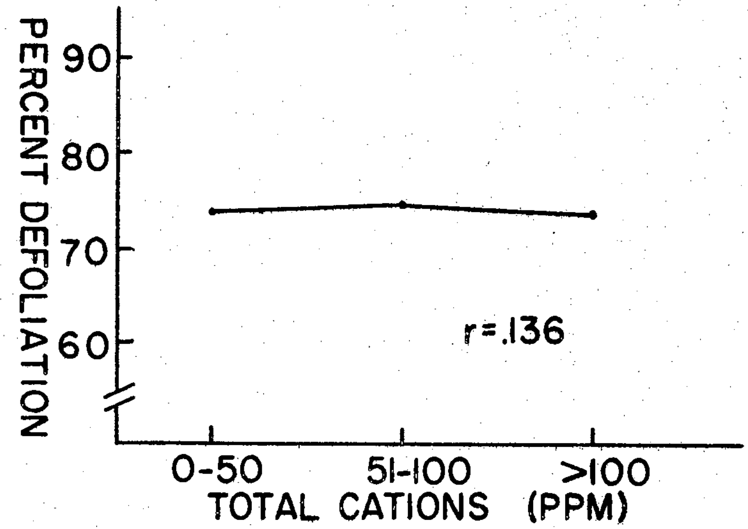

Figure 29. The Relationship Between Spray Water Cation Concentration and Defoliation of Blackjack and Post Oaks with 2,4,5-T

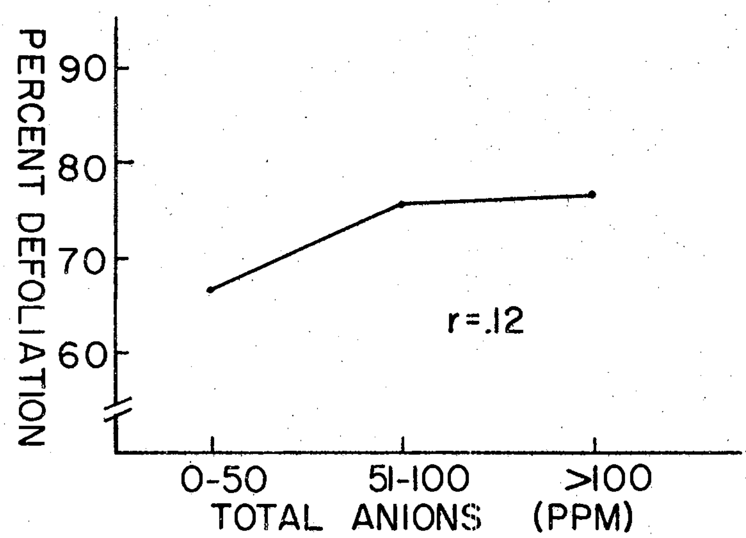

Figure 30. The Relationship Between Spray Water Anion Concentration and Defoliation of Blackjack and Post Oaks with 2,4,5-T

seven percent with a range in anion concentrations from 2-441 ppm.

The sodium absorption ratio (SAR) of waters used to prepare spray mixes had no significant effect on defoliation of blackjack and post oaks by 2,4,5-T (Figure 31). SAR of samples tested was either low or high as no samples tested had SAR values between 3.1 and 9.9. High SAR values were usually attributed to high sodium content which was as much as 22.1 millequivalents per liter.

Edaphic Conditions: Soil type had no influence on the susceptibility of blackjack and post oaks to aerially applied 2,4,5-T (Figure 32). Seventy-one of 79 total locations in the study occurred on sandy loam soil types, with only five and three locations having sand and sandy clay loam soil types respectively. The ecological character of blackjack and post oaks limits these plants to a range of sandy soil types as they are rarely encountered on limestone soils.

Soil depth had no significant effect on the susceptibility of oaks to 2,4,5-T. Differences in defoliations were less than five percent on soils of all depths (Figure 33). Thirty-five, 43, and one location occurred on soils in ranges of 0-15, 15-30, and $>$ 30 inches in depth respectively. This further shows the ecological and edaphic factors that limit blackjack and post oaks to shallower soils of upland ridges and slopes. In contrast, other oaks and associated hardwoods are usually the dominant species on deeper bottomland soils.

Topography had only a slight effect on blackjack and post oak defoliation by 2,4,5-T (Figure 34). Slightly higher defoliation was obtained from spraying blackjack and post oaks on bottomland areas, but no difference in oak response was observed on upland ridges or slopes. Associated hardwoods in bottomlands which occur with blackjack and

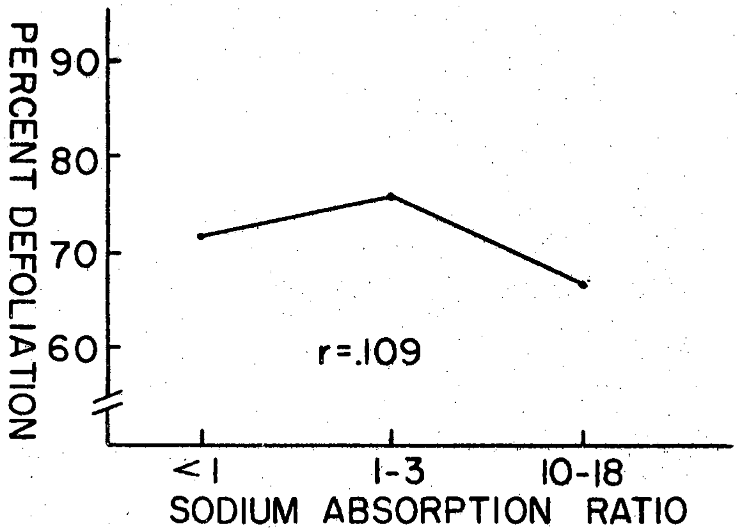

Figure 31. The Relationship Between Spray Water SAR and Defoliation of Blackjack and Post Oaks with 2,4,5-T

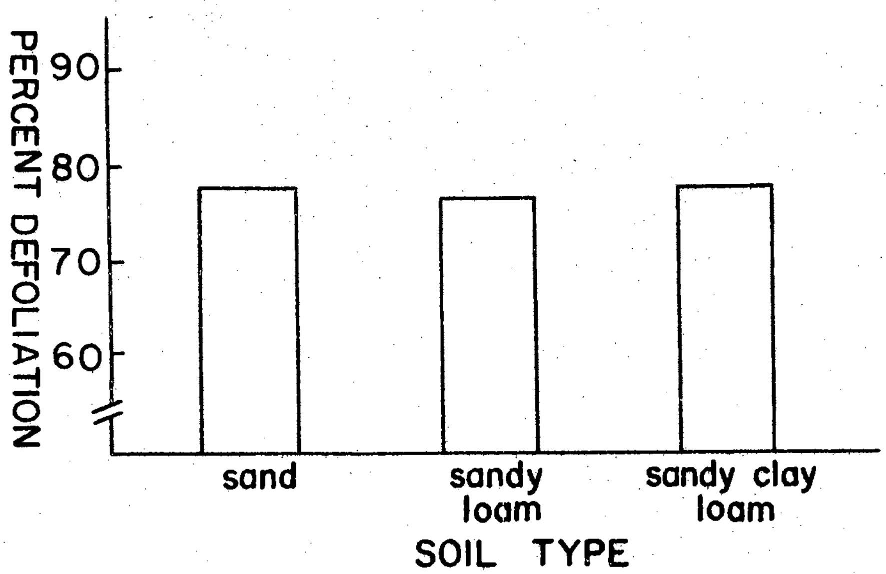

Figure 32. The Relationship Between Soil Type and Defoliation of Blackjack and Post Oaks with 2,4,5-T

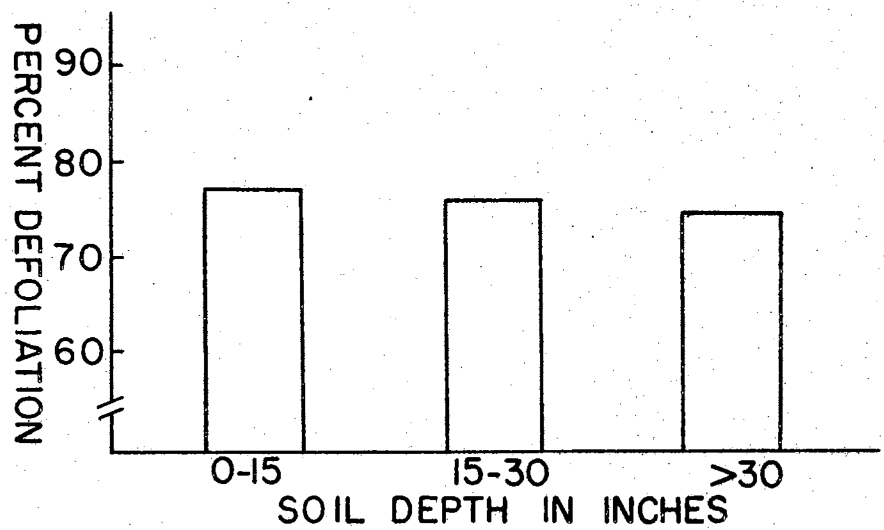

Figure 33. The Relationship Between Soil Depth and Defoliation of Blackjack and Post Oaks with 2,4,5-T

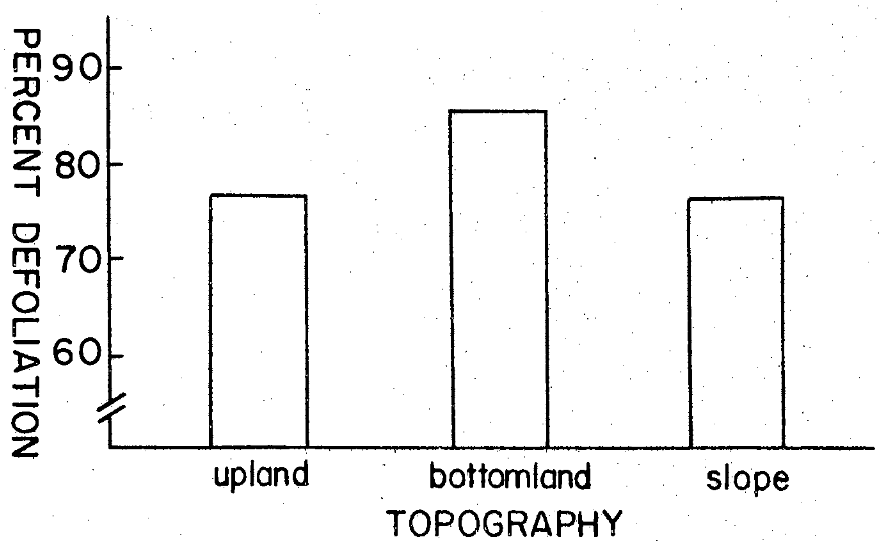

Figure 34. The Relationship Between Topography and Defoliation of Blackjack and Post Oaks with 2,4,5-T

post oaks were quite resistant to foliar applied 2,4,5-T and defoliation of all species on these sites was consistently lower. Higher defoliation on bottomlands could be caused by more active plant growth due to the more fertile soils and better soil moisture.

The influence of soil moisture at spray time on defoliation of blackjack and post oaks following 2,4,5-T treatment is shown in Figure 35. Data from sandy loam soil type was used to show the influence of soil moisture level on oak defoliation by 2,4,5-T. Sandy loam soils were the major soil type on 71 of 79 locations in the study. Defoliation of oaks was eight percent higher at a 5-10% soil moisture level than at the 0-5% level. Defoliation by 2,4,5-T decreased slightly with an increase in soil moisture from 5-10% to 20-25% but increased to 78% at 25-30% soil moisture. Some workers report a 50% reduction in translocation of 2,4-D in bean, corn, and soybean plant maintained at ½ field capacity or near the permanent wilting point (9, 38, 57). The percent soil moisture in sandy loam soils at field capacity would be approximately 20-30%. If the susceptibility of oaks was reduced at ½ field capacity, lower defoliation should be observed at 10-15% soil moisture. A slight decrease in defoliation was observed at 0-5% soil moisture but not at 10-15%. This indicates soil moisture at spray time may not influence the susceptibility of oaks to 2,4,5-T or if so, only at moisture levels below ½ field capacity. Other workers report that soil moisture following treatment with 2,4,5-T may affect susceptibility of winged elm and blackjack more than soil moisture at spray time (30, 72).

Soil temperature had no significant correlation with defoliation of oaks by 2,4,5-T. This factor had a correlation coefficient of 0.166

(Figure 36). Defoliation was higher at low soil temperatures, but temperatures above 90° F. were not encountered until late in the spray season. The influence of soil temperature is probably a reflection of poor plant condition, treatment date, and air temperatures as the soil temperatures were read in the 2-4 inch soil depth.

The major factors contributing to the success or failure of aerially applied 2,4,5-T in this study were found to be application date, frost free interval prior to application, air temperature at spray time, percent spray coverage, relative humidity at spray time, swath width, and total rainfall one month prior to spray application.

Factors which seemed to have a slight effect on 2,4,5-T activity were excessive leaf wax and cuticle, wind velocity, dew at spray time, insect damage, topography, plane type, and the difference in ester and amine formulations of 2,4,5-T.

Plant conditions which did not appear to influence the effectiveness of 2,4,5-T for control of blackjack and post oaks were retreatments up to three years following an initial treatment, tree size, and range condition.

Environmental factors which showed no significant effect on oak response to 2,4,5-T were wind direction at spray time, rain and cloud cover at spray time, and total rainfall six months prior, three months prior, and three months following spray application.

Application factors which had no significant effect on defoliation of oaks with 2,4,5-T within the limits encountered were airspeed, aircraft design, product concentration, rate of 2,4,5-T in excess of two pounds per acre, herbicide brand, boom pressure, and pH, conductivity, total cations, total anions, and SAR of spray water. Edaphic factors

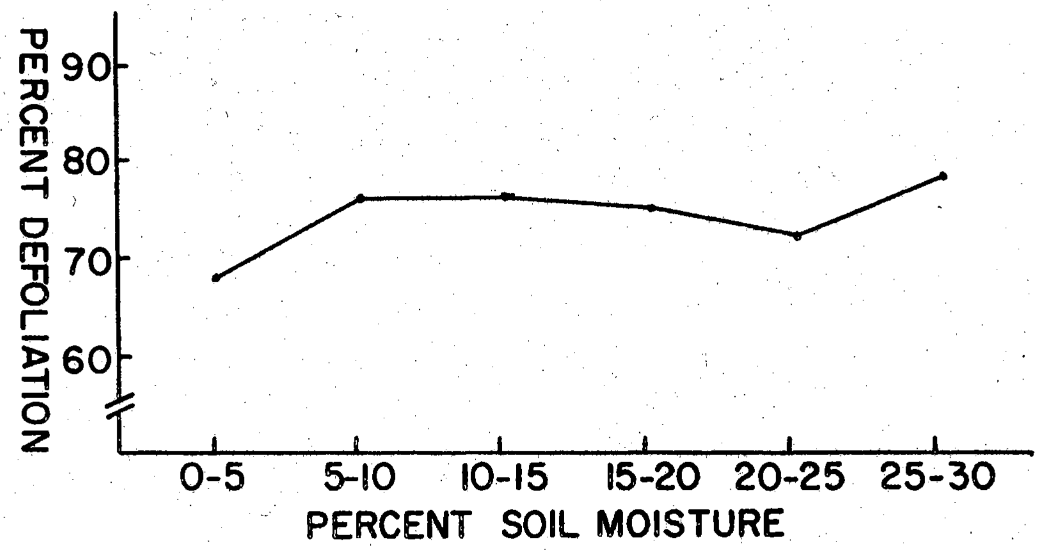

Figure 35. The Relationship Between Soil Moisture and Defoliation of Blackjack and Post Oaks with 2,4,5-T

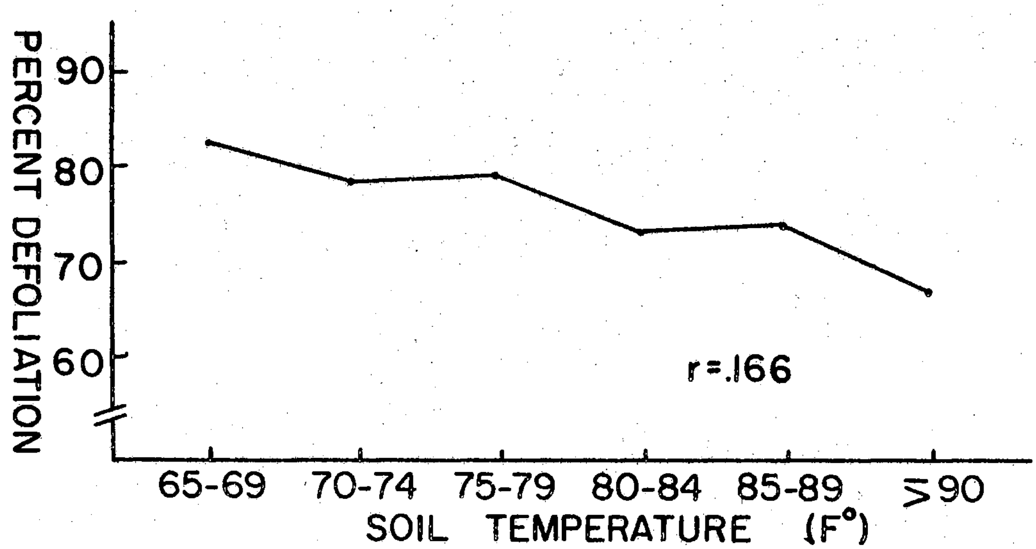

Figure 36. The Relationship Between Soil Temperature and Defoliation of Blackjack and Post Oaks with 2,4,5-T

had very little influence on 2,4,5-T effectiveness. Soil type, soil depth, soil moisture at spray time and soil temperature had no significant effect on defoliation of blackjack and post oaks by aerially applied 2,4,5-T.

Application date and frost free interval prior to 2,4,5-T application showed the seasonal susceptibility of blackjack and post oaks to 2,4,5-T. These two factors were given priority because when oaks are not susceptible to foliar applied 2,4,5-T, herbicide phytotoxicity will consistently be low. Reduced 2,4,5-T phytotoxicity after the period of maximum herbicidal effectiveness could be an indication of the combined adverse effects due to a number of other factors. Poor defoliation of oaks by 2,4,5-T after early July may be a reflection of decreased plant growth, higher daily air temperatures, excessive leaf wax and cuticle, and an adverse effect on spray coverage through higher air temperature and increased spray evaporation.

CHAPTER V

SUMMARY

Studies were conducted at 79 locations in 10 eastern Oklahoma counties to determine the factors adversely influencing the effectiveness of aerially applied 2,4,5-trichlorophenoxyacetic acid for control of blackjack and post oaks. Data on 36 factors which were suspected of having a possible influence on 2,4,5-T activity were collected at the site of application during the actual commercial spraying operation. Defoliation three months following herbicide application was used as the criterion for plant response.

Plant condition at spray time was found to have considerable influence on defoliation by 2,4,5-T. Application date and frost free interval prior to herbicide application showed definite and similar trends of influencing oak susceptibility to foliar applied 2,4,5-T. Maximum susceptibility occurred during a period of one to two weeks but satisfactory defoliation was obtained for a period of approximately two months from late May to early July. This corresponded to frost free intervals from 4-16 weeks prior to herbicide treatment. Moderate insect damage to oak foliage and a very waxy leaf condition at spray time slightly reduced 2,4,5-T effectiveness but were not present to a noticeable degree until later in the spray season when oaks were not growing actively.

Retreatment applications of 2,4,5-T were as successful as initial applications and oak susceptibility to retreatments did not appreciably decline 1-3 years following the initial treatment. Fire less than one year prior to application of 2,4,5-T resulted in 20% lower defoliation, but treatments on areas burned two or more years prior to spraying were as effective as treatments on unburned areas.

Range condition and tree size had no effect on oak response to aerially applied 2,4,5-T.

A number of environmental factors had highly significant correlations with oak defoliation by 2,4,5-T. Air temperature correlation was highly significant; temperatures above 90° F. resulted in defoliation of approximately 60% after treatment. Wind velocity above six mph reduced defoliation by 2,4,5-T about 10% and wind direction with plane flight resulted in slightly less defoliation than wind diagonal to or across plane flight. The correlation between relative humidity and defoliation by 2,4,5-T was highly significant, a 20% increase in relative humidity generally increasing defoliation about 10%. A noticeable amount of dew at spray time slightly increased defoliation by 2,4,5-T but cloud cover and rain at spray time had no significant influence on oak response. Total rainfall one month prior to 2,4,5-T application was significantly correlated with oak defoliation and was more critical than total precipitation during the previous six month winter dormant season, total rainfall three months prior to application, or total rainfall three months following herbicide treatment. Locations receiving 4.01-6.0 inches of total rainfall one month prior to spray treatment were defoliated 10% higher than areas receiving 0-2.0 inches total rainfall before treatment.

Defoliation by 2,4,5-T had a highly significant correlation with spray coverage and increased with spray coverage up to 16-18%. Further increases in coverage did not result in higher defoliation. Defoliation decreased as wider swath widths from 33-65 feet were used for 2,4,5-T application. A 50 foot swath was equally as effective to a 40 foot swath. Product concentration of 2,4,5-T had no effect on defoliation of oaks following application, and esters were slightly more effective than amine formulations. Two and three pound rates per acre of 2,4,5-T were equally effective for defoliation of blackjack and post oaks. Analysis of field mixes applied to sprayed areas showed samples containing less than 1.76 pounds of 2,4,5-T per five gallons resulted in lower defoliation after treatment. Aircraft design, plane type, and airspeed had no significant influence on defoliation by 2,4,5-T. Increases in boom pressure reduced 2,4,5-T phytotoxicity but was considered non-significant due to lack of a precise measurement and considerable variability. Conductivity, pH, total cations, total anions, and SAR of water used as carriers for 2,4,5-T had no significant effect on defoliation of blackjack and post oaks.

Soil type, soil depth, topography, soil moisture at spray time, and soil temperature had only slight or no effect on oak defoliation by 2,4,5-T as no edaphic factors showed significance.

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APPENDIX

TABLE V

ANALYSIS OF VARIANCE FOR AIR TEMPERATURE

Source	df	Sum of Squares	Mean Square	F
Regression	1	3,524.62	3,524.62	39.0**
Residual	77	6,946.38	90.21	
Total (y)	78	10,471.00		

TABLE VI

ANALYSIS OF VARIANCE FOR RELATIVE HUMIDITY

Source	df	Sum of Squares	Mean Square	F
Regression	1	2,336.20	2,336.20	22.12**
Residual	77	8,134.80	105.60	
Total (y)	78	10,471.00		

TABLE VII

ANALYSIS OF VARIANCE FOR TOTAL RAINFALL DURING PREVIOUS SIX MONTH DORMANT SEASON

Source	df	Sum of Squares	Mean Square	F
Regression	1	270.03	270.03	.89 (NS)
Residual	77	10,200.97	132.16	
Total (y)		10,471.00		

TABLE VIII

ANALYSIS OF VARIANCE FOR TOTAL RAINFALL
THREE MONTHS PRIOR TO SPRAYING

Source	df	Sum of Squares	Mean Square	F
Regression	1	391.59	391.59	2.98 (NS)
Residual	77	10,099.41	131.16	
Total	78	10,471.00		

TABLE IX

ANALYSIS OF VARIANCE FOR TOTAL RAINFALL
ONE MONTH PRIOR TO SPRAYING

Source	df	Sum of Squares	Mean Square	F
Regression	1	630.63	630.63	4.93*
Residual	77	9,840,37	127.79	
Total	78	10,471.00		

TABLE X

ANALYSIS OF VARIANCE FOR TOTAL RAINFALL
THREE MONTHS FOLLOWING SPRAYING

Source	df	Sum of Squares	Mean Square	F
Regression	1	18.96	18.96	.14 (NS)
Residual	77	10,452.04	135.74	
Total	78	10,471.00		

TABLE XI

ANALYSIS OF VARIANCE FOR DEGREE OF SPRAY COVERAGE

Source	df	Sum of Squares	Mean Square	F
Regression	1	5,888.69	2.944,34	57.02**
Residual	65	3,356.31	51.63	
Total (y)	67	9,244.00		
R = .739				

TABLE XII

ANALYSIS OF VARIANCE FOR pH OF WATER USED IN SPRAY MIX

Source	df	Sum of Squares	Mean Square	F
Regression	1	465.00	465.00	3.44 (NS)
Residual	74	9,831.00	135.22	
Total (y)	75	10,288.00		

TABLE XIII

ANALYSIS OF VARIANCE FOR CONDUCTIVITY OF WATER USED IN SPRAY MIX

Source	df	Sum of Squares	Mean Square	F
Regression	1	221.00	221.00	1.62 (NS)
Residual	74	10,067.00	136.04	
Total (y)	75	10,288.00		

TABLE XIV

ANALYSIS OF VARIANCE FOR TOTAL CATIONS IN SPRAY WATER

Source	df	Sum of Squares	Mean Square	F
Regression	1	192.00	192.00	1.48 (NS)
Residual	74	10,096.00	129.70	
Total (y)	75	10,288.00		

TABLE XV

ANALYSIS OF VARIANCE FOR TOTAL ANIONS IN SPRAY WATER

Source	df	Sum of Squares	Mean Square	F
Regression	1	149.00	149.00	1.08 (NS)
Residual	74	10,139.00	137.00	
Total (y)	75	10,288.00		

TABLE XVI

ANALYSIS OF VARIANCE FOR SAR OF WATER USED IN SPRAY MIX

Source	df	Sum of Squares	Mean Square	F
Regression	1	122.67	122.67	.83 (NS)
Residual	74	10,165.33	137.36	
Total (y)	75	10,288.00		

TABLE XVII

ANALYSIS OF VARIANCE FOR SOIL TEMPERATURE

Source	df	Sum of Squares	Mean Square	F
Regression	1	286.15	286.15	2.10 (NS)
Residual	77	10,184.85	135.90	
Total	78	10,471.00		

VITA

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Master of Science

Thesis: FACTORS INFLUENCING THE EFFECTIVENESS OF COMMERCIAL AERIAL APPLICATIONS OF 2,4,5-TRICHLOROPHENOXYACETIC ACID FOR CONTROL OF BLACKJACK AND POST OAKS

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