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FINAL REPORT ON RESEARCH TO IDENTIFY EFFECTIVE FOLIAR SPRAYS AND MECHANIZED SPRAY DELIVERY SYSTEMS FOR SELECTIVE CONTROL OF MESQUITE ON RIGHTS-OF-WAY

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16. Abstract

High-volume foliar sprays containing 0.5% clopyralid + 0.5% triclopyr ester applied during July, August, or mid-October provided levels of rootkill sufficiently high (58 - 98%) to justify the adoption of this practice for control of mesquite on Texas highway rights-or-way. Spray carriers containing 0.5% non-ionic surfactant or 5% diesel fuel oil performed equally for this leaf spray. Mesquite rootkill was not increased by increasing the concentrations of clopyralid, triclopyr ester, or diesel fuel oil in the spray mixture. Mesquite control increased with longer intervals after mowing that allowed the mesquite to develop sufficient leaf surface area for absorption of lethal doses of herbicide and the foliage to mature and begin translocating carbohydrates and the herbicides downward into the basal meristems and roots. Mechanized, automated spray delivery systems that were developed and proven effective for selective application of leaf sprays to mesquite plants included a personnel carrier, mechanical-sensing automatic sprayer, light-sensing automatic sprayer, and an automatic all-terrain vehicle (ATV) sprayer. All mechanized systems were more cost effective than the application of Pathfinder II herbicide stem sprays by ground crews, but less cost-effective than the selective application of leaf sprays to mesquite by ground crews. The automatic ATV sprayer was the most cost efficient mechanized spraying system at mesquite densities <400 plants/acre, and the personnel carrier was the most cost-effective system at mesquite densities >400 plants/acre. All mechanized spraying systems were more efficient relative to acres treated/hour than ground crews applying stem or leaf sprays. The application of stem sprays by ground crews was less labor-efficient than the application of leaf sprays by ground crews.

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LIST OF ABBREVIATIONS

a.e.	acid equivalent
ATV	all-terrain vehicle
diam.	diameter
F	Fahrenheit
ft	foot (feet)
gal	gallon(s)
hr	hour
i.d.	inside dimension
in.	inch(es)
lb	pound(s)
ln	natural logarithm
LSD	least significant difference
min	minute
no.	number
oz	ounce(s)
P	probability level
psi	pounds per square inch
PTO	power take off
PVC	polyvinyl chloride
r^2	correlation coefficient
rpm	revolutions per minute
sec	second(s)
YAT	year(s) after treatment
yr	year

INTRODUCTION and BACKGROUND

Honey mesquite (Prosopis glandulosa var. glandulosa) is a major problem on highway rights-of-way in the western two-thirds of the State of Texas. Mesquite thorns puncture tires of motor vehicles and right-of-way maintenance equipment, resulting in considerable expense and a safety hazard. Annual mowing of roadsides only temporarily suppresses mesquite, and this practice is increasingly expensive. Mesquite mowed in the autumn often grows 2 to 3 ft tall during the subsequent growing season. The only herbicide treatment currently utilized by the Texas Department of Transportation for mesquite control is the low-volume basal application (stem spray) of Pathfinder II as an individual plant treatment. This method is highly effective, but extremely labor intensive, especially for control of heavy infestations of multiple-stemmed mesquite regrowth growing in association with dense, herbaceous vegetation. This research project was initiated in 1995 to develop or identify more cost- and labor-efficient technology for mesquite control in highway rights-of-way.

REVIEW of PREVIOUS WORK

High-volume foliar sprays (leaf sprays) containing 0.5% clopyralid monoethanolamine salt + 0.5% triclopyr butoxyethyl ester are widely used for control of small mesquite on rangelands (McGinty and Ueckert 1995). This leaf spray killed an average of 80% (range 61 - 93%) of the mesquite treated in 1995 in five large-plot trials on rangelands in west-central Texas (Ueckert et al. 1997). Results from these trials and from our research in 1995 on highway rights-of-way (Ueckert and McGinty 1995) revealed that leaf sprays were much less labor intensive and less expensive than basal stem sprays for controlling multiple-stemmed mesquite regrowth. Leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester are phytotoxic to many broadleaved plants (e.g. forbs and weeds), but grasses are resistant. Populations of broadleaved plants usually re-establish in 1 to 2 yrs after treatment.

Clopyralid and triclopyr ester are registered for use on highway rights-of-way as Transline and Garlon 4, respectively. The ester formulation of triclopyr (Garlon 4) is generally more effective than triclopyr amine (Garlon 3A) for mesquite control because of greater penetration of the ester through the leaf surfaces (Jacoby and Meadors 1983, Bovey and Meyer 1987). Clopyralid is the most effective herbicide known for control of mesquite by foliar application (Bovey and Meyer 1985, Jacoby et al. 1981), probably because it is absorbed and translocated downward in greater concentrations than other herbicides (Bovey et al. 1986, Bovey et al. 1988). Adding the butoxyethyl ester of triclopyr to clopyralid (1:1 ratio) in foliar sprays enhanced the deposition of clopyralid upon mesquite leaves, the absorption and downward translocation of clopyralid, and mesquite mortality, compared to that achieved with clopyralid alone (Bovey et al. 1988, Bovey and Whisenant 1991).

Top-removal of mesquite, such as by mowing, stimulates sprouting of dormant basal buds and the development of multiple-stemmed regrowth that is more resistant to broadcast herbicide applications as compared to undisturbed plants (Jacoby et al. 1990). Leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester applied in early August killed only 42% of the mesquite regrowth that had been topkilled by fire 1 yr prior to spraying, compared to 80% for mesquite that had been topkilled by fire 2 yr prior to spraying (D.N. Ueckert, unpublished data). The current recommendation is to delay the treatment of mesquite regrowth until it is about 4 ft in height before applying broadcast herbicide applications or leaf sprays to individual mesquite plants (DowElanco 1990). Since allowing mesquite in highway rights-of-way to grow to a height of 4 ft before spraying is not usually feasible, increasing the herbicide and/or adjuvant concentrations in leaf sprays should be investigated as mechanisms for achieving adequate herbicide absorption, downward translocation, and acceptable levels of mesquite regrowth mortality.

Because of the vast acreage of mesquite-infested rights-of-way and the limited labor force available to the Texas Department of Transportation, mechanized and automated systems are needed which can deliver effective herbicide treatments to mesquite with minimal labor input. These spraying systems must selectively apply the herbicide treatment to the mesquite plants, with minimal damage to associated grasses and wildflowers, and with minimal risk of physical drift of herbicide off the target areas. A limited amount of work has been done to develop automated herbicide delivery systems for control of woody plants on rangelands (Mayeux and Crane 1985, Wiedemann et al. 1992), but none are available commercially that are suited for selective application of leaf sprays to regrowth mesquite in rights-of-way.

STATEMENT of RESEARCH OBJECTIVES

Objective 2: Determine the minimum concentrations of clopyralid (Transline) and triclopyr ester (Garlon 4) and the optimal herbicide carrier in high-volume foliar sprays of these herbicides for effective control of mesquite regrowth in highway rights-of-way.

Objective 3: Design and fabricate mechanized and automated systems for application of proven tactical mesquite control techniques, and evaluate the efficiency of these systems for control of mesquite regrowth in highway rights-of-way.

RESEARCH APPROACH/PROCEDURES

Objective 2: Identify effective leaf sprays for control of mesquite regrowth.

One small-plot field experiment was installed in mid October 1995 and 12 were installed during June, July, and August 1996 (four each month) on highway rights-of-way in west-central Texas. Dates and locations for the 13 experiments are shown in Table 1.

Treatments included in the October 1995 experiment included 1:1 ratio mixtures of clopyralid and triclopyr ester at 0.5% + 0.5%, 0.75% + 0.75%, or 1.0% + 1.0% applied as high-volume foliar sprays in water + 0.5% Silwet L-77 surfactant (polyalkyleneoxide modified heptamethyltrisiloxane and allyloxypolyethylene glycol methyl ether), or in oil:water emulsions containing 5% diesel fuel oil, 25% diesel fuel oil, or 5% vegetable oil (improved JLB Oil Plus). The commercial emulsifier Triton X-100 was used at 1 oz/gal of oil to create the oil:water emulsions during agitation in the spray tanks. Treatments applied in the 1996 experiments included 1:1 ratio mixtures of clopyralid and triclopyr ester at 0.5% + 0.5%, 1.0% + 1.0%, or 2.0% + 2.0% applied as foliar sprays in water + 0.5% non-ionic surfactant [25% nonyphenol polyethylene glycol ether (Surf Wet NP)], or in diesel fuel oil:water emulsions containing 5% or 20% diesel fuel oil. Foliar sprays were applied to the foliage and stems of individual mesquite plants to the point of runoff with backpack sprayers in the October 1995 experiment and with all-terrain vehicles (ATVs) equipped with spray tanks, electric pumps, hoses, and spray guns with ConeJet 5500-PPB-X6 adjustable cone nozzles in the 1996 experiments. Experiments were arranged as completely randomized designs with three replications of each treatment, except that single plots were treated at the Schleicher County site.

Plot sizes varied depending upon the density of the mesquite. Plots extended from fence lines to the edge of the strip-mowed swaths adjacent to the pavements. Mesquite that had been strip-mowed during the season of treatment were not sprayed. Mesquite at the Tom Green County site had never been mowed. Mesquite at the Coke County site had not been mowed for about 3 yr, and that at the study sites in Menard, Edwards, and Sterling Counties had not been mowed for about 2 yr at time of treatment. At all other study sites the mesquite had been mowed during the autumn preceding the 1996 treatments.

Each plot was evaluated by a team of three or four workers at 2 yr post-treatment. Each worker carefully examined all mesquite in a belt transect about 6 ft wide and parallel with the long axis of each plot. Mesquite plants with live tissue were recorded as live and those with no live tissue were recorded as dead. The percentage of dead plants in each plot was calculated. The data were subjected to analyses of variance and means were separated by least significant difference (LSD) at the 0.05 probability level, where appropriate.

Table 1. Dates and locations of small-plot field experiments installed to identify the optimal concentrations of clopyralid (Transline) and triclopyr ester (Garlon 4) in leaf sprays and the optimal carrier for these sprays to achieve acceptable control of mesquite regrowth on highway rights-of-way in west-central Texas.

Date	County	Location
Oct. 16-17, 1995	Tom Green	East Loop 306 between FM 765 and US 87
June 18, 1996	Schleicher	US 190 between reference markers 358 & 360
June 19, 1996	Reagan	US 67 between reference markers 754 & 756
June 20, 1996	Menard	FM 2092 between reference markers 420 & 422
June 21, 1996	Runnels	FM 2333 between reference markers 344 & 346
July 22, 1996	Edwards	FM 2630 between reference markers 452 & 454
July 23, 1996	Concho	FM 2134 between reference markers 364 & 366
July 24, 1996	Coke	FM 2742 from FM 2059 west 2 miles
July 24, 1996	Sterling	SH 163 between reference markers 450 & 452
Aug. 19, 1996	Crockett	FM 1964 from 2 miles W. of SH 137, then 2 miles W.
Aug. 19, 1996	Irion	SH 163 between reference markers 484 & 486
Aug. 20, 1996	Glasscock	FM 1357 between reference markers 340 & 342
Aug. 20, 1996	Nolan	FM 1170 between reference markers 385 & 387

Objective 3: Design, fabricate, and evaluate automated spray systems.

We concentrated on developing automated delivery systems for selectively applying mesquite leaf sprays because of the high cost of Pathfinder II herbicide and the problems envisioned in designing and fabricating an automatic spraying system capable of precisely and selectively applying a stem spray completely around the circumference of all basal mesquite stems.

Personnel Carrier

A personnel carrier was designed and fabricated to be mounted on the front-end loader frame of a farm tractor to transport a crew of three workers selectively spraying mesquite with sprayguns as the tractor traversed mesquite-infested rights-of-way (Figure 1). The 8-ft-long center section of the personnel carrier tool bar was constructed from 3- x 3- x 0.13-in. square tubing. Brackets attached to the center section allowed the center section to be pinned to the lift arms of a front-end loader mounted on a 40-hp tractor. A 10-ft long piece of 2.5- x 2.5- x 0.37-in. square tubing was telescoped 4 ft into each end of the tool bar center section and held in place by set screws, resulting in a total tool bar width of 20 ft. Heavy duty plastic seats, equipped with seat belts and foot rests, were bolted on at the center of the tool bar and 16 in. from each end to allow a crew of three workers to spray a 24-ft swath. A 25-gal poly spray tank equipped with a 1.4 gal/min, 12-volt electric pump was attached to the 3-point hitch of the tractor in a bracket, and hoses supplied sprayguns, equipped with ConeJet 5500 PPBX-8 adjustable cone nozzles, for each of the three workers.

Mechanical-Sensing Automatic Sprayer

We fabricated an automatic sprayer with a 12-ft boom mounted on the front-end loader frame of a 40-hp farm tractor that utilized mechanical sensors to detect mesquite and to activate pressure-sensitive valves which supplied spray to the nozzles (Figure 2). The basic design of this sprayer originated as the "Brush Robot" in about 1985 with Carl A. Johnson & Sons, Inc. (Thrall, Texas), and the sprayers were manufactured until about 1990 by Continental Belton (Belton, Texas). Brush Robots were designed to be attached onto the rear of tractors, on the 3-point hitch. Extensive testing of the original design in 1996 and 1997 suggested that the sprayer had very desirable features, but that the boom and mechanical sensors would be more effective if mounted on the front of the tractor to facilitate more precise and timely adjustment of the height of the sensing arms for intercepting mesquite canopies.

The center section of the boom was constructed from an 8-ft-long piece of 8-in. structural channel iron with brackets attached that allowed it to be pinned to the front-end loader lift arms. Twenty-six-in. extensions, also constructed of 8-in. channel iron, were attached to each end of the boom with hinges that allowed the extensions to be folded forward or to be removed.

A sheet metal shield to protect the sprayer nozzles and connecting plumbing was bolted along the top edge of the 8-in. channel iron. Twenty-four nozzle-sensing arm assemblies, spaced on 6-in. centers and plumbed with 0.75-in. PVC pipe and fittings, were attached along the trailing edge of the sheet metal shield with "U" bolts.

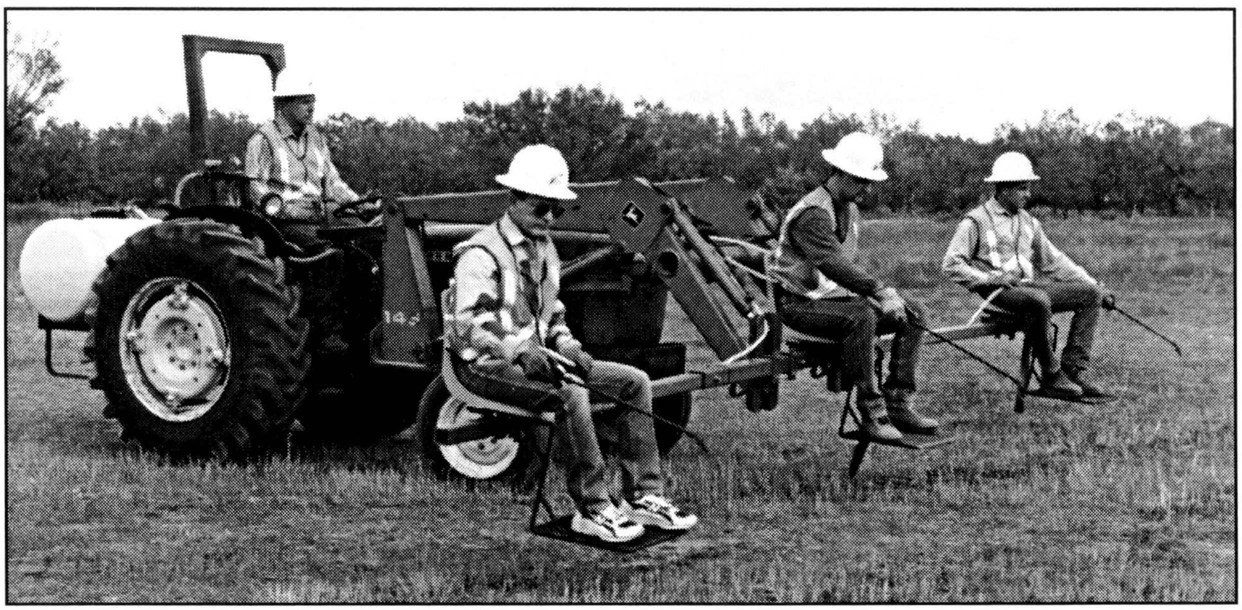

Figure 1. Personnel carrier designed to allow three workers to selectively apply leaf sprays to mesquite over a 24-ft swath in highway rights-of-way.

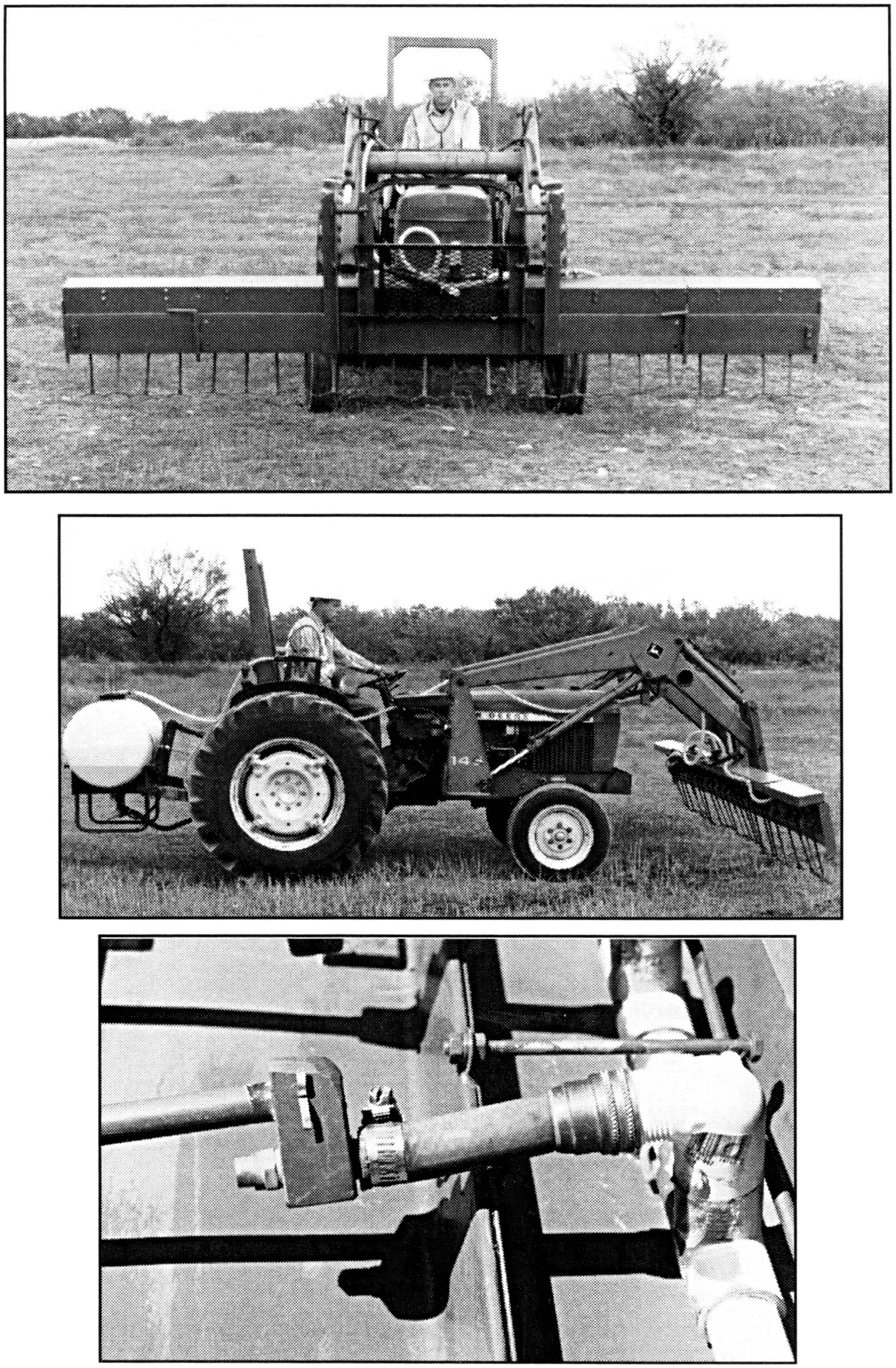

Figure 2. Mechanical-sensing automatic sprayer with a 12-ft-wide boom (bottom view: close up of omni valve and transition block assembly).

Each nozzle-sensing arm assembly consisted of an omni valve (Handee-Bend water nozzle; Milton Industries, Inc., Chicago, Illinois); a shop-built transition block assembly made from 1- x 1- x 2-in. PVC; a 1-gal/min flat-fan nozzle (VeeJet 95-10); and a sensing arm made from ¼-in. schedule 80 PVC pipe. A "foliage finger", cut from a truck mud flap, was attached to the lower end of each sensing arm with screws. A 110-gal poly spray tank was mounted on the 3-point hitch of the tractor, and a PTO pump supplied the spray to the boom and nozzles.

Light-Sensing Automatic Sprayer

A light-sensing automatic sprayer (Figure 3), similar to the "Scan Ray II" (Bowman Mfg. Co., Inc.; Newport, Arkansas), was designed and fabricated under a sub-contract by Harold T. Wiedemann, P.E. (Texas Agricultural Experiment Station - Vernon). The boom was constructed from 3- x 3- x 0.19-in. square tubing. The 6-ft-long center section of the boom was attached to the front-end loader frame on a 40-hp farm tractor. A 3-ft-long extension was attached to each end of the boom center section on hinges that allowed the boom extensions to flex upward for spraying on uneven terrain and for transporting. The boom was designed with four 3-ft-wide sections, each equipped with a 2-gal/min, flat-fan nozzle (TeeJet 11020), solenoid valve, modulated light sender and receiver, and a timer/relay. When any object (e.g. mesquite leaves or stems) breaks the horizontal light beam, an electrical impulse opens the solenoid valve which releases spray through the nozzle. The timer/relay controls the duration of time the solenoid valve remains open.

The light senders and receivers were positioned 6.5 in. in front of the leading edge of the boom and the nozzles were positioned 12 in. above the lower edge of the boom and 5 in. behind the trailing edge of the boom. A retaining bar made of 1- x 1- x 0.13-in. square tubing was attached with 2- x 0.25-in. flat steel 10 in. behind the lower edge of each boom section to hold mesquite stems and leaves at the proper distance from the nozzles during spraying. Triangle-shaped teeth were welded onto the lower surface of the boom and retaining bar to prevent taller mesquite plants from spreading laterally beyond the spray patterns of the nozzles. The light senders and receivers, solenoid valves and timer/relays were purchased from Bowman Mfg. Co., Inc. (Newport, Arkansas).

A 55-gal poly spray tank mounted in a frame was attached to the 3-point hitch of the tractor. The spray was supplied to the boom and nozzles with a PTO pump (Ace model # PTOC 600-10; Ace Pump Corp.; Memphis, Tennessee).

Automatic All-terrain Vehicle Sprayer

An automatic sprayer that could be mounted onto an all-terrain vehicle (ATV) and that depended upon the operator to detect and selectively spray mesquite plants was fabricated in our shop (Figure 4). The frame and boom assembly of the sprayer were constructed from 1- x 1- x 0.13-in. square tubing. The 2.8-ft-wide x 3.2-ft-long frame was attached to the top of the front rack of an ATV with "U" bolts. Diagonal support braces welded to the frame and bolted to the lower front frame of the ATV provided additional support. The 6-ft-long spray-boom assembly was attached to the sprayer

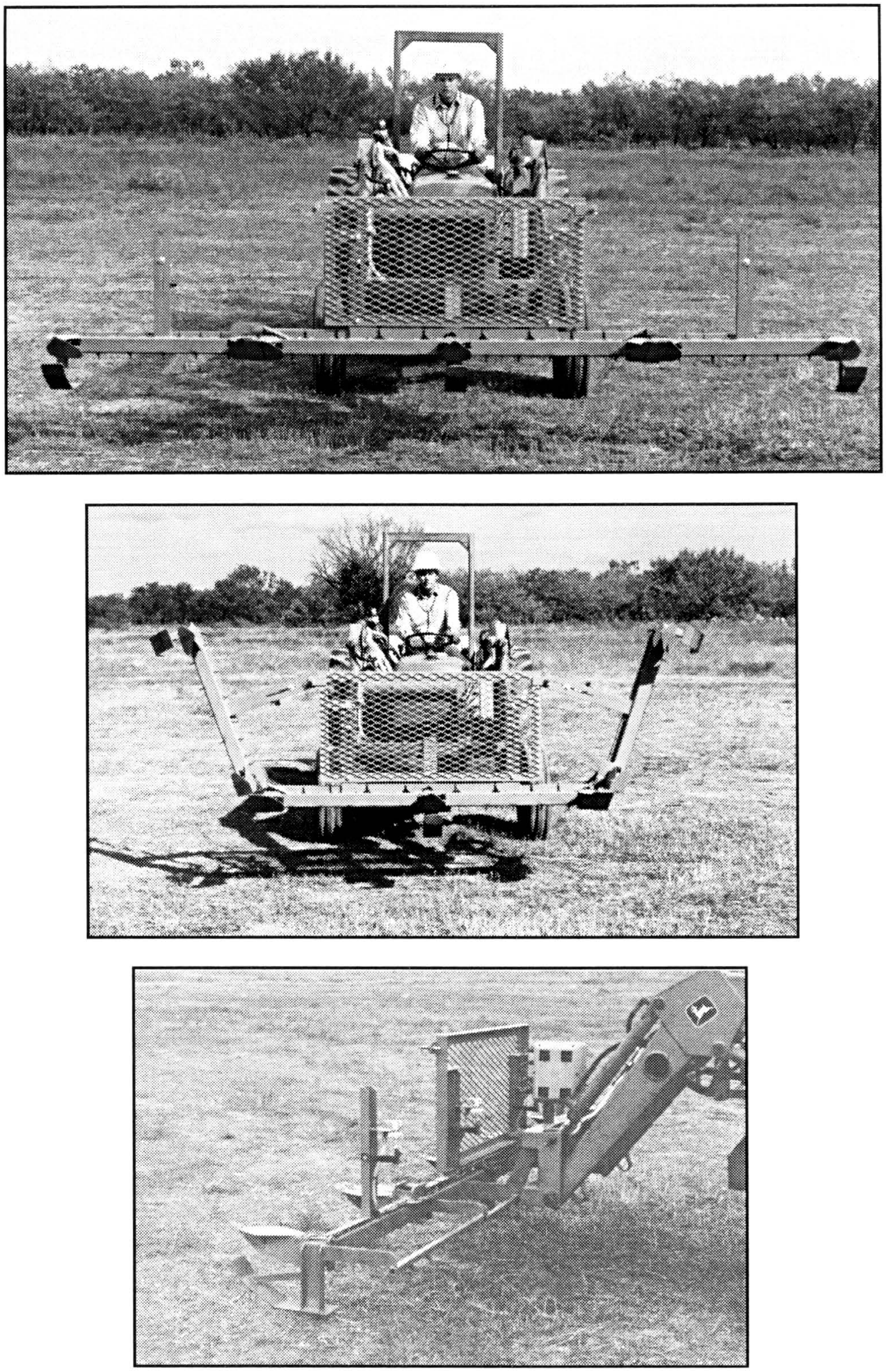

Figure 3. Light-sensing automatic sprayer, which selectively applies leaf spray to mesquite over a 12-ft-wide swath when their leaves or stems break horizontal beams of modulated light.

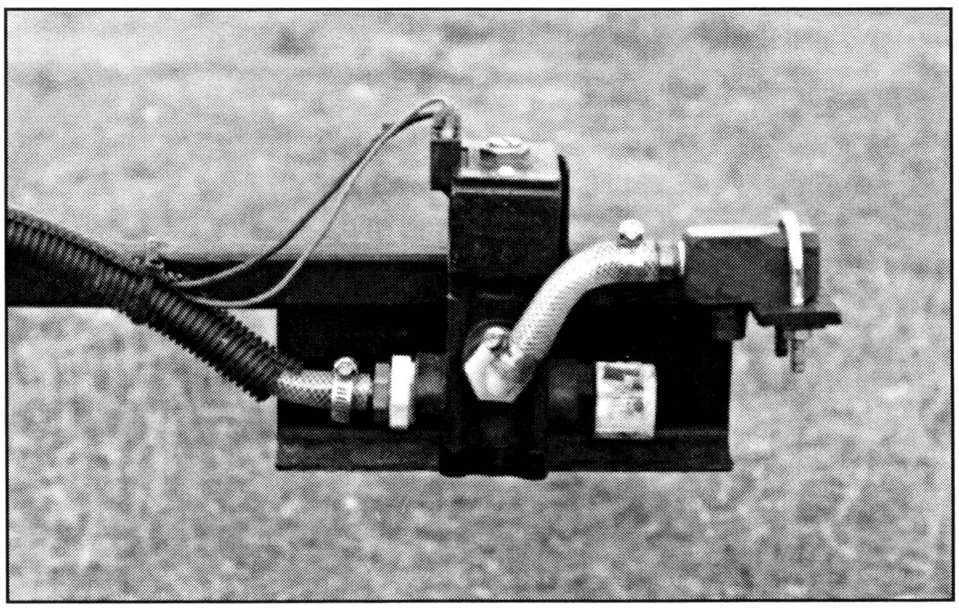

Figure 4. Automatic all-terrain vehicle sprayer with 3 spray nozzles for selective application of leaf sprays to mesquite across a 9-ft-wide swath (side view and close up of one nozzle and solenoid valve assembly).

frame 2-ft in front of the ATV. The spray boom was designed so that its height could be adjusted by loosening set screws which allow the vertical members of the spray boom assembly to be raised or lowered through 4-in.-long sleeves made of 1.25- x 1.25- x 0.09-in. square tubing bolted onto the sprayer frame.

Three 2-gal/min nozzles (Spraco 76402004), each screwed into a transition block constructed from 1- x 1- x 2-in. PVC, were attached along the trailing edge of the boom, with one in the center of the boom and the others positioned 3-ft either side of the center. The supply of spray to each nozzle is controlled by a solenoid valve (DirectoValve 144V; Spraying Systems Co.; Wheaton, Illinois) mounted on a bracket adjacent to the nozzle. The nozzles were positioned above the outlets of the solenoid valves to minimize the loss of spray from the nozzle and connecting hose when traveling between mesquite plants. Each solenoid valve is controlled by a 12-volt electrical circuit and push button switch which is mounted on the ATV.

A 7.5-ft wide bending-and-retaining bar assembly constructed from 1- x 1- x 0.13-in. square tubing was attached onto the front of the sprayer frame beneath the spray nozzles to hold mesquite leaves and stems at the proper distance from the nozzles during spraying. The retaining bar was spaced 10 in. behind the bending bar, and these bars were positioned so that the spray was directed into the center of this 10-in.-wide space. The bending-and-retaining bar assembly was designed so that its height could be adjusted by loosening set screws and sliding the two vertical members of the bar assembly through two 4-in. sleeves made from 1.25- x 1.25- x 0.09-in. square tubing welded to the sprayer frame. Triangle-shaped teeth were welded onto the lower surfaces of the bending and retaining bars to prevent the taller mesquite plants from spreading laterally beyond the nozzle spray pattern.

A 25-gal poly spray tank was attached onto the rear rack of the ATV. The spray was supplied to the boom and nozzles by a 12-volt, 3-gal/min diaphram pump (Shurflo). A pressure tank made from 6-in. diam. PVC pipe and end caps was attached to the rear of the ATV and connected between the pump and the spray boom via 0.375-in. i.d. hose to minimize rapid cycling of the pump.

Each nozzle applies spray over a 3-ft-wide swath, resulting in a 9-ft effective swath width. The ATV driver visually detects mesquite plants as the ATV is driven forward. He activates the left, center, or right nozzle to selectively spray mesquite plants as they pass beneath these nozzles by depressing the electric switch near his left toe, left thumb, or right toe, respectively.

Other Mechanized Systems Considered

We conducted field evaluations of a shop-built carpeted roller (Mayeux and Crane 1985) and a Rotowiper (Bissett Engineering International LTD, P.O. Box 333, Ashburton 8300, New Zealand) in highway rights-of-way in Tom Green County in 1996-97 (Ueckert and McGinty 1998). These mechanized systems did not deliver an adequate amount of herbicide solution onto the leaves and stems of mesquite regrowth to be effective, and the herbicide solution was not uniformly distributed along the carpeted cylinders when working on the sloping topography in ditches. Consequently, these herbicide-delivery systems were not considered as acceptable for mesquite control in highway rights-of-way.

Field Evaluations of Mechanized Spraying Systems

The personnel carrier, mechanical-sensing automatic sprayer (operated at 18 and at 30 psi pressure on the boom), light-sensing automatic sprayer (operated with 0.3- and 0.5-sec timers), and automatic ATV sprayer were evaluated in numerous field trials to evaluate their performance relative to cost ($/acre) and efficiency (acres treated/hr). A leaf spray containing 0.5% clopyralid + 0.5% triclopyr ester in a water carrier containing 0.25% non-ionic surfactant and 0.25% Hi-Light spray-marking dye was used in all trials. Plot size was variable, but generally 1 acre in size. The time (hr) and volume of spray mixture (gal) required to treat each plot were recorded. The numbers of mesquite plants sprayed and missed in each plot were counted by workers walking either behind the sprayers or through the plots after the plots were sprayed. To calculate cost ($/acre) for operating each spraying system, labor was valued at $12/hr. The leaf spray mixture was valued at $1.83/gal based on retail prices of the spray ingredients. The tractor + personnel carrier, tractor + mechanical-sensing automatic sprayer, tractor + light-sensing automatic sprayer, and the ATV + automatic sprayer were valued at $16, $19, $22 and $4/hr, respectively.

Data for each spraying system were subjected to regression analyses to quantify the relationships between operating cost ($/acre) and the number of mesquite plants sprayed/acre, and between efficiency (acres treated/hr) and the number of mesquite plants sprayed/acre. Graphs of these relationships were prepared. The regression equations were also utilized to generate cost and efficiency values over an array of mesquite/acre values to facilitate comparing the efficiencies of the automatic spraying systems at equivalent mesquite densities.

To facilitate comparisons of costs and efficiencies of the mechanized spraying systems to those for selected hand-spraying methods, we subjected data collected for hand-spraying methods in 1995 (Ueckert and McGinty 1995) to similar regression analyses. The hand-spraying methods included: stem sprays of Pathfinder II herbicide applied by workers using backpack sprayers; stem sprays of 15% Garlon 4 + 85% diesel fuel oil applied by workers with backpack sprayers; leaf sprays applied by ground crews using backpack sprayers; and leaf sprays applied by three-man crews using an ATV equipped with a 25-gal spray tank, electric pump, and hoses for three sprayguns. Cost for labor for all hand-spraying methods was valued at $12/man-hr. Costs for Pathfinder II, the Garlon 4 + diesel fuel oil mixture, and the leaf spray mixture were valued at $27.18/gal, $13.73/gal, and $1.83/gal, respectively. Cost for the ATV was valued at $4.00/hr.

FINDINGS/DISCUSSION

Objective 2: Identify effective leaf sprays for control of mesquite regrowth.

1995 Experiment

The treatments were applied on October 16-17, 1995, which was later into the autumn than is normally recommended for mesquite leaf sprays (McGinty and Ueckert 1995). However, the mesquite foliage was in good condition and there was no new growth on the stem tips. Air temperatures during treatment applications ranged from 80 to 89°F and soil temperatures at 1 ft deep were 70 to 74°F. The mesquite at the study site in Tom Green County averaged 2 to 3 ft tall and most plants had only one to a few stems, suggesting that the site had not been mowed after the mesquite established. All herbicide treatments resulted in high levels (≥ 86%) of mesquite mortality (Table 2). Leaf sprays containing 0.75% clopyralid + 0.75% triclopyr applied in a carrier containing 5% diesel fuel oil resulted in 100% mesquite mortality at 2 yr after treatment, but this level of mortality was not significantly different from that achieved with sprays containing 0.5% clopyralid + 0.5% triclopyr with 5% or 25% diesel fuel oil in the carriers. Mesquite mortality achieved with leaf sprays containing 0.5% clopyralid + 0.5% triclopyr and 5% diesel fuel oil (98%) was similar to that achieved with sprays containing the same herbicide concentrations with 0.5% Silwet L-77 surfactant (90%), but significantly greater than that achieved with leaf sprays containing the same herbicide concentrations with 5% vegetable oil (86%) (Table 2). Data from this experiment strongly indicated there was no advantage to increasing the concentrations of clopyralid and triclopyr above 0.5% each in mesquite leaf sprays, and that the spray adjuvants tested generally performed about equally. The high levels of mesquite mortality achieved in this experiment, as compared to the 1996 experiments, was a function of the facts that this mesquite had never been mowed, that the mesquite had sufficient leaf surface area for adequate herbicide absorption, and that carbohydrates were probably being translocated downward into the basal meristems and roots at the time of spraying.

1996 Experiments

When the data collected at 2 yr after treatment were analyzed separately for each experiment, there were significant differences among treatments within only five of the 12 experiments (Appendices A, B, and C), but there were no consistent patterns or trends among the experiments. Data from the 12 experiments reflected high levels of variability in mesquite response among replications within an experiment and among locations.

When the data from the four experiments within each month of treatment were pooled and subjected to analysis of variance, there were no significant treatment differences within the June, July or August 1996 dates of application (Table 3). Similarly, there were no significant treatment effects when the data from all 12 experiments were pooled for analysis (Table 3). These statistical tests confirmed that there was no advantage to increasing the concentrations of clopyralid and triclopyr ester in leaf sprays above 0.5% + 0.5%, and that there was no advantage of any particular adjuvant or adjuvant concentration relative to increasing mesquite mortality.

Table 2. Mean percent (%) mortality of mesquite along Loop 306 East in Tom Green County at 2 years after treatment (YAT) with leaf sprays containing various concentrations of clopyralid (Transline) and triclopyr ester (Garlon 4) and various adjuvants on October 16-17, 1995.

Treatment		
Herbicide		Mortality @
Transline + Garlon 4	Adjuvant	2 YAT[1/]
%		
.5 + .5	.5% Silwet L-77	90 cd
.75 + .75	.5% Silwet L-77	90 bcd
1 + 1	.5% Silwet L-77	93 a-d
.5 + .5	5% Diesel	98 abc
.75 + .75	5% Diesel	100 a
1 + 1	5% Diesel	90 bcd
.5 + .5	25% Diesel	98 ab
.75 + .75	25% Diesel	95 abc
1 + 1	25% Diesel	96 abc
.5 + .5	5% JLB oil	86 d
.75 + .75	5% JLB oil	93 a-d
1 + 1	5% JLB oil	98 abc

[1/] Means within the column followed by a similar lower case letter are not significantly different according to $LSD_{0.05}$.

Table 3. Mean percent (%) mortality of regrowth mesquite in highway rights-of-way at 2 years after treatment (YAT) with leaf sprays containing various concentrations of clopyralid (Transline) and triclopyr ester (Garlon 4) and various adjuvants during June, July, or August 1996 at 12 locations in western Texas.

Treatment		Mortality @ 2 YAT [1]			
Herbicide		Month treated			
Transline + Garlon 4	Adjuvant	June[2]	July[3]	August[4]	Mean
%		- - - - - -	- - - -	% - - - -	- - - -
.5 + .5	.5% Surfactant	55	68	71	65
1 + 1	.5% Surfactant	35	64	71	57
2 + 2	.5% Surfactant	39	45	67	50
.5 + .5	5% Diesel	35	58	68	54
1 + 1	5% Diesel	44	60	67	57
2 + 2	5% Diesel	43	40	48	43
.5 + .5	20% Diesel	50	36	53	46
1 + 1	20% Diesel	40	58	70	56
2 + 2	20% Diesel	36	46	66	50
	Average[5] =	42 x	53 y	65 z	53

[1] Means within a column were not significantly different according to analysis of variance at the 5% probability level ($P \leq 0.05$).
[2] Average for experiments in Schleicher, Reagan, Menard, and Runnels Counties.
[3] Average for experiments in Edwards, Concho, Coke, and Sterling Counties.
[4] Average for experiments in Crockett, Irion, Glasscock, and Nolan Counties.
[5] Means within the Average row followed by a similar lower case letter are not significantly different according to $LSD_{0.05}$.

However, there was a significant effect of time of treatment in that August treatments killed significantly more mesquite than July treatments, and July treatments killed significantly more mesquite than June treatments (Table 3). Averaged over all treatments, leaf sprays applied in August killed an average of about 65% of the mesquite treated, compared to 53% for leaf sprays applied in July, and to only 42% for those applied in June 1996. These results reflect the importance of allowing sufficient time for mesquite canopy development following mowing to provide sufficient leaf surface area for adequate herbicide absorption and translocation into the basal meristems and roots. The results also indicate that the susceptibility of mesquite to foliar sprays increases as the growing season progresses. Each additional month for canopy growth and development increased mesquite mortality by 11 to 12 percentage units. The lack of responses in mesquite mortality to increasing concentrations of clopyralid and triclopyr in these 12 experiments was in agreement with results from the 1995 experiment. Results from these 12 experiments confirmed that there was no advantage to increasing the concentrations of clopyralid and triclopyr above 0.5% each in leaf sprays. The lack of any response to adjuvant treatments in the 1996 experiments indicated that there was no advantage to increasing the concentration of diesel fuel oil above 5% in the leaf spray mixture, and that 5% diesel fuel oil and 0.5% non-ionic surfactant performed similarly as spray adjuvants.

The mesquite mortality values reported for the 1995 and 1996 experiments are conservative estimates because dead plants with no green tissues were more difficult for workers to see during the final evaluation compared to live plants, and because many of the smaller mesquite plants killed by herbicide treatments had deteriorated or been broken off and scattered by the time of the final evaluation at 2 yr after treatment. The conservative estimates of mesquite mortality achieved with leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester during October 1995 (90 - 98%), July 1996 (58 - 68%), and August 1996 (68 - 71%) are considered adequate to justify the effort and expense of treatment (Figure 5).

Objective 3: Design, fabricate, and evaluate automated spraying systems.

All automatic spraying systems performed well during the field trials. The statistics on performance of the four spraying systems are shown in Appendix D, and the regression models for the spraying systems and hand-spraying methods are shown in Table 4. Appendix E presents the proportion of total cost for spray, labor, and machine time for each automatic spraying system.

Personnel Carrier

The personnel carrier functioned well and the workers, who were accustomed to hand spraying mesquite while walking, were very pleased to be able to spray while seated. The 1.4 gal/min diaphragm pump supplied more than ample spray volume and pressure to supply the three sprayguns. The number of mesquite sprayed on the 12 plots averaged 285 plants/acre (Appendix D). The maximum tractor speed that would allow the workers to thoroughly spray the mesquite was about 1 mile/hr, and the tractor occasionally had to stop to allow the workers adequate time to thoroughly spray larger mesquite plants or clusters of small mesquite. Even at this slow ground

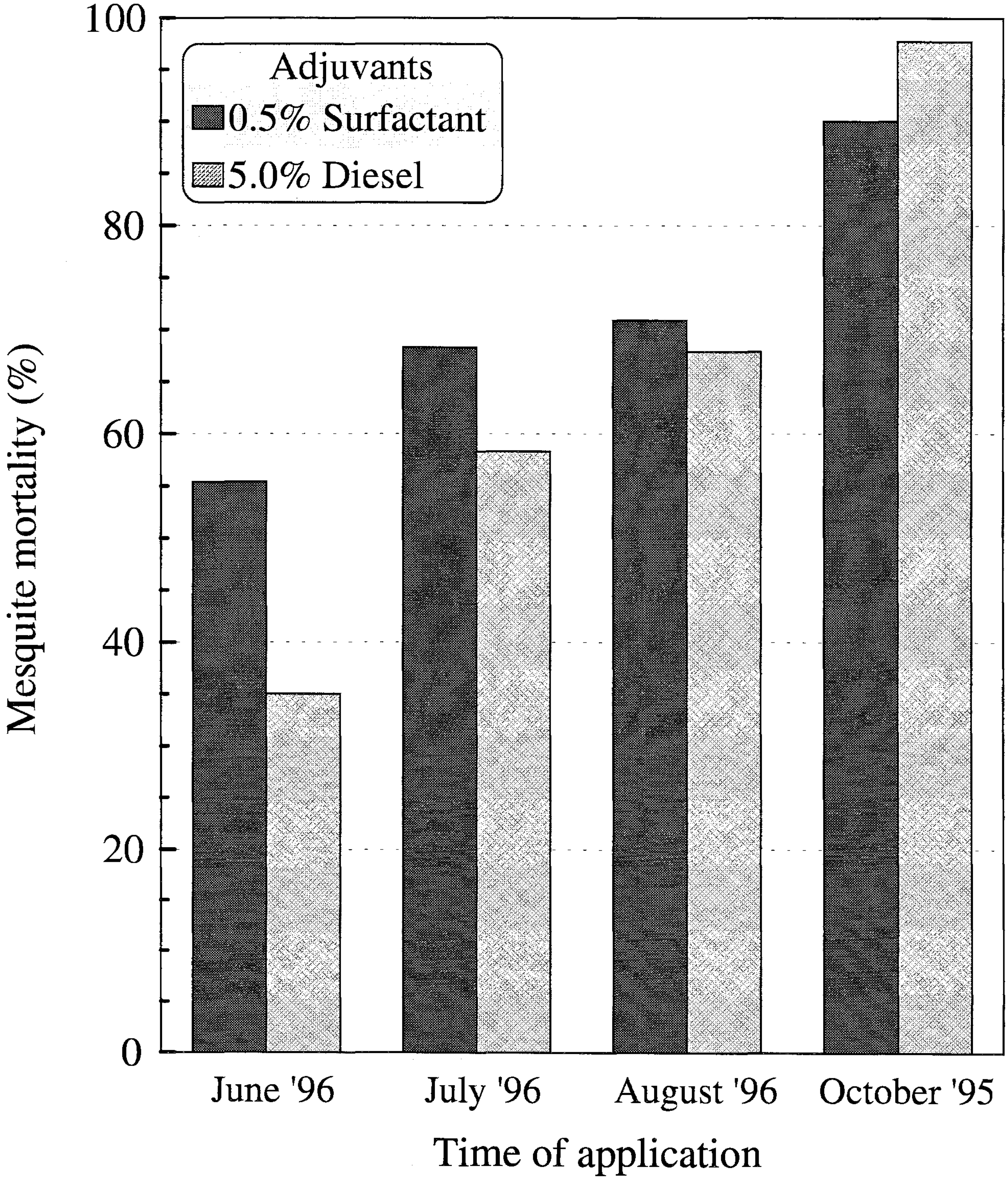

Figure 5. Mean percent (%) mortality of mesquite at 2 years after treatment in October 1995, June, July, or August 1996 with selective applications of leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester and either 0.5% surfactant or 5.0% diesel fuel adjuvants.

Table 4. Regression models, correlation coefficients (r^2), and probability values (P) for cost ($/acre) and efficiency (acres/hr) for mechanized spraying systems and hand-spraying methods for selectively treating regrowth mesquite in rights-of-way. Cost and efficiency are the dependent variables (Y) and number of mesquite sprayed/acre is the independent variable (X).

Spraying system or method	Regression Model	r^2	P[1/]
	Cost ($/acre)		
Personnel carrier	Y = -23.71 + 9.336 lnX	0.91	< 0.0001
Mechanical-sensing @ 18 psi	Y = 8.89 + 0.066 X	0.65	< 0.0003
Mechanical-sensing @ 30 psi	Y = -26.08 + 10.133 lnX	0.88	0.0006
Light-sensing @ 0.3-sec	Y = 14.42 + 0.073 X	0.84	< 0.0001
Light-sensing @ 0.5-sec	Y = 9.89 + 0.115 X	0.77	0.0018
Automatic ATV	Y = 6.03 + 0.064 X	0.94	< 0.0001
Stem spray (Pathfinder II)	Y = 10.64 + 0.149 X	0.99	< 0.0001
Stem spray (Garlon 4 + diesel)	Y = 7.79 + 0.099 X	0.99	< 0.0001
Leaf spray (backpacks)	Y = 6.57 + 0.024 X	0.96	< 0.0001
Leaf spray (3 men/ATV)	Y = 4.69 + 0.033 X	0.96	< 0.0001
	Efficiency (acres/hr)		
Personnel carrier	Y = 8.54 - 0.861 lnX	0.94	< 0.0001
Mechanical-sensing @ 18 psi	Y = 7.57 - 0.737 lnX	0.65	< 0.0003
Mechanical-sensing @ 30 psi	Y = 9.63 - 1.114 lnX	0.96	< 0.0001
Light-sensing @ 0.3-sec[2/]			NS
Light-sensing @ 0.5-sec[2/]			NS
Automatic ATV	Y = 10.17 - 1.279 lnX	0.60	< 0.0001
Stem spray methods	$Y = 38.15\ X^{-0.7374}$	0.97	< 0.0001
Leaf spray (backpacks)	Y = 4.92 - 0.656 lnX	0.84	< 0.0005
Leaf spray (3 men/ATV)	Y = 5.53 - 0.684 lnX	0.81	< 0.0001

[1/] Significance of regression model.

[2/] Regression models for efficiency of the light-sensing automatic sprayers were not significant at $P \leq 0.05$.

speed, the efficiency of the implement and 4-man crew averaged 3.99 acres/hr. An average of 2.66 oz of the spray mixture was applied per mesquite plant sprayed.

Total cost for operating the personnel carrier (Y) increased logarithmically as the number of mesquite sprayed/acre (X) increased (Figure 6). The relationship was estimated by the equation $Y = -23.71 + 9.336 \ln X$. The relationship between efficiency (acres/hr) (Y) and the number of mesquite treated/acre (X) for the personnel carrier was estimated by the equation $Y = 8.54 - 0.861 \ln X$ (Figure 7), indicating that efficiency decreased logarithmically as mesquite density increased. An average of only 5.6% of the mesquite were missed during operation of the personnel carrier (Appendix D).

Mechanical-Sensing Automatic Sprayer

Mounting the spray boom of the mechanical-sensing automatic sprayer on the front-end loader frame greatly reduced operator fatigue and improved the operator's ability to maintain the proper height of the sensing arms and foliage fingers to maximize interception of mesquite canopies and to minimize interception of tall grass and weeds. The 12-ft boom performed well on flat terrain, but the optimal height of the foliage fingers could not be maintained across the entire span of the boom when operating within ditches. Removal of the 26-in. boom extensions would alleviate this problem, but we did not remove the extensions during field trials. The optimum rate of travel for the tractor was about 1.9 miles/hr (2nd gear @ 2100 rpm) to achieve thorough coverage of the mesquite foliage and stems with the spray mixture.

Pressure on the boom and nozzles was maintained at 18 psi during testing of the mechanical-sensing automatic sprayer on fifteen 1-acre plots. The average number of mesquite sprayed on these plots was 417 plants/acre (Appendix D). Efficiency of the sprayer on these plots averaged 3.25 acres/hr. The average amount of spray mixture applied per mesquite plant was 4.76 oz. An average of 12.7% of the mesquite plants were missed by the mechanical-sensing automatic sprayer.

The relationship between total cost (Y) and number of mesquite plants sprayed/acre (X) with the mechanical-sensing automatic sprayer operated at 18 psi was estimated by the equation $Y = 8.89 + 0.066 X$ (Figure 8). This equation suggests that it cost about $8.89/acre to operate the sprayer plus $0.066/mesquite plant treated. The efficiency of the mechanical-sensing automatic sprayer operated at 18 psi pressure on the boom (Y) decreased logarithmically as the number of plants sprayed/acre (X) increased, and efficiency of this delivery system was estimated by the equation $Y = 7.57 - 0.737 \ln X$ (Figure 9).

In October 1998 the mechanical-sensing automatic sprayer was equipped with a new PTO pump (Ace model # PTOC 600-10), then tested with 30 psi pressure on the spray boom on eight 1-acre plots where the average mesquite density was 98 plants/acre (Appendix D). Efficiency of the sprayer during these trials averaged 4.73 acres/hr. The average volume of spray applied was 9.34 oz/mesquite plant sprayed, which was 2X the volume applied by this system when operated at 18

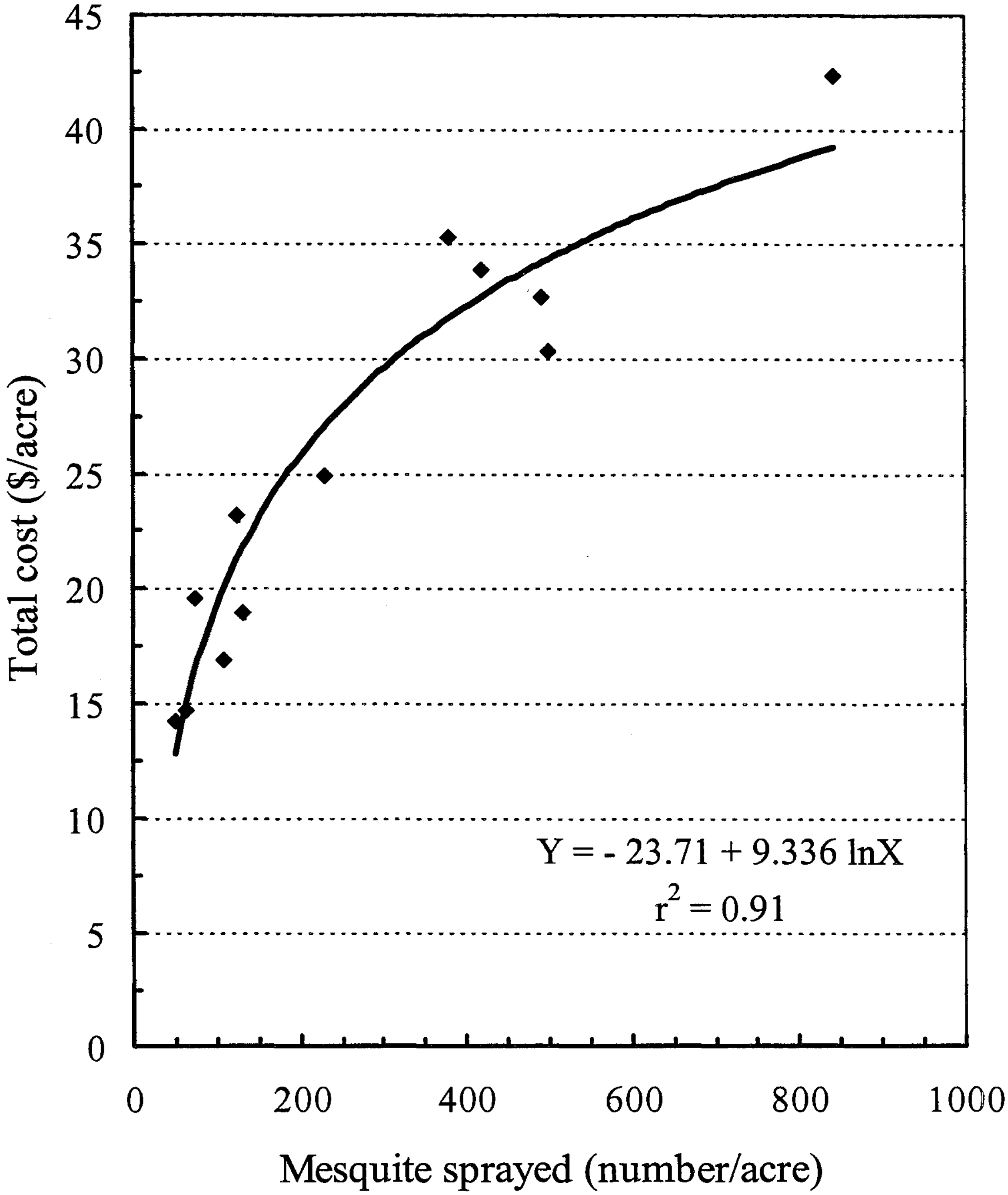

Figure 6. Relationship between cost ($/acre) and mesquite sprayed (number/acre) for selective application of leaf sprays containing 0.5% clopyralid and 0.5% triclopyr ester to mesquite in highway rights-of-way with a personnel carrier mounted on a 40-hp tractor (4-man crew).

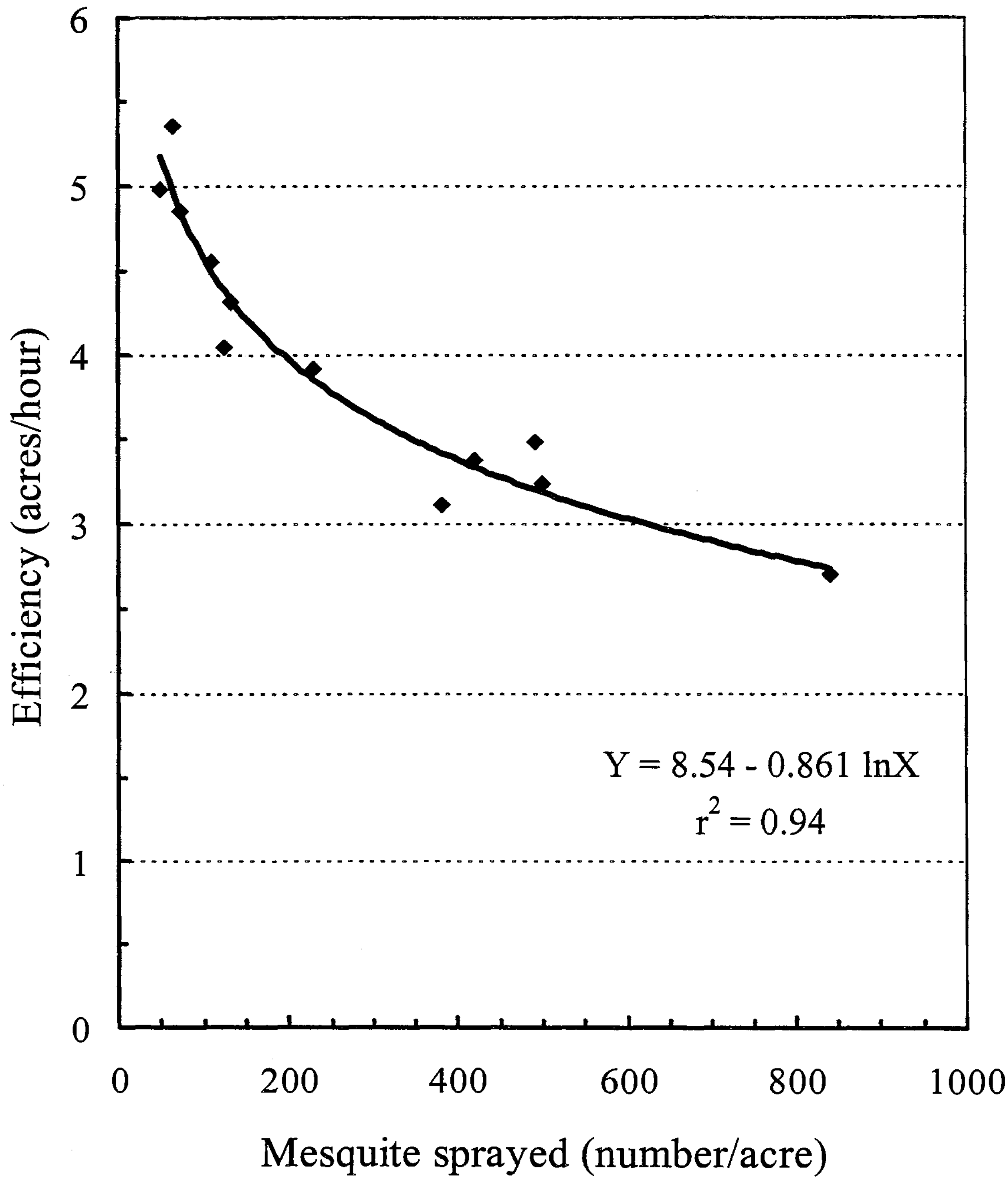

Figure 7. Relationship between efficiency (acres/hour) and mesquite sprayed (number/acre) for selective application of leaf sprays to mesquite in highway rights-of-way with a personnel carrier mounted on a 40-hp tractor (4-man crew).

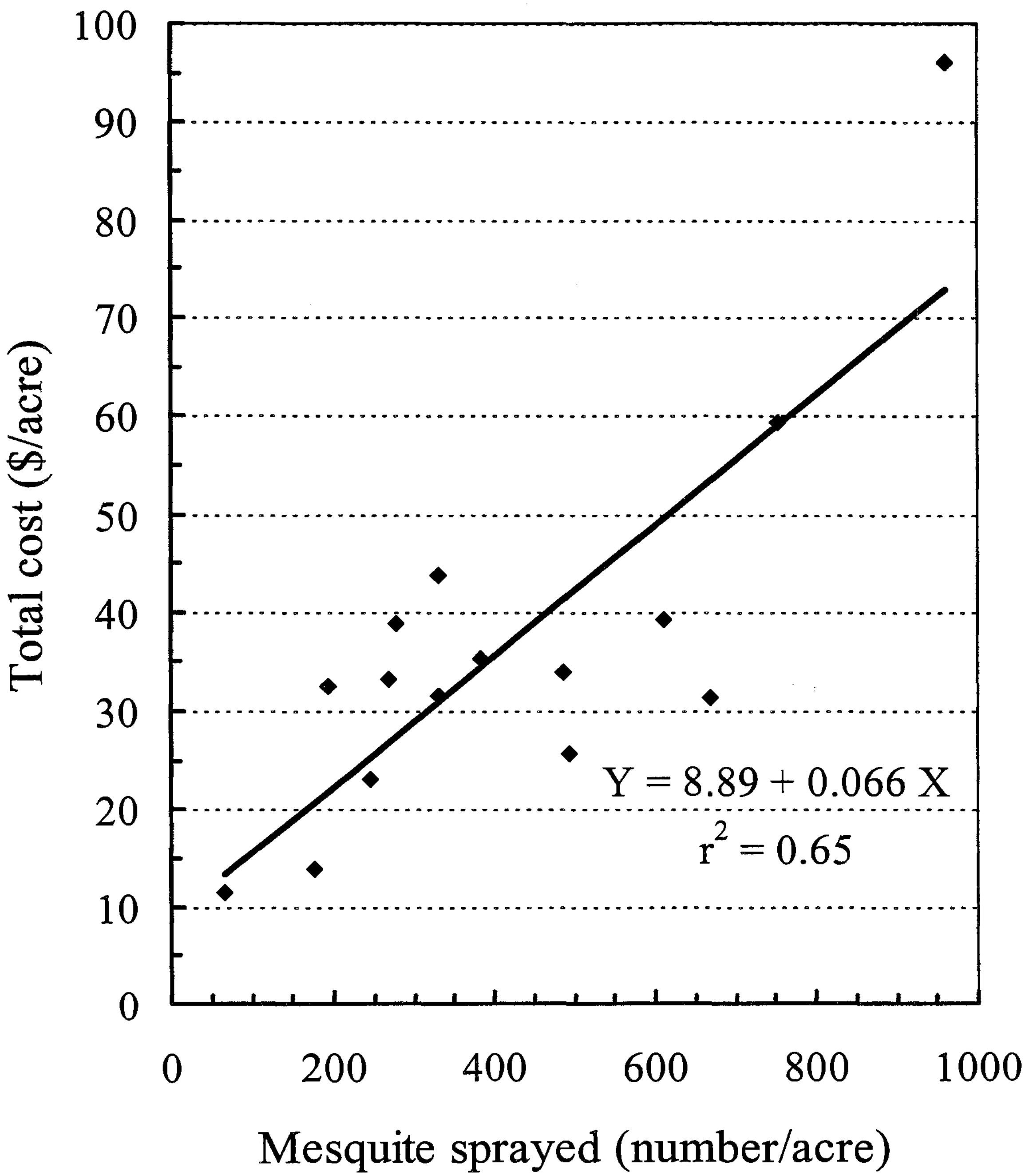

Figure 8. Relationship between cost ($/acre) and mesquite sprayed (number/acre) for selective application of leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester to mesquite in highway rights-of-way with a mechanical-sensing automatic sprayer operated at 18 psi.

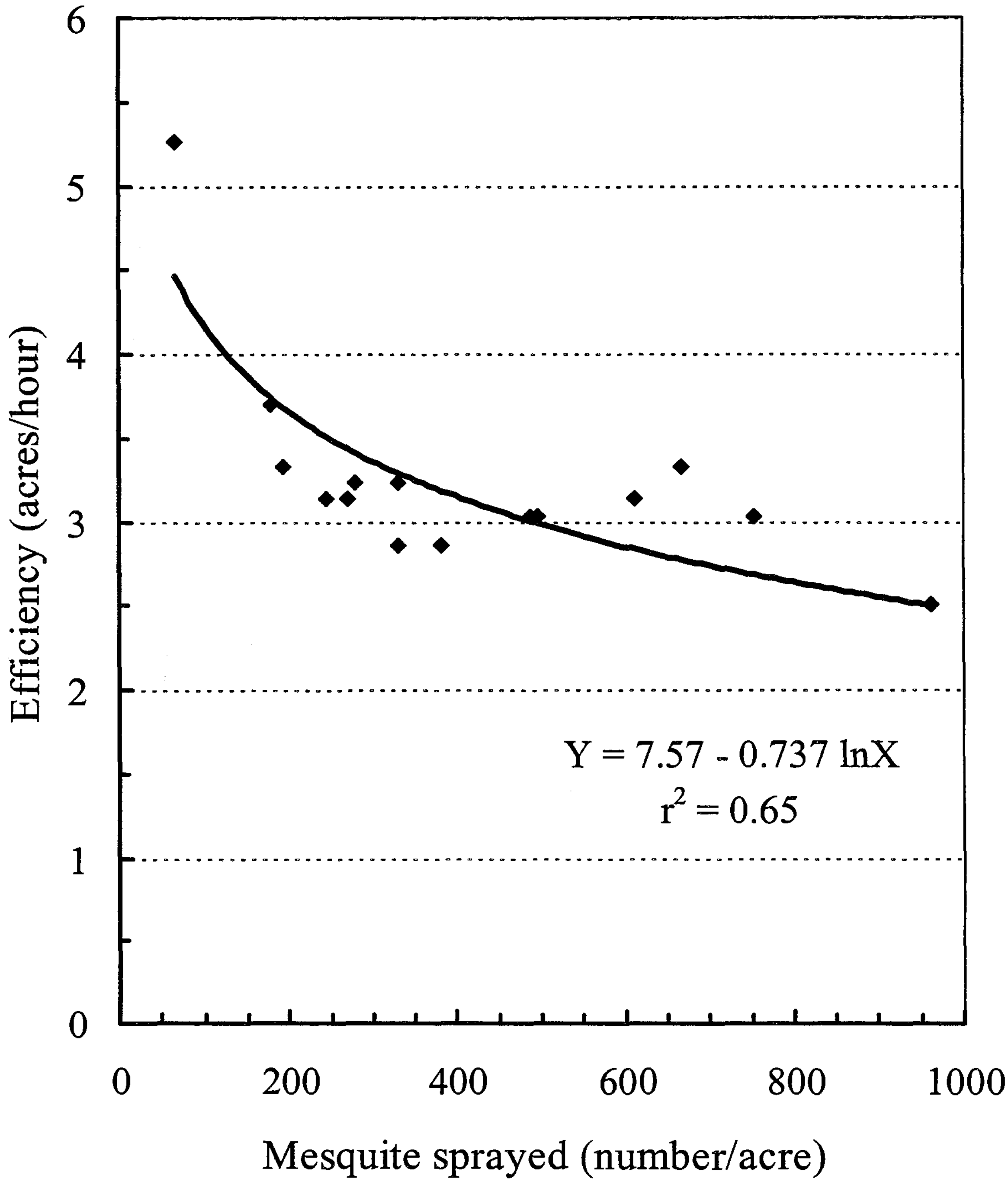

Figure 9. Relationship between efficiency (acres/hour) and mesquite sprayed (number/acre) for selective application of leaf sprays to mesquite in highway rights-of-way with a mechanical-sensing automatic sprayer operated at 18 psi.

psi pressure. An average of 23.3% of the mesquite were missed by the mechanical-sensing automatic sprayer during these eight trials.

The relationship between total cost (Y) and number of mesquite plants sprayed/acre (X) for the mechanical-sensing automatic sprayer operated at 30 psi pressure on the boom was estimated by the logarithmic relationship $Y = -26.08 + 10.133 \ln X$ (Figure 10). The efficiency of the mechanical-sensing automatic sprayer operated at 30 psi pressure decreased logarithmically as the number of mesquite plants sprayed/acre increased. This relationship was estimated by the equation $Y = 9.63 - 1.114 \ln X$ (Figure 11), where Y = efficiency in acres treated/hr, and X = the number of mesquite plants sprayed/acre.

Light-Sensing Automatic Sprayer

The light-sensing automatic sprayer was field tested with the timers set on 0.3 sec on twenty 1-acre plots. The optimum ground speed selected to achieve thorough coverage of the mesquite foliage and stems with the spray mixture was 1.9 miles/hr (2nd gear @ 2100 rpm). The number of mesquite plants sprayed/acre on the 20 plots averaged 303 (Appendix D). Efficiency of the spraying system averaged 3.17 acres/hr. The average volume of spray applied was 6.02 oz/plant sprayed. An average of 24.1% of the mesquite plants were missed by the light sensors in these trials.

The relationship between total cost (Y) and the number of mesquite plants sprayed/acre (X) with the light-sensing automatic sprayer with 0.3-sec timers was estimated by the equation $Y = 14.42 + 0.073 X$ (Figure 12). This suggested that total cost for selectively spraying mesquite with the light-sensing automatic sprayer with 0.3-sec timers was $14.42/acre plus $0.073 for each mesquite plant treated. The efficiency of the light-sensing automatic sprayer operated with timers set at 0.3 sec was not correlated with the number of mesquite plants sprayed/acre ($r^2 = 0.14$) ($P = 0.10$) (Figure 13).

In the field trials discussed above, we noticed that the 0.3-sec timers frequently closed the solenoid valve prematurely, before many of the smaller mesquite plants with few stems were completely sprayed. Consequently, new timer/relays were installed and an additional nine 1-acre plots were treated with timers set on 0.5 sec. The number of mesquite plants treated on these nine plots averaged 85 plants/acre (Appendix D). Efficiency of the sprayer averaged 4.28 acres/hr. The average volume of spray mixture applied was 9.88 oz/mesquite plant sprayed, which was 1.6X the volume applied/plant with 0.3-sec timers. The 0.5-sec timers appeared to continue applying the spray slightly longer than necessary, thus it was concluded that 0.4-sec timers should be appropriate when operating at 1.9 mile/hr speed. An average of 24.7% of the mesquite plants in the plots were missed by the light-sensing automatic sprayer.

The relationship between total cost (Y) and the number of mesquite plants sprayed/acre (X) for the light-sensing automatic sprayer with timers set at 0.5-sec was estimated by the equation $Y = 9.89 + 0.115 X$ (Figure 14). This indicated that the total cost was about $9.89/acre plus $0.115 for each mesquite plant sprayed. The efficiency (acres/hr) of the light-sensing automatic sprayer with timers set at 0.5 sec was not correlated with the number of mesquite plants sprayed/acre ($r^2 = 0.02$) ($P = 0.69$) (Figure 15).

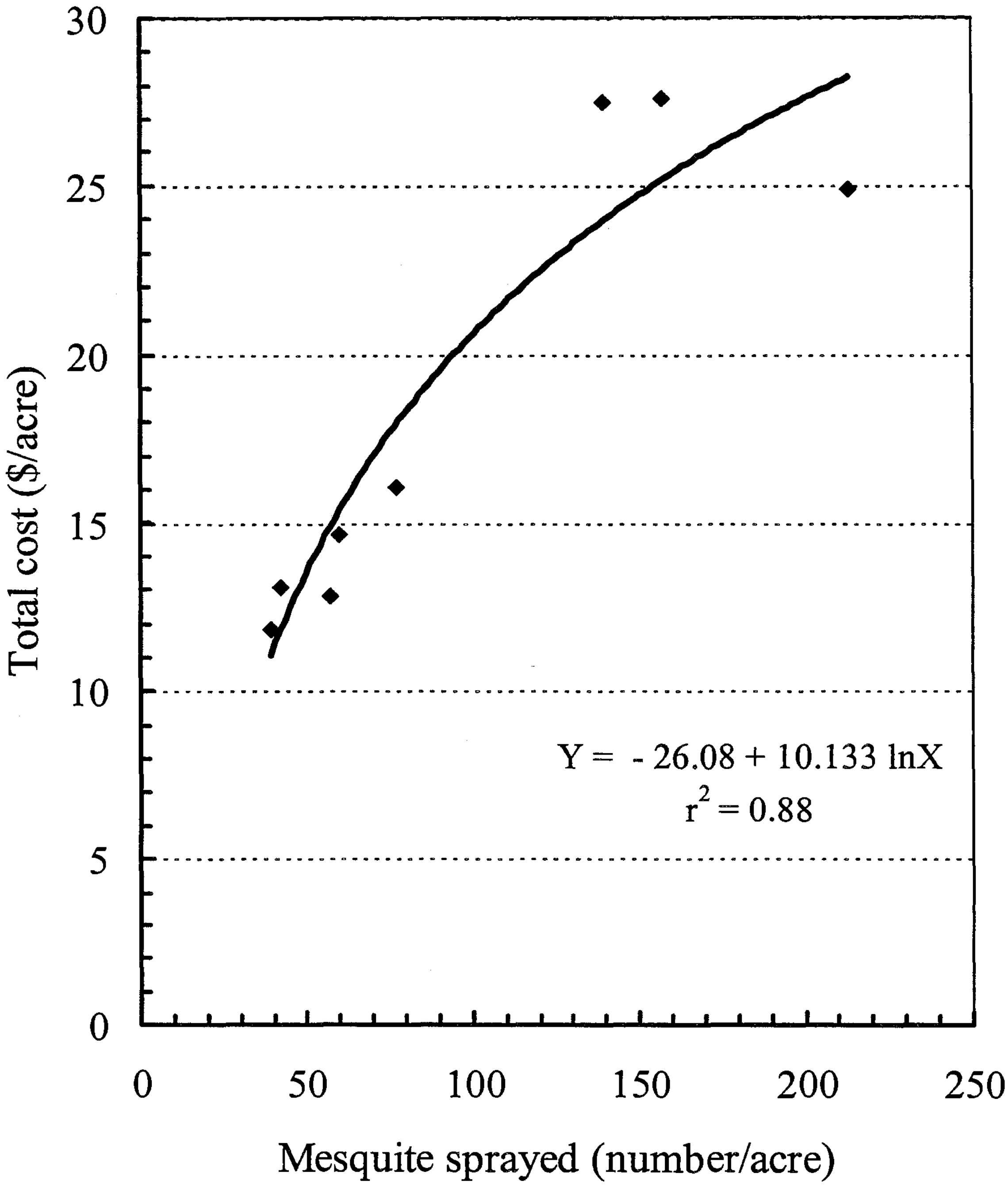

Figure 10. Relationship between cost ($/acre) and mesquite sprayed (number/acre) for selective application of leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester to mesquite in highway rights-of-way with a mechanical-sensing automatic sprayer operated at 30 psi.

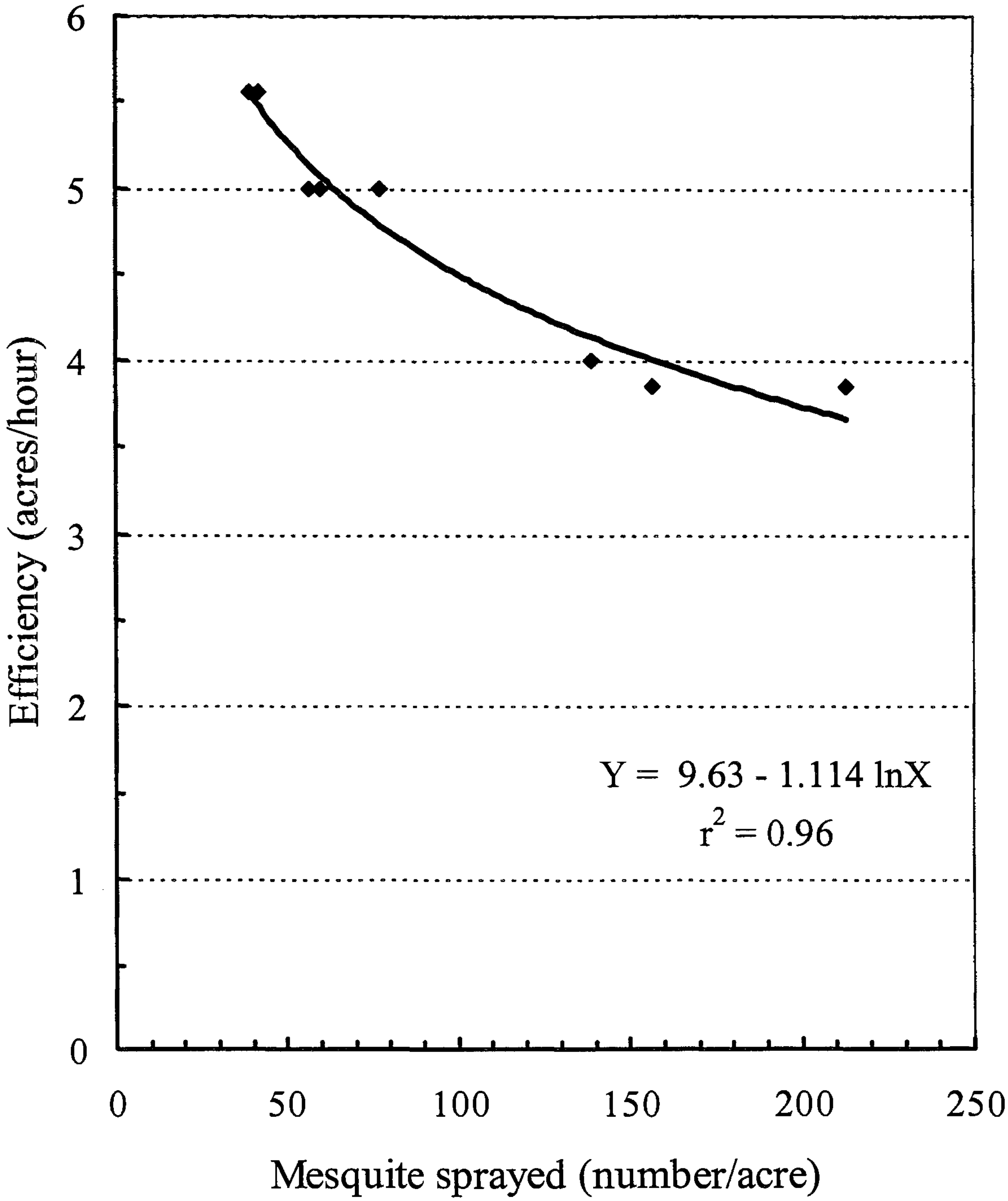

Figure 11. Relationship between efficiency (acre/hour) and mesquite sprayed (number/acre) for selective application of leaf sprays to mesquite in highway rights-of-way with a mechanical-sensing automatic sprayer operated at 30 psi.

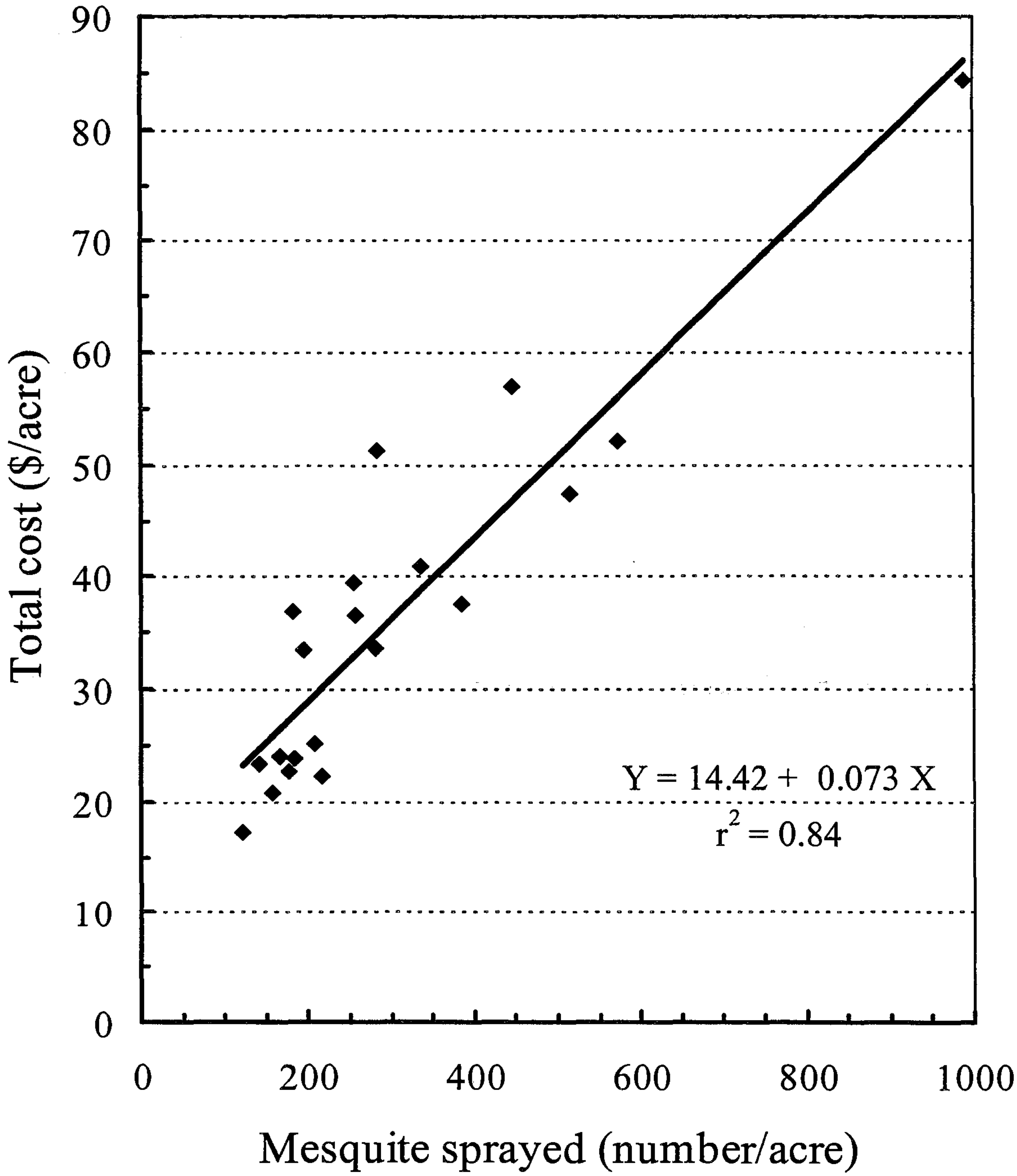

Figure 12. Relationship between cost ($/acre) and mesquite sprayed (number/acre) for selective application of leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester to mesquite in highway rights-of-way with a light-sensing automatic sprayer with timers set at 0.3 sec.

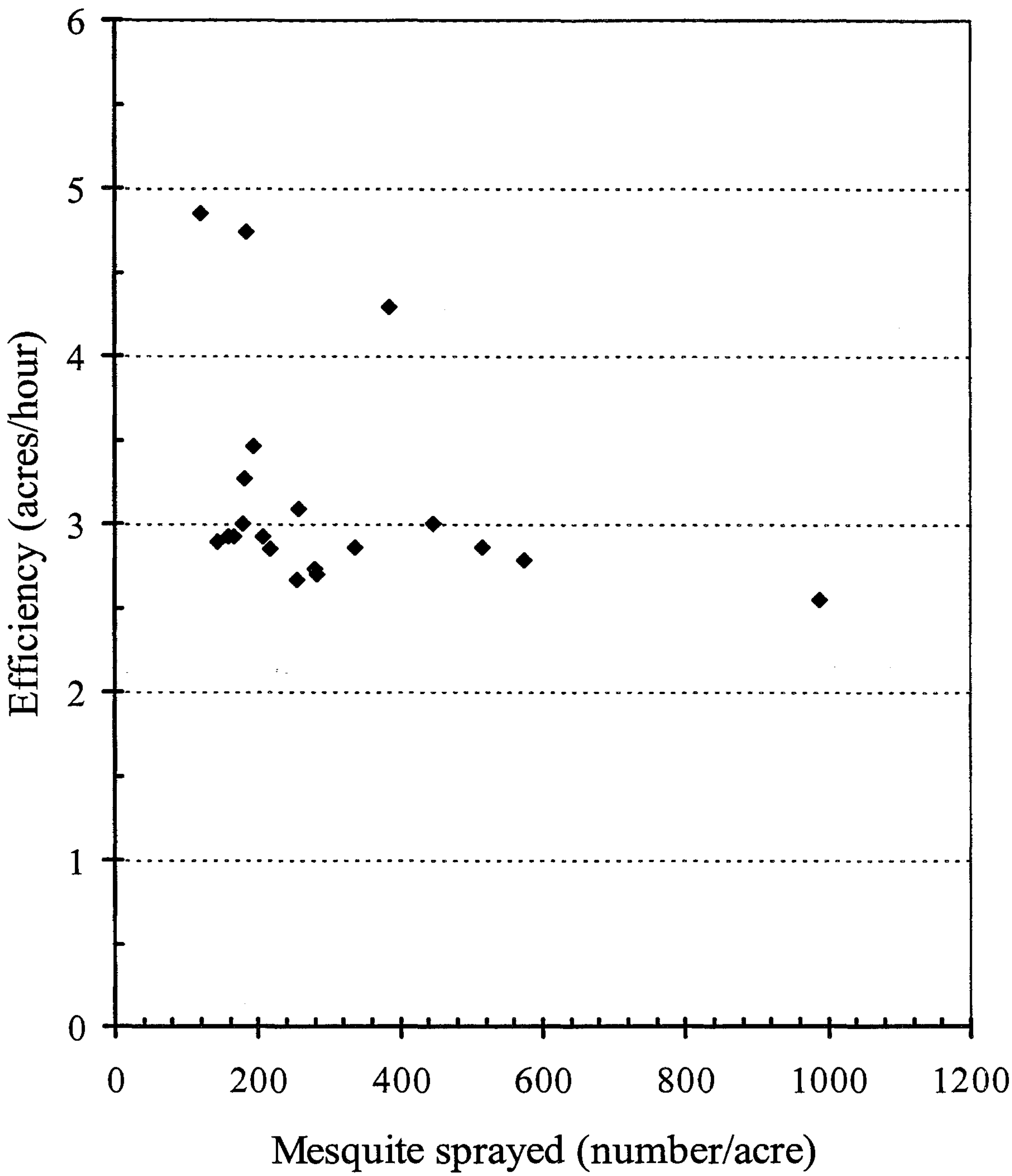

Figure 13. Data points for efficiency (acres/hour) at various numbers of mesquite sprayed/acre for selective application of leaf sprays to mesquite in highway rights-of-way with a light-sensing automatic sprayer with timers set at 0.3 sec. Efficiency was not significantly related to number of mesquite sprayed/acre.

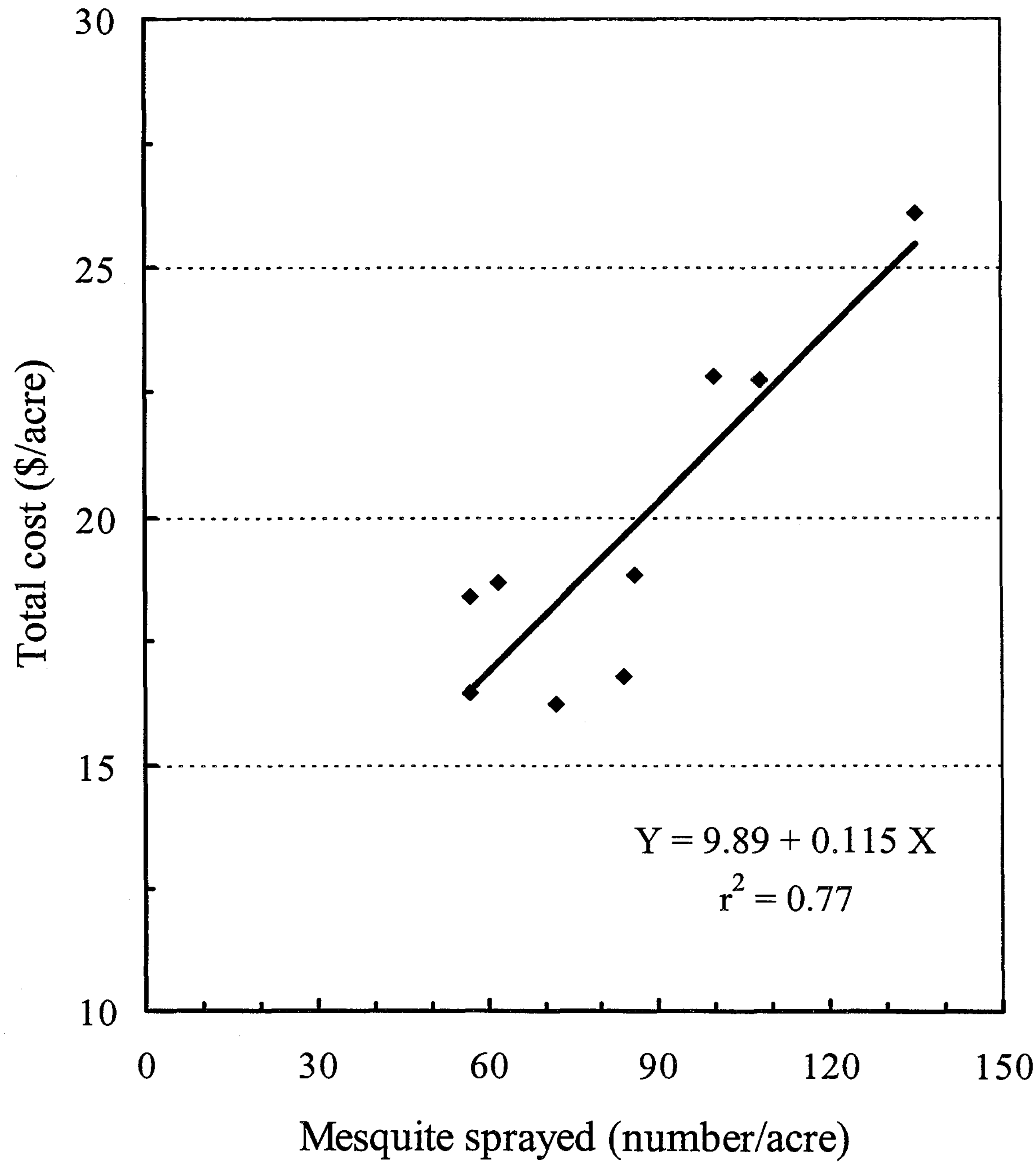

Figure 14. Relationship between cost ($/acre) and mesquite sprayed (number/acre) for selective application of leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester to mesquite in highway rights-of-way with a light-sensing automatic sprayer with timers set at 0.5 sec.

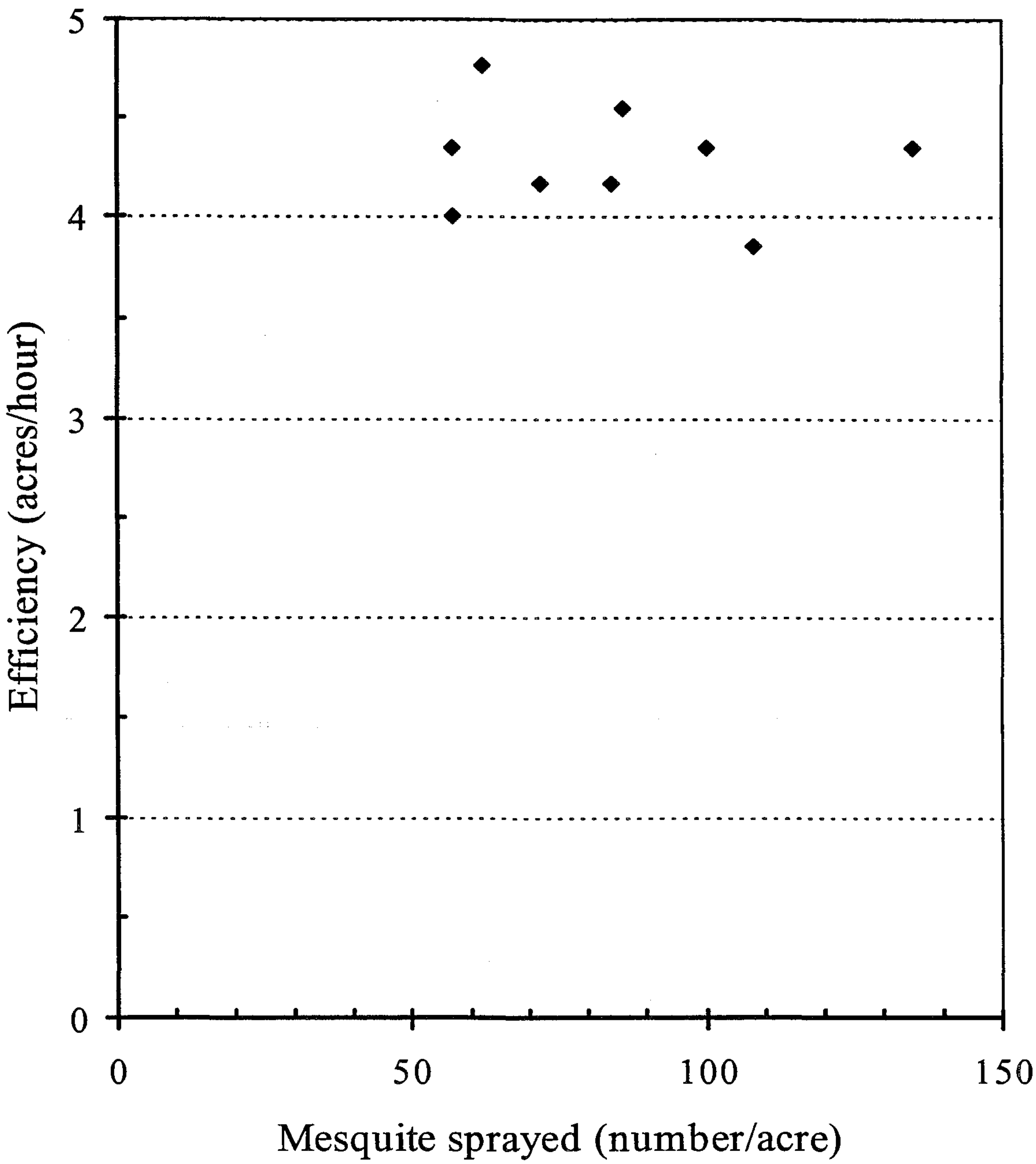

Figure 15. Data points for efficiency (acres/hour) at various numbers of mesquite sprayed /acre for selective application of leaf sprays to mesquite in highway rights-of-way with a light-sensing automatic sprayer with timers set at 0.5 sec. Efficiency was not significantly related to number of mesquite sprayed/acre.

Automatic All-terrain Vehicle Sprayer

The automatic ATV sprayer was evaluated on thirty-eight 1-acre plots. Operators became efficient in operating the sprayer after 0.5 to 1 hr of practice. The bending/retaining bar assembly proved very beneficial in achieving adequate coverage of the mesquite foliage and stems with the spray mixture. The optimal ground speed of the ATV for adequate spray coverage on the mesquite was about 1 mile/hr (equivalent to a very slow walk), but the speed could easily be increased during travel between mesquite plants where the mesquite plant density was low. Operator fatigue was a problem when mesquite densities exceeded 200 to 300 plants/acre.

The average number of mesquite plants sprayed/acre on the 38 plots was 175 (Appendix D). Efficiency of the automatic ATV sprayer averaged 4.01 acres/hr. The average volume of spray applied was 5.62 oz/mesquite plant sprayed. An average of 13.4% of the mesquite plants in the plots were missed either because the operator did not see them or because the spray delivery was not properly timed.

The relationship between total cost (Y) and the number of mesquite plants sprayed/acre (X) with the automatic ATV sprayer was estimated by the equation $Y = 6.03 + 0.064 X$ (Figure 16). This suggested that total cost for selectively spraying mesquite with this spraying system was $6.03/acre plus $0.064 for each mesquite plant treated. The relationship between efficiency in acres/hr (Y) and number of mesquite plants sprayed/acre (X) with the automatic ATV sprayer was estimated by the equation $Y = 10.17 - 1.279 \ln X$ (Figure 17). Efficiency of this spraying system decreased logarithmically as mesquite density increased.

Comparative Costs and Efficiencies of Mechanized Spraying Systems and Hand-spraying Methods

Comparative costs for selectively applying leaf sprays to mesquite with the automated spraying systems and four hand-spraying methods are shown in Table 5. The cost/acre data clearly demonstrate that mesquite in highway rights-of-way can be treated at lower costs with any of the automatic spraying systems than with stem sprays of Pathfinder II, regardless of the mesquite density. However, ground crews applying stem sprays of Pathfinder II will miss a lower percentage of the mesquite than will be missed by the more highly automated systems, such as the mechanical-sensing and light-sensing sprayers. Furthermore, the level of mesquite mortality achieved with Pathfinder II stem sprays will often be greater than that achieved by automatic delivery systems selectively applying leaf sprays. The data in Table 5 also definitively show that mesquite can be selectively treated with leaf sprays using backpack sprayers or by an ATV sprayer equipped for a three-man crew at about half the cost of using automatic spraying systems.

Costs for selectively applying leaf sprays with the automatic ATV sprayer were lower than those for the mechanical-sensing and light-sensing sprayers at all mesquite densities, and lower than those for the personnel carrier at mesquite densities ≤400 plants/acre (Table 5). However, operator fatigue

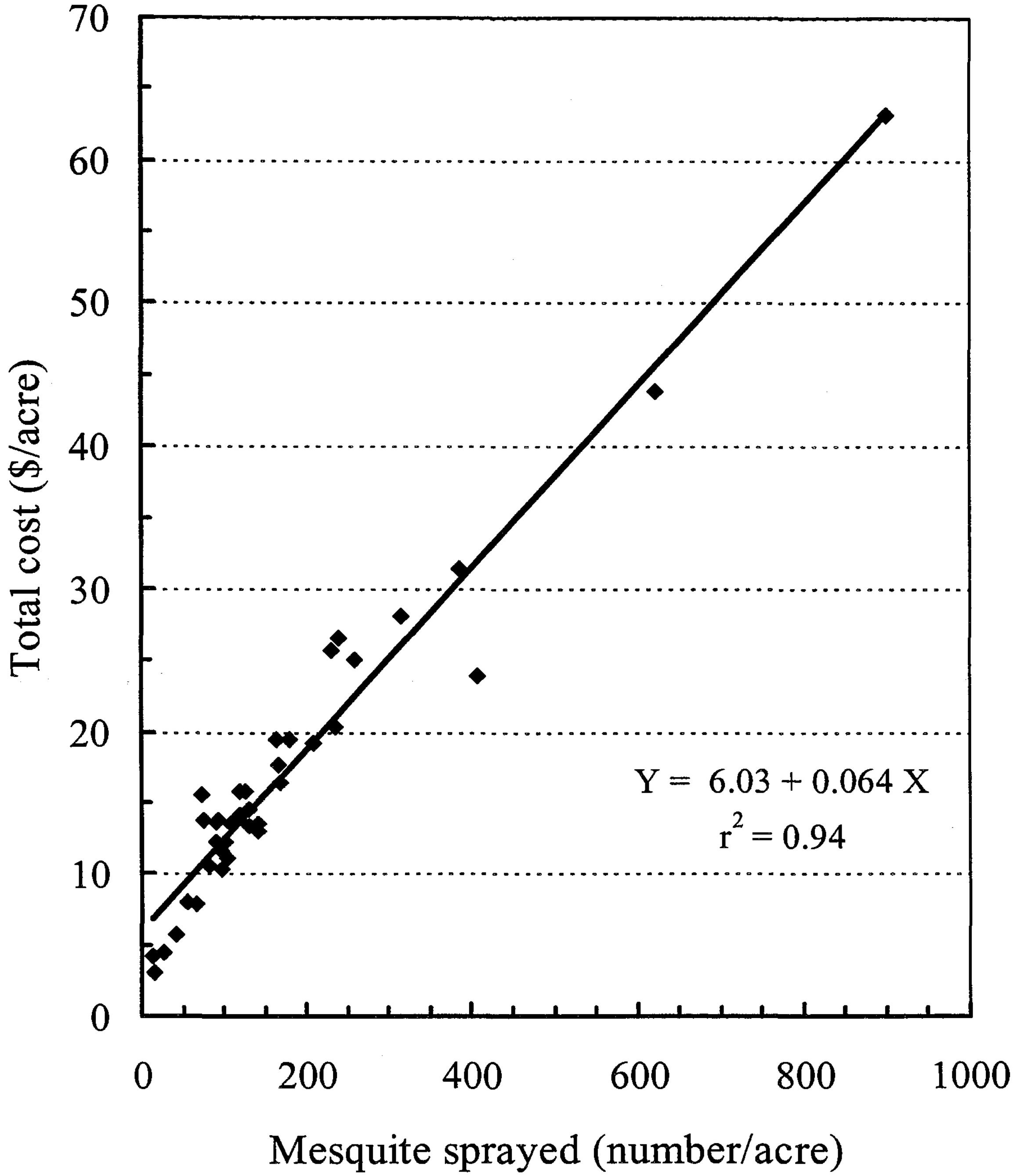

Figure 16. Relationship between cost ($/acre) and mesquite sprayed (number/acre) for selective application of leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester to mesquite in highway rights-of-way with an automatic ATV sprayer equipped with 2-gal/min nozzles.

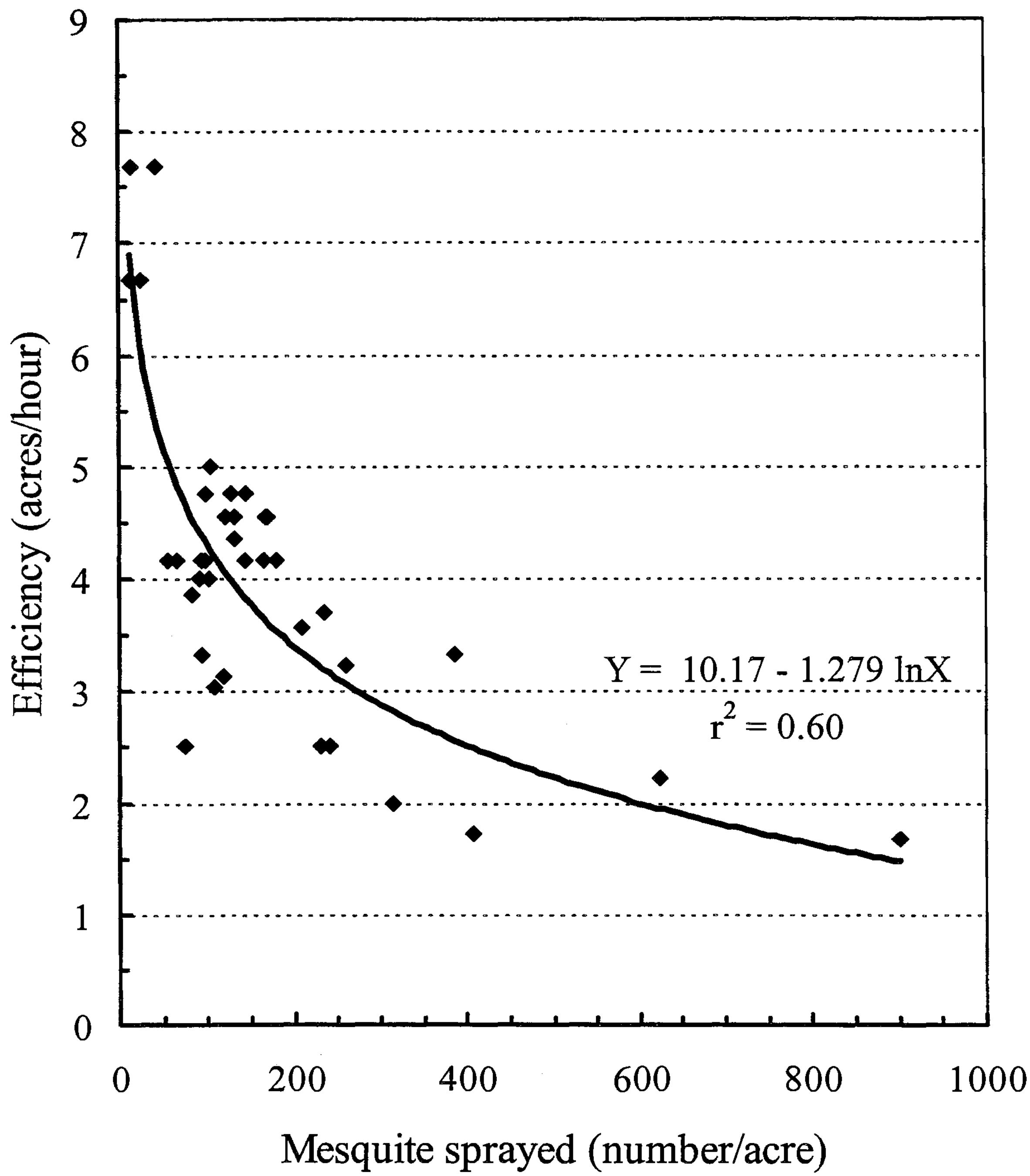

Figure 17. Relationship between efficiency (acres/hour) and mesquite sprayed (number/acre) for selective application of leaf sprays to mesquite in highway rights-of-way with an automatic ATV sprayer equipped with 2-gal/min nozzles.

Table 5. Comparative costs ($/acre) for selectively spraying various numbers of mesquite/acre with the personnel carrier (PC), mechanical-sensing automatic sprayer (M-S), light-sensing automatic sprayer (L-S), automatic ATV sprayer (ATV), stem spraying with Pathfinder II (Stem-PF), stem spraying with Garlon 4 + diesel fuel oil (Stem - G+D), leaf spraying with backpack sprayers (Leaf - BP), and leaf spraying with ATV sprayer with three-man crew (Leaf - ATV). Cost values were calculated from the respective regression equations (Table 4) for the spraying systems or methods. Cost values were rounded to the nearest $1.

	Number of mesquite sprayed/acre									
Spraying system or method	50	100	200	300	400	500	600	700	800	900
Mechanized	Cost ($/acre)									
PC	13	19	26	29	32	34	36	37	39	40*
M-S (18 psi)	12*	15	22	29	35	42	48	55	62	68
M-S (30 psi)	14	21	28	—	—	—	—	—	—	—
L-S (0.3 sec)	—[1/]	22*	29	36	44	51	58	65	73	80
L-S (0.5 sec)	16*	21	33*	—	—	—	—	—	—	—
Automatic ATV	9	12	19	25	32	38	44	51	57	64
Hand spraying										
Stem - PF	18	26	40	55	70	85	100	115	130	145
Stem - G+D	13	18	28	37	47	57	67	77	87	97
Leaf - BP	8	9	11	14	16	19	21	23	26	28
Leaf - ATV	6	8	11	15	18	21	24	28	31	34

* Regression equation applied slightly beyond the range of the field data.

[1/] Dashes indicate that no field data were collected for the respective number of mesquite sprayed/acre and spraying system.

becomes a problem with the automatic ATV sprayer where mesquite densities exceed 200 to 300 plants/acre. Costs for using the mechanical-sensing sprayer at 18 psi were lower than those for the personnel carrier at lower mesquite densities (≤200 plants/acre), whereas the personnel carrier was less expensive than the mechanical-sensing sprayer at densities ≥400 plants/acre. The personnel carrier was the most cost efficient mechanized system at mesquite densities ≥500 plants/acre. The light-sensing automatic sprayer was the least cost-efficient method at all mesquite densities compared to the other automated spraying systems and to the hand-spraying methods.

The Texas Department of Transportation's limited labor force and the large acreage of mesquite-infested rights-of-way in many counties may dictate the selection of mesquite control technology that is highly efficient relative to the acreage that can be treated per hour or per man-hr of labor available. Comparative data on efficiencies (acres/hr) for the mechanized spraying systems and four hand-spraying methods are presented in Table 6. These data indicate that the mechanical-sensing sprayer, light-sensing sprayer, and automatic ATV sprayer were capable of treating more acres per man-hr of labor than the personnel carrier and hand-spraying methods. The one-man automatic spraying systems treated over 4 acres/hr at low mesquite densities (100 plants/acre) and 1.5 to 2.7 acres/hr in high mesquite densities (900 plants/acre). The hand spraying methods treated only 1.3 to 2.4 acres/man-hr at low mesquite densities (100/acre) and only 0.3 to 0.9 acres/man-hr at high mesquite densities (900/acre). When the efficiency of the four-man personnel carrier crew was converted to acres treated/man-hr, it was less efficient at all mesquite densities than the three-man crews hand spraying from an ATV equipped with a spray tank and electric pump. The stem spray method was the least labor efficient of all methods evaluated at mesquite densities ≥200 plants/acre. Workers applying stem sprays could treat only 1.3 acre/man-hr at low mesquite densities (100/acre) and only 0.3 acre/man-hr in high mesquite densities (≥600 plants/acre) (Table 6). The three-man crew using sprayguns from an ATV sprayer covered more acres/hr than any of the other spraying methods or systems (Table 6).

In relation to "environmental friendliness" as well as minimizing treatment costs in mesquite control projects, an important consideration in comparing spraying systems or methods is the amount of herbicide released into the environment. The amounts of herbicide applied per acre, expressed in pounds of acid equivalent, for the mechanized spraying systems and hand-spraying methods are shown in Figure 18. These data indicate that applying stem sprays of Pathfinder II or a mixture of Garlon 4 + diesel fuel oil (15% + 85%) were the least efficient with respect to the amount of herbicide deposited in the environment. Applying leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester using backpack sprayers, an ATV rigged for three workers, or the personnel carrier were the most efficient methods, and the mechanized spraying systems were intermediate. Among the mechanized spraying systems, the personnel carrier was the most efficient and the light-sensing automatic sprayer was the least efficient (Figure 18).

Applying leaf sprays selectively by the hand-spraying methods reduces the amount of herbicide released into the environment because the adjustable cone nozzles have a low output and the narrow cone-shaped spray pattern facilitates application of the spray primarily to the target plants. The mechanical-sensing automatic sprayer, light-sensing automatic sprayer, and the automatic ATV

Table 6. Comparative efficiencies (acres/hr) for selectively spraying various numbers of mesquite plants/acre with the personnel carrier (PC), mechanical-sensing automatic sprayer (M-S), light-sensing automatic sprayer (L-S), automatic ATV sprayer (ATV), stem spraying with Pathfinder II (Stem - PF), stem spraying with Garlon 4 + diesel fuel oil (Stem - G + D), leaf spraying with backpack sprayers (Leaf - BP), and leaf spraying with an ATV sprayer (Leaf - ATV). Efficiency values were calculated from the respective regression equations (Table 4) for the spraying systems or methods. Efficiency values were rounded to the nearest 0.1 acre.

Spraying system or method	Number of mesquite sprayed/acre									
	50	100	200	300	400	500	600	700	800	900
Mechanized	Efficiency (acres/hr)									
PC (4-man crew)	5.2	4.6	4.0	3.6	3.4	3.2	3.0	2.9	2.8	2.7[1/]
PC (per man)	1.3	1.1	1.0	0.9	0.8	0.8	0.8	0.7	0.7	0.7[1/]
M-S (18 psi)	4.7[1/]	4.2	3.7	3.4	3.2	3.0	2.9	2.7	2.6	2.6
M-S (30 psi)	5.3	4.5	3.7	—[2/]	—	—	—	—	—	—
L-S (0.3 sec)[3/]										
L-S (0.5 sec)[3/]										
Automatic ATV	5.2	4.3	3.4	2.9	2.5	2.2	2.0	1.8	1.6	1.5
Hand-spraying										
Stem - PF	2.1	1.3	0.8	0.6	0.5	0.4	0.3	0.3	0.3	0.3
Stem - G+D	2.1	1.3	0.8	0.6	0.5	0.4	0.3	0.3	0.3	0.3
Leaf - BP	2.4	1.9	1.4	1.2	1.0	0.8	0.7	0.6	0.5	0.5
Leaf - ATV (3-man crew)	8.6	7.1	5.7	4.9	4.3	3.8	3.5	3.1	2.9	2.6
Leaf - ATV (per man)	2.9	2.4	1.9	1.6	1.4	1.3	1.2	1.0	1.0	0.9

[1/] Regression equation applied slightly beyond the range of the field data.

[2/] Dashes indicate that no field data were collected for the respective number of mesquite/acre and spraying system.

[3/] There was no correlation between efficiency and number of mesquite sprayed/acre for the light-sensing automatic sprayer. Average efficiency using 0.3-sec timers was 3.2 acres/hr to spray an average of 303 mesquite/acre. Average efficiency using 0.5-sec timers was 4.3 acres/hr to spray an average of 85 mesquite/acre.

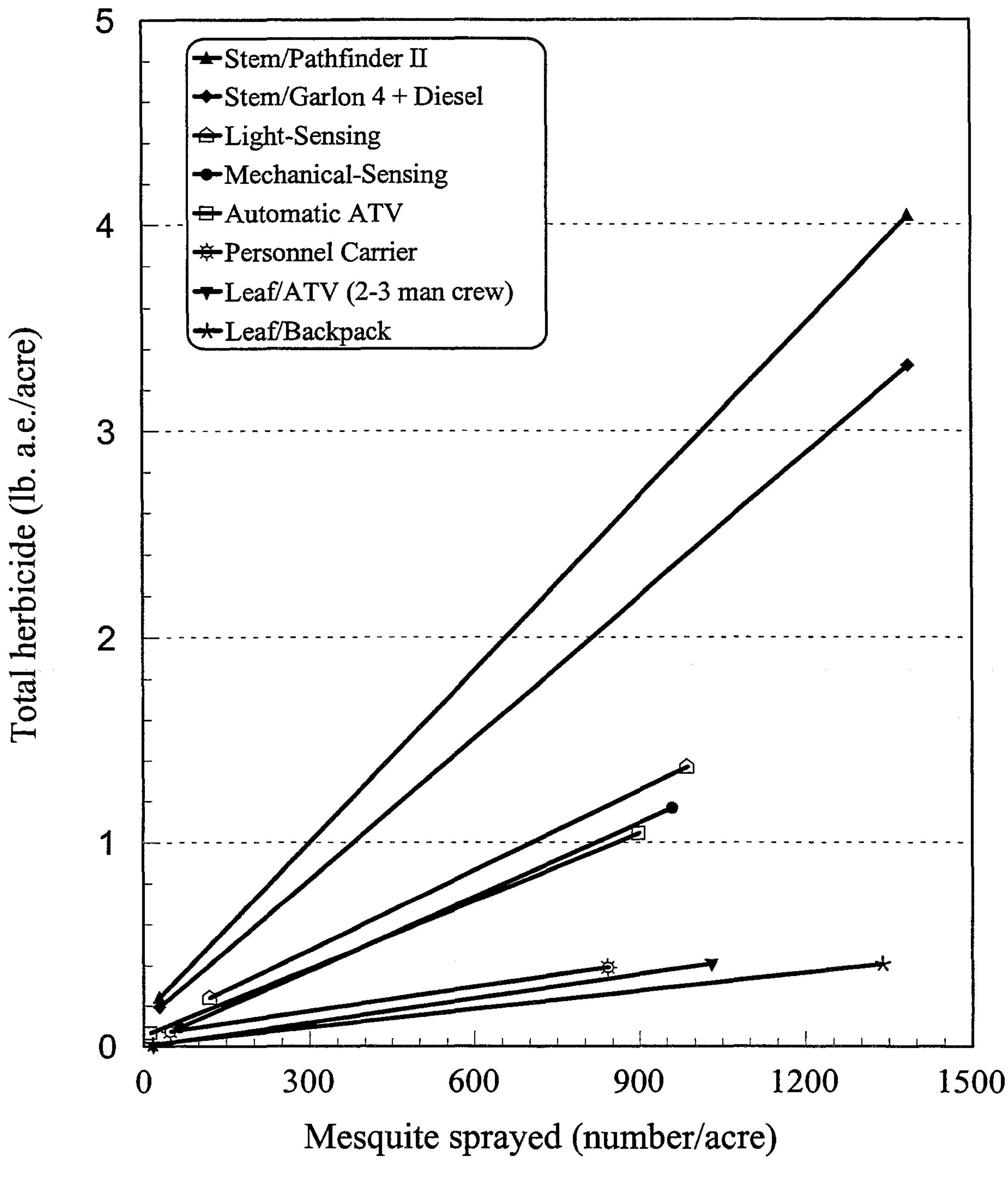

Figure 18. Total amount of clopyralid and/or triclopyr (lb. acid equivalent/acre) applied for spraying various numbers of mesquite/acre with four mechanized spray delivery systems and four hand-spraying methods.

sprayer are equipped with nozzles with large orifices and a wide spray pattern. The high-volume nozzles are necessary to allow these sprayers to achieve sufficient coverage of spray on the mesquite plants while maintaining a relatively constant rate of travel. Each nozzle on the automatic ATV system and light-sensing spraying system sprays a 3-ft-wide band, even though the mesquite plant being sprayed may be only 1 ft or less in diameter. The stem spray methods were the least efficient relative to the amount of herbicide released because of the multiple-stem growth form of regrowth mesquite and because the sprays contain much greater concentrations of herbicide compared to leaf sprays (± 15% vs 1%).

CONCLUSIONS

This final report provides information and technology that the Texas Department of Transportation will be able to adopt and utilize immediately to improve the cost and labor efficiency of its mesquite control projects. Results from 13 field experiments demonstrated that properly timed leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester could provide an acceptable level of rootkill of mesquite in highway rights-of-way to justify the expense and effort of treatment. This leaf spray was most effective if applied during July (58 - 68% mesquite mortality) through mid October (90 - 98% mesquite mortality). The spray does not damage associated grasses and has minimal impact on wildflowers when applied during the period specified above because most wildflowers are dormant or dead during this time. The spray is "environmentally friendly" in that lower herbicide rates (lb of herbicide acid equivalent/acre) are applied for low-to-moderate mesquite densities than are normally applied when broadcast sprays of these herbicides are utilized.

The efficacy of this leaf spray for killing mesquite that had been mowed the previous autumn or earlier increased with the length of the post-mowing interval and as the growing season progressed, probably because longer time for growth provided sufficient leaf surface area for absorption and downward translocation of a lethal dose of the herbicides into the roots and basal meristems (bud zones). The cessation of new mesquite canopy growth and maturation of the foliage that usually occurs by mid summer is believed to contribute to improved efficacy of leaf sprays because at this point in the annual growth cycle the foliage is producing a surplus of photosynthates (carbohydrates), and downward translocation of photosynthates into the basal bud zone and roots is occurring. After being absorbed by the leaves, clopyralid and triclopyr are translocated in the carbohydrate stream, and as such it is critical that the net flow of carbohydrates is downward when the leaf sprays are applied so that lethal concentrations of the herbicides can be moved into the meristematic region at or below the soil surface and into the roots.

Increasing the concentrations of clopyralid and triclopyr ester in leaf sprays above 0.5% + 0.5% did not improve mesquite control, probably because applying the lower concentrations as wetting sprays ("spray to wet") deposited sufficient herbicide on the leaves to saturate their absorption capacity. Carriers for the leaf spray containing 0.5% non-ionic surfactant or 5% diesel fuel oil performed similarly, and mesquite control was not improved by increasing the concentration of diesel fuel oil in the carrier to 20 or 25%.

This study identified and developed four mechanized and automated spraying systems capable of selectively applying leaf sprays to mesquite in highway rights-of-way. All four systems were durable and proved capable of selectively treating mesquite infestations at considerable lower costs/acre than the Texas Department of Transportation's current mesquite control treatment, hand spraying the basal stems with Pathfinder II. However, costs/acre for selectively applying leaf sprays to mesquite using the mechanized spraying systems was about 2X that for ground crews to apply the same leaf sprays using backpack sprayers or an ATV equipped for three workers. The automatic ATV sprayer was the most cost-effective mechanized spraying system for mesquite densities <400 plants/acre, primarily because of its lower hourly cost, but operator fatigue was a problem where mesquite numbers exceed 200 to 300/acre. The personnel carrier was the most cost-effective mechanized spraying system for mesquite densities >400 plants/acre. The light-sensing automatic sprayer was the least cost-effective mechanized system because of the high cost of its electronic components and the higher volume of spray applied per mesquite.

In contrast to their greater cost, the automatic spraying systems were more efficient in terms of acres treated/man-hr than the hand-spraying methods currently being used by ground crews on rights-of-way, rangelands or pastureland because the mechanized systems generally maintain a constant or variable ground speed, whereas ground crews generally must pause or stop at each mesquite plant. The stem spray method was the least efficient of all the methods evaluated because mesquite regrowth plants have multiple stems, and the lower 12 in. of each stem must be thoroughly covered with the spray. Dense cover of grasses and weeds in rights-of-way often make treatment of every stem difficult and laborious.

Efficiency of the mechanical-sensing and light-sensing spray systems, in terms of the percentage of mesquite plants missed, was much lower than that for the personnel carrier, automatic ATV sprayer, and the hand spraying methods. The mechanical-sensing sprayer missed 13 to 23% of the mesquite plants and the light-sensing sprayer missed 24 to 25% (Appendix D). Only about 6% and 13% of the mesquite were missed by the personnel carrier and automatic ATV sprayers, respectively. Ground crews applying stem or leaf sprays routinely miss about 5% of the mesquite plants.

Relative to the volume of leaf spray applied to each mesquite plant, the mechanized spray delivery systems were considerably less efficient than workers using backpack sprayers or an ATV sprayer rigged with three sprayguns. The average volumes of leaf spray applied per mesquite plant for the personnel carrier, automatic ATV sprayer, mechanical-sensing sprayer (18 psi), and light-sensing sprayer (0.3-sec timers) were 2.7, 5.6, 4.8, and 6.0 oz/plant, respectively (Appendix D), compared to 1.0 and 1.5 oz/plant for leaf spraying with backpack sprayers and with an ATV rigged with three sprayguns, respectively (Ueckert and McGinty 1995). Average volume of stem spray applied to each mesquite by workers using backpack sprayers was 0.6 oz/plant.

The Transline (clopyralid) herbicide label limits the amount that can be applied per acre in any year to 1.33 pint. For leaf sprays containing 0.5% clopyralid + 0.5% triclopyr ester, this equates to 33.25 gal/acre of the spray mixture. The legal limit for clopyralid was exceeded in only one test plot with the mechanical-sensing sprayer (18 psi pressure) in which 961 mesquite plants/acre were treated, and in only one plot where 988 mesquite plants/acre were treated with the light-sensing sprayer (0.3-sec timers). Only 10.2 gal of the spray were required to treat 842 mesquite plants/acre with the personnel carrier, and only 29.3 gal of spray were required to treat 900 mesquite plants/acre with the automatic ATV sprayer. Ground crews applying this leaf spray to mesquite with backpack sprayers used only 10.3 gal to treat 1,341 mesquite plants/acre, and crews using an ATV sprayer equipped with three sprayguns used only 13.5 gal to treat 1,033 mesquite plants/acre. The Garlon 4 (triclopyr ester) herbicide label allows the application of as much as 8 quarts/acre/yr, therefore the Transline limit (1.33 pint/acre) and the high cost when this limit is approached will be the major considerations when the leaf spray is being used.

RECOMMENDATIONS for IMPLEMENTATION

1. The use of Pathfinder II stem sprays should be restricted to areas with very sparse mesquite infestations, fragile areas, steep slopes, areas inaccessible with mechanized equipment, or areas around interchanges or urban areas that are mowed several times each year.

2. If large acreages of mesquite-infested right-of-way are targeted for treatment with stem sprays, the stem spray should be mixed by Texas Department of Transportation personnel using 15% Garlon 4 + 85% diesel fuel oil to reduce treatment costs.

3. Utilize leaf sprays containing 0.5% clopyralid (Transline) + 0.5% triclopyr ester (Garlon 4) in water carriers containing either 0.5% non-ionic surfactant or 5% diesel fuel oil (with an emulsifier) rather than Pathfinder II stem sprays to the greatest extent possible in areas where the rights-of-way are only mowed each autumn or less frequently. Allow the mesquite to grow until late July, or later if possible, prior to initiating leaf spraying operations.

4. If mesquite control projects are planned that involve ground crews applying leaf sprays over large acreages, then utilize ATV's to transport the spray tank and pump and rig the sprayer with hoses and sprayguns for three workers to minimize worker fatigue and to maximize the acreage that can be treated per day.

5. Utilize the mechanized and automatic spraying systems described in this report to the greatest extent possible for mesquite control projects over very large acreages, or elsewhere if maximizing the acreage treated/man-hr of labor is critical. Utilize the automatic ATV sprayer for mesquite densities ≤300 plants/acre and the personnel carrier for mesquite densities >300 plants/acre if cost savings is an important consideration. Use the mechanical-sensing or light-sensing sprayers if efficiency of labor is extremely important.

6. Allow mesquite to grow as long as possible following mowing prior to applying leaf sprays. Allow mesquite that has been mowed in the autumn to grow from spring green-up until at least late July before applying leaf sprays.

7. Prior to initiating a right-of-way mesquite control project, conduct a survey to estimate the mesquite density. Then refer to Table 5 in this report to estimate the cost ($/acre) for the method(s) you are considering. If the estimated cost exceeds $31 - $35/acre, and if broadcast overspraying is a viable alternative, then consider applying an overspray containing 0.25 lb clopyralid + 0.25 lb triclopyr ester/acre (but refer to recommendation 8).

8. Initiate research studies immediately to determine the efficacy of broadcast oversprays containing clopyralid + triclopyr ester at 0.25 + 0.25 lb/acre, 0.25 + 0.5 lb/acre, and 0.5 + 0.5 lb/acre rates for control of mesquite regrowth in highway rights-of-way. This information is needed to determine whether broadcast overspraying is a viable treatment alternative for rights-of-ways with extremely heavy mesquite infestations.

9. Initiate mesquite control projects in rights-of-way while mesquite plant densities (number of plants/acre) are low to moderate, rather than delaying treatments until heavy infestations have developed.

10. Utilize the training videos and the revised sections of the Herbicide Operations Manual (Appendix F) being produced by this project to train all Texas Department of Transportation personnel who will be involved in mesquite control projects.

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APPENDIX A

Mean percent (%) mortality of regrowth mesquite in highway rights-of-way at 2 years after treatment (YAT) with leaf sprays containing various concentrations of clopyralid (Transline) and triclopyr ester (Garlon 4) and various adjuvants during June 1996 in four western Texas counties.

Treatment		Mortality @ 2 YAT[1]				
Herbicide		Replications (sites)[2]				
Transline + Garlon 4	Adjuvant	1[3]	2	3	4	Mean
%		%				
.5 + .5	.5% Surfactant	81	65 abc	55	20	55
1 + 1	.5% Surfactant	57	35 de	25	21	35
2 + 2	.5% Surfactant	60	68 ab	24	4	39
.5 + .5	5% Diesel	53	32 e	43	12	35
1 + 1	5% Diesel	65	54 b-e	53	5	44
2 + 2	5% Diesel	62	83 a	23	2	43
.5 + .5	20% Diesel	83	39 cde	73	5	50
1 + 1	20% Diesel	57	61 a-d	40	3	40
2 + 2	20% Diesel	50	51 b-e	36	7	36

[1] Means within a column followed by a similar lower case letter are not significantly different according to $LSD_{0.05}$. Absence of lower case letters within a column indicates no significant differences among treatments.

[2] Sites: 1= Schleicher County; 2 = Reagan County; 3 = Menard County; and 4 = Runnels County.

[3] The experiment at Site 1 was not replicated, thus the data were not subjected to statistical analysis.

APPENDIX B

Mean percent (%) mortality of regrowth mesquite in highway rights-of-way at 2 years after treatment (YAT) with leaf sprays containing various concentrations of clopyralid (Transline) and triclopyr ester (Garlon 4) and various adjuvants during July 1996 in four western Texas counties.

Treatment		Mortality @ 2 YAT[1/]				
Herbicide		Replications (sites)[2/]				
Transline + Garlon 4	Adjuvant	1	2	3	4	Mean
%		----------	----------	%	----------	----------
.5 + .5	.5% Surfactant	37 ab	71 a	85	81	68
1 + 1	.5% Surfactant	36 ab	75 a	62	82	64
2 + 2	.5% Surfactant	12 b	41 abc	86	42	45
.5 + .5	5% Diesel	60 a	55 abc	62	57	58
1 + 1	5% Diesel	62 a	75 a	68	35	60
2 + 2	5% Diesel	3 b	53 abc	75	28	40
.5 + .5	20% Diesel	33 ab	28 bc	61	22	36
1 + 1	20% Diesel	66 a	19 c	54	91	58
2 + 2	20% Diesel	19 b	58 ab	80	30	46

[1/] Means within a column followed by a similar lower case letter are not significantly different according to $LSD_{0.05}$. Absence of lower case letters within a column indicates no significant differences among treatments.

[2/] Sites: 1 = Edwards County; 2 = Concho County; 3 = Coke County; and 4 = Sterling County.

APPENDIX C

Mean percent (%) mortality of regrowth mesquite in highway rights-of-way at 2 years after treatment (YAT) with leaf sprays containing various concentrations of clopyralid (Transline) and triclopyr ester (Garlon 4) and various adjuvants during August 1996 in four western Texas counties.

Treatment		Mortality @ 2 YAT[1]				
Herbicide		Replications (sites)[2]				
Transline + Garlon 4	Adjuvant	1	2	3	4	Mean
%		---------------- % ----------------				
.5 + .5	.5% Surfactant	76	79 a	62 bc	67	71
1 + 1	.5% Surfactant	78	62 ab	89 a	56	71
2 + 2	.5% Surfactant	70	56 ab	84 a	57	67
.5 + .5	5% Diesel	73	61 ab	73 abc	66	68
1 + 1	5% Diesel	75	57 ab	79 ab	58	67
2 + 2	5% Diesel	62	23 c	82 a	24	48
.5 + .5	20% Diesel	62	42 bc	59 c	50	53
1 + 1	20% Diesel	74	61 ab	88 a	56	70
2 + 2	20% Diesel	65	43 bc	81 a	76	66

[1] Means within a column followed by a similar letter are not significantly different according to $LSD_{0.05}$. Absence of lower case letters within a column indicates no significant differences among treatments.

[2] Sites: 1= Crockett County; 2 = Irion County; 3 = Glasscock County; and 4 = Nolan County.

APPENDIX D

Statistics from field evaluations of the personnel carrier, mechanical-sensing automatic sprayer, light-sensing automatic sprayer, and automatic ATV sprayer during 1996 - 1999.

Spraying System	Statistic	Mesquite sprayed (no./acre)	Spray mixture (gal/acre)	Labor (man-hr/acre)	Total cost ($/acre)	Efficiency (acres/hr)	Mesquite missed (%)	Spray/ mesquite (oz)	Trials (no.)
Personnel carrier	Mean	285	4.8	1.04	25.57	3.99	5.59	2.66	12
	S.D.	245	3.1	0.22	9.16	0.83	2.48	1.29	
	Max.	842	10.2	1.48	42.35	5.35	10.53	6.05	
	Min.	50	0.7	0.75	14.24	2.70	2.13	1.46	
Mechanical-sensing Sprayer (18 psi)	Mean	417	14.7	0.32	36.60	3.25	12.75	4.76	15
	S.D.	245	10.4	0.05	20.09	0.62	5.30	1.96	
	Max.	961	45.7	0.40	96.03	5.26	23.04	8.42	
	Min.	67	3.0	0.19	11.38	2.50	5.16	2.16	
Mechanical-sensing Sprayer (30 psi)	Mean	98	6.5	0.22	18.55	4.73	23.26	9.34	8
	S.D.	64	3.2	0.03	6.90	0.72	4.46	2.09	
	Max.	213	10.8	0.26	27.63	5.56	32.14	12.50	
	Min.	39	3.4	0.18	11.80	3.85	16.93	5.53	
Light-sensing Sprayer (0.3 sec)	Mean	303	13.9	0.33	36.44	3.17	24.08	6.02	20
	S.D.	204	8.4	0.05	16.17	0.67	12.95	1.79	
	Max.	988	38.8	0.39	84.34	4.85	48.03	10.18	
	Min.	121	5.0	0.21	17.13	2.55	9.30	3.32	

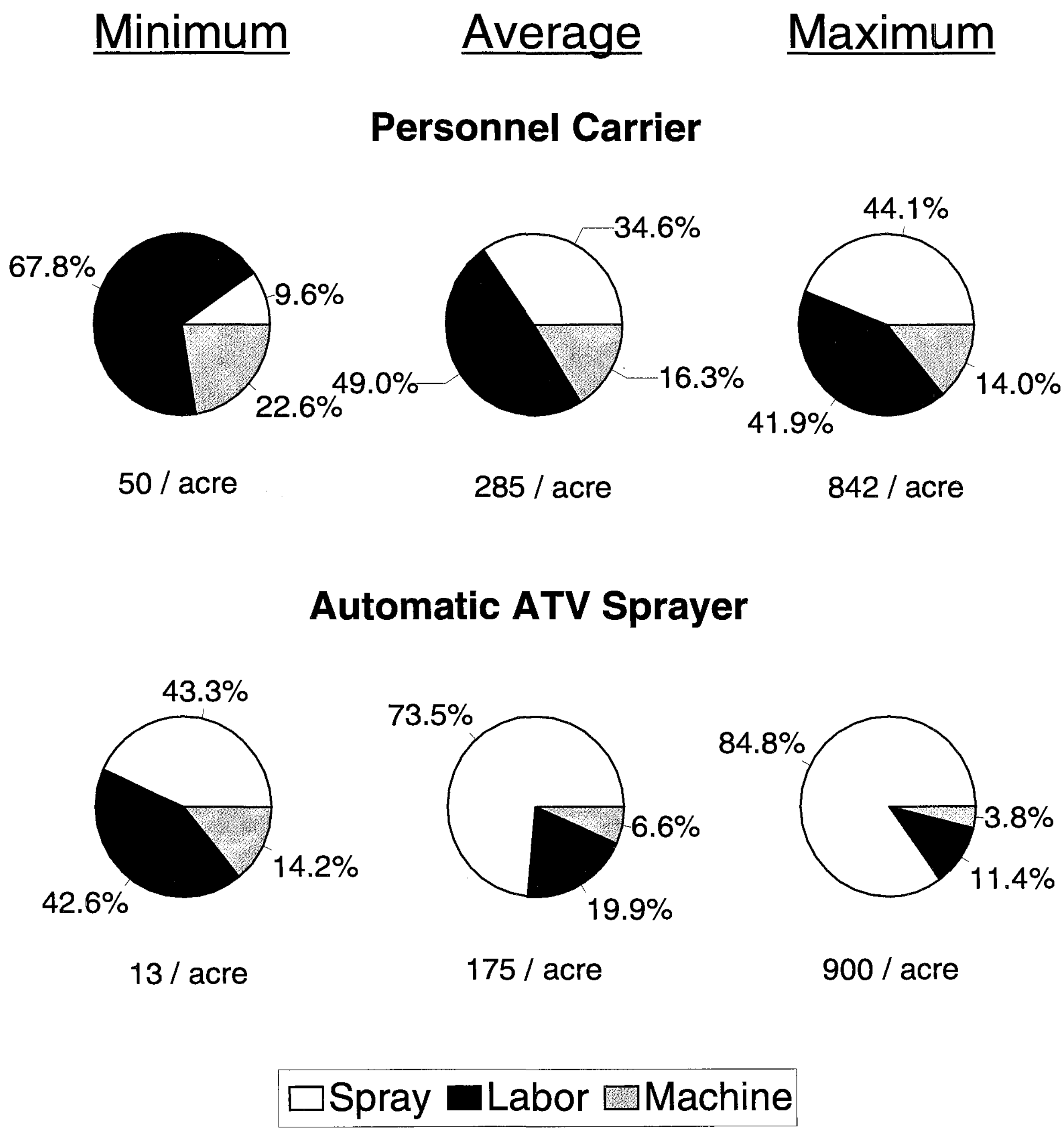
APPENDIX D (continued)

Statistics from field evaluations of the personnel carrier, mechanical-sensing automatic sprayer, light-sensing automatic sprayer, and automatic ATV sprayer during 1996 - 1999.

Spraying System	Statistic	Mesquite sprayed (no./acre)	Spray mixture (gal/acre)	Labor (man-hr/acre)	Total cost ($/acre)	Efficiency (acres/hr)	Mesquite missed (%)	Spray/ mesquite (oz)	Trials (no.)
Light-sensing Sprayer (0.5 sec)	Mean	85	6.4	0.23	19.66	4.28	24.70	9.88	9
	S.D.	26	1.9	0.02	3.45	0.28	6.35	1.89	
	Max.	135	10.0	0.26	26.12	4.76	32.71	13.01	
	Min.	57	4.4	0.21	16.21	3.85	14.01	7.16	
Automatic ATV Sprayer	Mean	175	6.9	0.28	17.13	4.01	13.36	5.62	38
	S.D.	170	5.4	0.11	11.15	1.43	7.46	1.30	
	Max.	900	29.3	0.60	63.20	7.69	31.78	9.85	
	Min.	13	0.5	0.13	3.00	1.67	0.0	2.51	

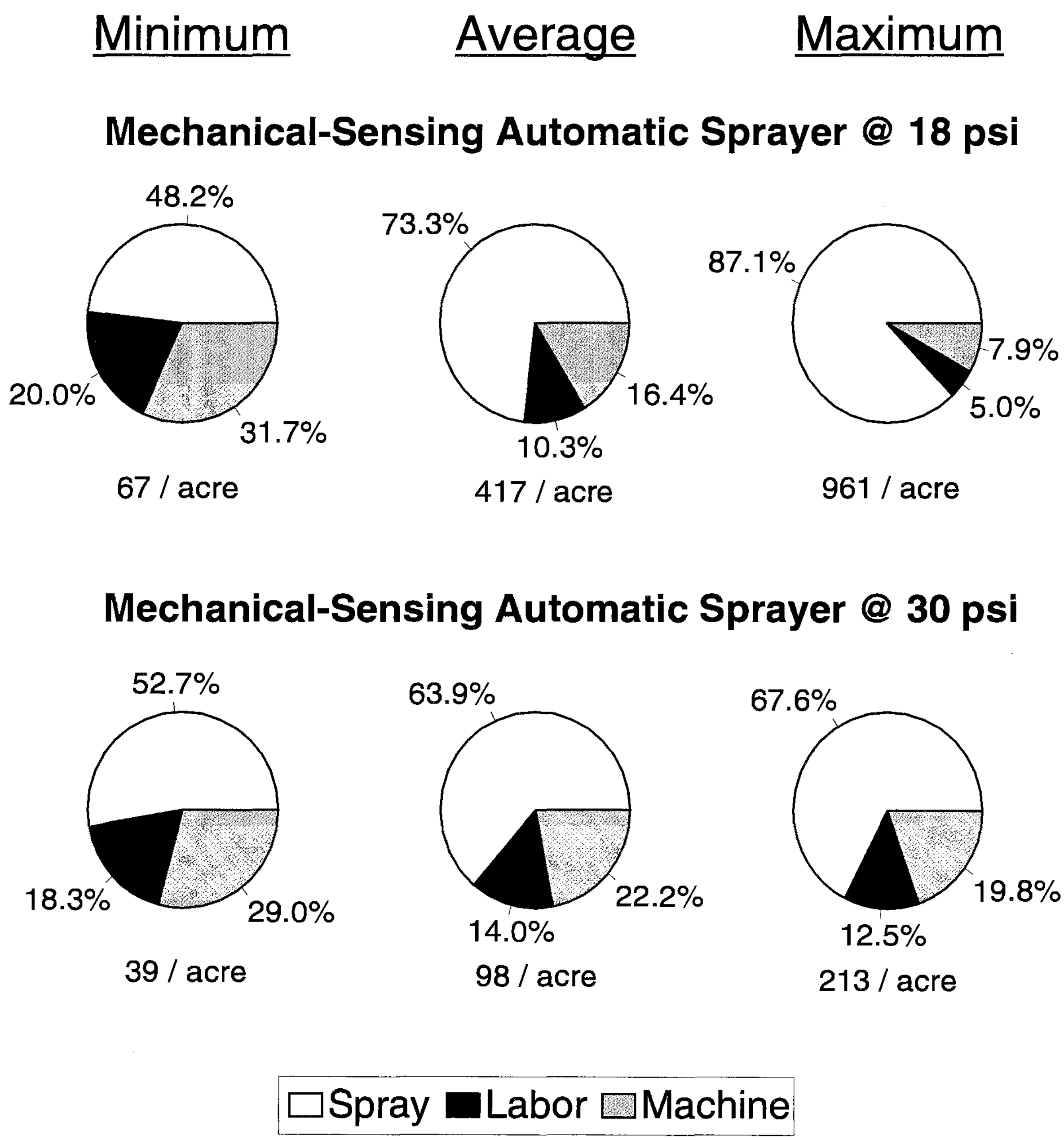
APPENDIX E

Spray, labor, and machine costs, as a percentage of the total cost, at the minimum, average, and maximum number of mesquite plants sprayed/acre with the personnel carrier and automatic ATV sprayer.



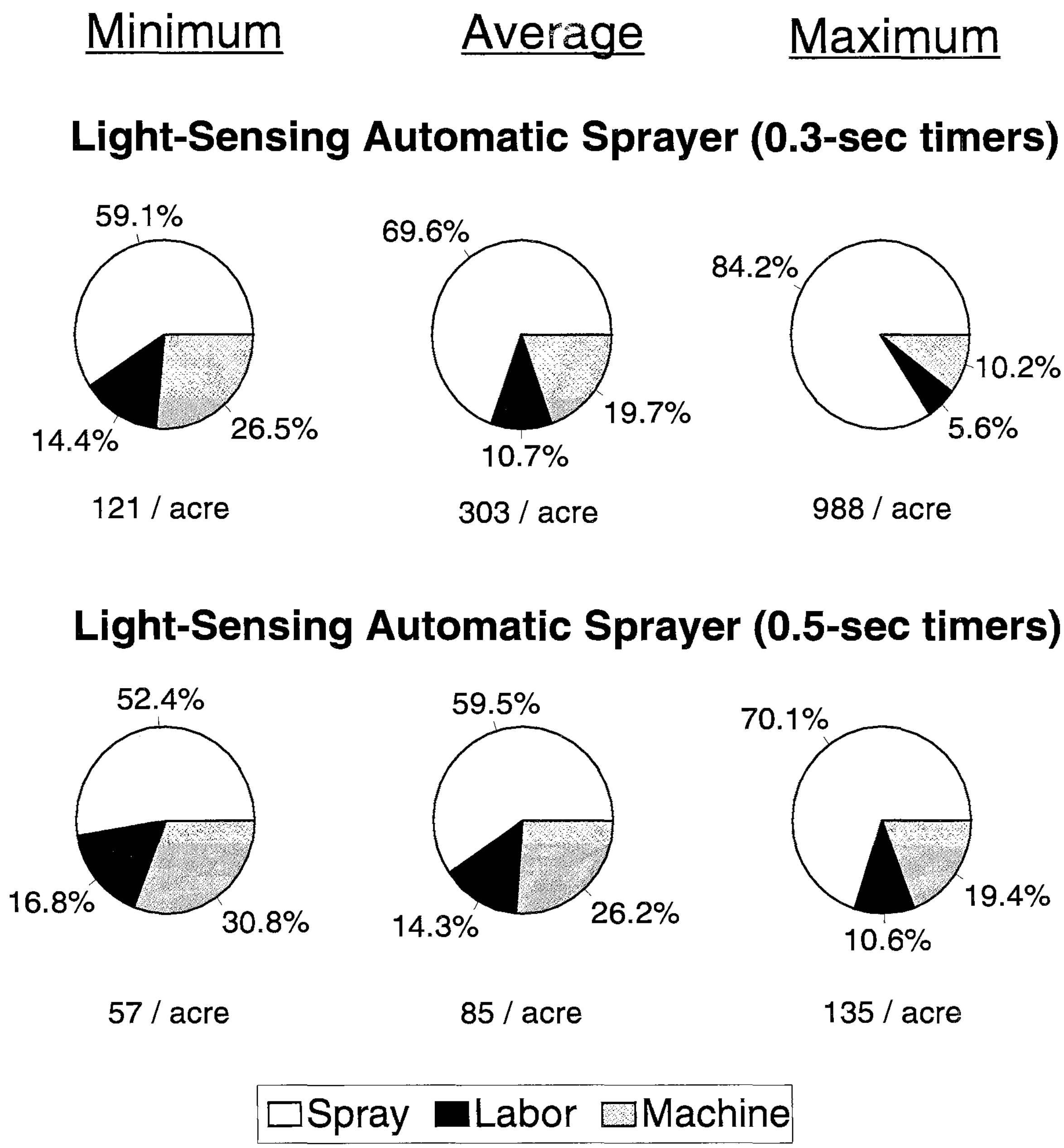
APPENDIX E (continued)

Spray, labor, and machine costs, as a percentage of the total cost, at the minimum, average, and maximum number of mesquite plants sprayed/acre with the mechanical-sensing automatic sprayer at 18 and 30 psi.



APPENDIX E (continued)

Spray, labor, and machine costs, as a percentage of the total cost, at the minimum, average, and maximum number of mesquite plants sprayed/acre with the light-sensing automatic sprayer with 0.3- and 0.5-sec timers.



APPENDIX F

Suggested Additions and Modifications to TxDOT Herbicide Operations Manual

Allan McGinty and Darrell Ueckert

Insert the following new sections (5.4, 5.5, 5.6, 5.7 and 5.8):

5.4 Backpack Sprayers

The backpack sprayer is one of the most versatile pieces of equipment for mesquite control on highway rights-of-way. They can be purchased with either diaphragm or piston pumps. Either type of pump works well for spraying mesquite. One important modification to most backpack sprayers is to add a quality "after market" shoulder harness, which shifts much of the weight from the shoulders to the hips. This increases comfort of use and reduces user fatigue.

Backpack sprayers can be used to apply individual plant leaf sprays or stem sprays by simply selecting the appropriate spray nozzle. An adjustable cone nozzle capable of delivering a coarse spray, such as the **ConeJet®** 5500-PPB-X6 or X8, is recommended for applying leaf sprays. Nozzle selection is extremely critical when using stem sprays to reduce cost of application, obtain acceptable control, and to reduce damage to grasses and wildflowers. For stem sprays, a **ConeJet®** 5500-X1 adjustable cone nozzle is recommended. This nozzle has a very small orifice, which reduces the quantity of spray applied by 80 percent compared to standard backpack sprayer nozzles. A 100-mesh screen with a check valve should be placed behind the nozzle, to reduce dripping and clogging of the nozzle.

5.5 Personnel Carriers

Worker comfort and safety can be increased by using personnel carriers. Personnel carriers eliminate the need for workers to walk, and they place the weight of the spray mix, tank, and pump on the vehicle, rather than the worker, thus greatly reducing personnel fatigue. This equipment can be shop constructed using square tubing. A seat, seatbelt and foot rest are provided for each worker. Shades could also be added to reduce heat stress. The personnel carrier can be attached to the front end loader of a small-to-medium horsepower tractor. The tractor driver adjusts the height of the workers to place them in the best position to spray the mesquite below. Equipping the spraying system with a **Shurflo®** 12-volt pump, rated at 1.4 gallons per minute, provides sufficient pressure and spray volume for three sprayguns. The pump used should be equipped with viton valves and santoprene diaphragms. Sprayguns should be tipped with **ConeJet®** 5500-PPB-X8 adjustable nozzles that deliver a coarse spray.

5.6 All-terrain Vehicles

All-terrain vehicles or similar vehicles equipped with spray systems are ideally suited for selectively applying leaf sprays to mesquite. For under $200, a spray system consisting of a tank, pump and spraygun can be mounted on an all-terrain vehicle or any vehicle equipped with a 12-volt battery and alternator. If using a 4-wheel all-terrain vehicle, tank size should not exceed 25 gallons for safety reasons. When equipped with a **Shurflo®** 12-volt pump, rated at 1.4 gallons per minute, there is sufficient pressure and volume for up to three sprayguns if desired. The pump used should be equipped with viton valves and santoprene diaphragms. For applying leaf sprays, the sprayguns should be tipped with **ConeJet®** 5500-PPB-X6 or X8 adjustable nozzles that deliver a coarse spray. The advantage of using a spray system mounted on an all-terrain vehicle or similar vehicle is that the vehicle supports the weight of the spray mix, tank and pump. User fatigue is greatly reduced compared to backpack sprayers. When rigged with three sprayguns, each spray rig is capable of treating 500 to 700 mesquite per hour. Spraying systems mounted on all-terrain vehicles are not well suited for stem sprays.

Leaf spraying can be automated to reduce labor requirements and costs. The most basic automatic spray system is designed for an all-terrain vehicle. Three flat-fan, 2-gallon-per-minute, spray nozzles are placed 3-feet apart on a frame mounted on the front of the all-terrain vehicle. Each nozzle is controlled by a separate solenoid valve and a push-button switch that is activated by the operator. A 12-volt **Shurflo®** pump rated at 3-gallons per minute is used to pressurize the system. In use, the operator simply drives over or near small mesquite, and activates the appropriate nozzle as the mesquite plant passes underneath. The sprayer frame has bending and retaining bars to hold the mesquite an appropriate distance beneath the nozzles to insure thorough coverage by the spray pattern. This type of system is very effective on low-density mesquite, but as mesquite numbers exceed 200 to 300 plants per acre, it becomes increasingly difficult for the operator to properly activate the nozzles over extended periods of time without excessive fatigue. Significant advantages of this spray system is that application is not affected by the height of grass or weeds, and relatively few mesquite plants are missed. The operators eye is used to sense the mesquite, and the operator selectively activates the appropriate nozzle by pressing an electric switch as the mesquite passes underneath. Although this spray system is not available commercially, it can be easily constructed in a shop from readily available parts and supplies.

5.7 Mechanical-Sensing Sprayer

Automation on a larger scale is exemplified by the mechanical-sensing automatic activated spraying system. The spray boom is mounted in front of a tractor for improved visibility. The height of the spray boom is adjusted up or down with hydraulic cylinders depending upon the height of the mesquite. At 6-inch intervals along the spray boom, "**Handee-Bend®**" valves are mounted and attached to 1-gallon per minute flat-fan nozzles. A rigid sensing arm is attached below each nozzle and valve. Resistance on each sensor arm, as it intercepts mesquite stems, opens the valve, delivering a targeted, concentrated spray, through the nozzle to mesquite passing under the spray boom. These "**Handee-Bend®**" valves are mechanical in operation and are easy and inexpensive to replace if needed. For maximum sensitivity the lower edge of the spray boom should be rotated forward, about 15 degrees, in the direction of travel. Other parts of this spray system include a large-volume poly spray tank and a high-volume PTO pump to pressurize the boom to about 20 psi pressure. A pressure regulator should be used to avoid delivery of a fine mist that might drift with wind off the target area. The spray boom can be built in various widths, although a width of 8-feet, with pivoting 2-foot extensions on each side, is versatile and allows the spray boom to be folded for travel. One, or both, 2-foot extensions can be removed when working in narrow rights-of-way or where the terrain is uneven.

To effectively use this mechanical-sensing sprayer, the operator must adjust the spray boom height so that the foliage fingers at the bottom of the sensing arms intercept mesquite stems but not grass, wildflowers or weeds. An operator can selectively spray mesquite only 6 inches tall in areas where little or no other vegetation is present. This sprayer is not effective, and should not be used, where grass, wildflower or weeds are as tall as the mesquite. A disadvantage of this spraying system is that a substantial proportion (12 to 23%) of the mesquite will be missed, primarily those mesquite shorter than surrounding grass and weeds.

The advantages of the mechanical-sensing sprayer is that it allows one operator to selectively apply leaf sprays to mesquite plants over large acreages in a relatively short period of time. Labor or tractor efficiency are reduced only slightly as mesquite density increases. Also, this equipment is very simple to maintain and repair, and can be constructed in most shops with readily available and inexpensive parts. The carrier for the leaf spray should be water plus 0.5% non-ionic surfactant. Diesel fuel oil should not be added to the spray mixture when using this spraying system because the "**Handee Bend®**" valves are not oil resistant.

5.8 Light-Sensing Automatic Sprayer

A more "high-tech" automated, selective sprayer uses a modulated light beam to sense the mesquite passing under the spray boom. As a mesquite stem, or any other object, breaks the light beam, a solenoid valve automatically opens a 2-gallon per minute nozzle that sprays a 3-feet-wide section under the boom. A relay/timer controls the solenoid, timing the spray release, so that the entire plant is sprayed as it passes underneath. A large-volume poly tank is used for the spray mix and a high-volume PTO pump pressurizes the boom to about 30 psi pressure. Pressure on the boom should be regulated to avoid delivery of a fine mist that might drift with wind off the target area. The operator adjusts the height of the spray boom with hydraulic cylinders so that only the mesquite stems and not grass, wildflowers or weeds, activate the nozzles. Each nozzle can be fitted with an optional "hood" to reduce herbicide drift if needed. The boom is 12-feet-wide, and can be folded to a width of only 7 feet for travel.

This light-sensing automatic sprayer can only be used where the mesquite is taller than other vegetation in the rights-of-way. Disadvantages of the light-sensing sprayer are the high cost of materials and the complexity of the electronics involved. Field maintenance and repair will be more difficult than for the mechanical-sensing sprayer. Also, this sprayer will miss mesquite plants (up to 23% in field trials) not taller than surrounding weeds and grass. The efficiency of the light-sensing sprayer is reduced only slightly as mesquite density increases.

Edit 6.0 heading to read:

6.0 Surfactants and Emulsifiers

Replace section 6.4 with the following text:

6.4 General Characteristics of Emulsifiers

The spray carrier for broadcast oversprays for mesquite control should be a diesel fuel oil:water emulsion. Emulsifiers are necessary to make diesel fuel oil and water mix. To properly mix, first fill the spray tank half full of water. Add the proper amount of **Tansline®** herbicide to the spray tank. Measure the diesel required to make a 1:5 oil:water emulsion, which is simply one part diesel fuel oil to 5 parts water in the spray tank. Add the emulsifier and the required amount of **Garlon 4®** to the diesel. Shake vigorously. Pour the mixture of diesel, **Garlon 4®** and emulsifier into the spray tank, then fill the tank with water under pressure. Agitation is required to insure the spray mixture remains in an emulsion.

Add the following new sections (6.5, 6.6 and 6.7):

6.5 Mixing Rates for Department Stocked Emulsifiers

Suggested mixing rates are 1 to 4 ounces of emulsifier for every gallon of diesel fuel oil used.

6.6 Emulsifiers Approved for Use with Department Approved Herbicides

The following is a list of some of the emulsifiers currently approved for broadcast oversprays of herbicides **Transline®** and **Garlon 4®** to control mesquite.

Products	Manufacturer
Merge®	Shield Enterprises Inc.
Sponto 712T®	Loveland Industries
Triton X-100®	Union Carbide Corporation

6.7 Precautions Using Surfactants and Emulsifiers

1. Always wear goggles and gloves when mixing. Surfactants, emulsifiers, herbicides and their carriers can cause eye or skin irritation.

2. Wash thoroughly after handling.

3. Some surfactants are flammable and may burn with explosive violence. The liquid quickly evaporates and forms a vapor which can catch fire. Keep away from heat, open flames, sparks and hot surfaces. Invisible vapor spreads easily and can be set on fire by such sources as pilot lights, welding equipment, electric motors and switches. The fire and explosive hazard increases as the liquid temperature rises. Use only in well-ventilated areas. Keep surfactant or emulsifier containers closed when not in use. Clean up spills immediately.

4. Do not weld, heat or drill the container. Dispose of empty containers immediately according to label directions.

Modify table in 10.1 to include Garlon 4 *as common trade name of triclopyr.*

Rewrite second paragraph of 13.5 to read as follows and renumber this section as 13.5.1

Mesquite in rights-of-way may be mowed annually during the autumn full-width mowing. Alternatively, where the plants are large enough or mesquite removal is desired, the herbicides **Pathfinder II®** can be applied undiluted, or **Garlon 4®** mixed with diesel fuel oil can be used as low-volume basal bark (stem spray) treatments. Individual plant leaf sprays or broadcast "oversprays" that include a mixture of **Garlon 4®** and **Transline®** can also be used.

Add the following sections (13.5.2 and 13.5.3)

13.5.2 Estimating Mesquite Density on Highway Rights-of-Way

It is important to estimate mesquite density on highway rights-of-way when selecting a suitable treatment method. To accurately estimate mesquite density follow the five simple steps below. Once mesquite density has been determined, the chart in section 13.5.3 can be used to identify those treatment method(s) suitable.

Step 1. To estimate mesquite density on highway rights-of-way, first pick a representative area. From a marked and visible location, walk 363 feet (approximately 121 steps) across the diagonal of the right-of-way.

Step 2. Turn around and slowly return along the same line to the starting point. As you proceed, count every mesquite rooted within 3 feet of your path (about an arm's length on both your right and left sides.

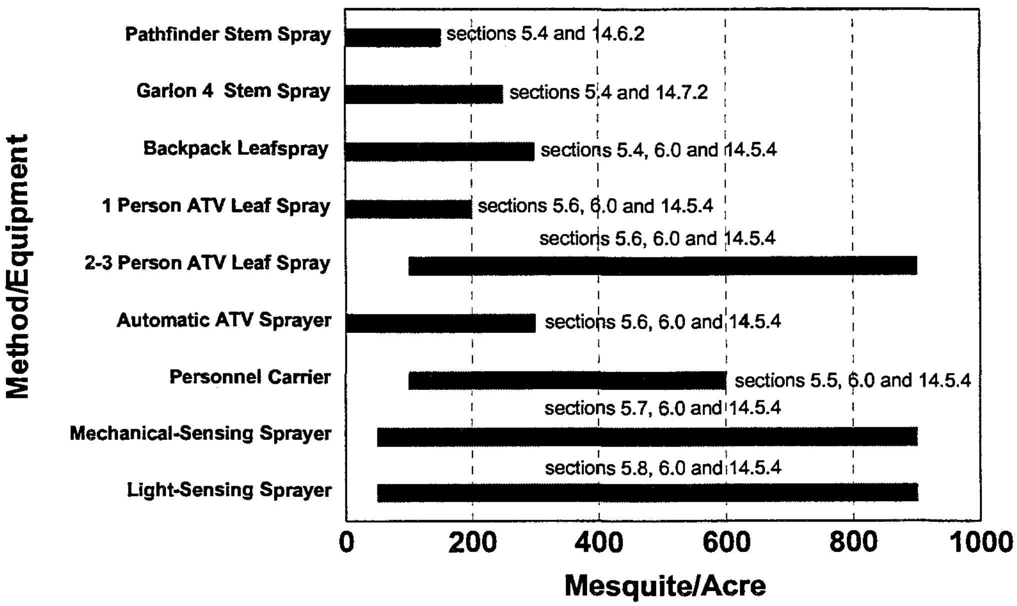
Step 3. To calculate the number of mesquite per acre, multiply the number of mesquite counted along the line by 20. For example, if you counted 25 mesquite, then the density is 500 mesquite per acre (25 x 20 = 500).

Step 4. Repeat this procedure in at least three more representative areas.

Step 5. Total the averages, then divide by the number of samples to calculate an average mesquite density for the right-of-way. For example if you had four estimates of 160, 100, 60 and 80 mesquite per acre, then your average plant density is 100 plants per acre (160+100+60+80=400; 400/4=100).

13.5.3 General Decision Aid for Selection of Treatment Methods Suitable for Control of Different Densities of Mesquite on Highway Rights-of-Way

The following chart, shows those treatment methods and equipment generally suitable for control of different densities of mesquite. To use the chart, locate on the bottom axis, the estimated number of mesquite on the right-of-way. If the shaded bar for a particular method and equipment extends over that number, then that method and equipment is suitable to use.



Note: When individual plant leaf spray volumes approach 33 gallons/acre, a broadcast overspray must be used to prevent exceeding label limits for herbicide applied.

Rewrite 14.5.1 to read:

Transline® is a selective, post-emergence, foliar-applied herbicide that controls certain broadleaf weeds (musk thistle and giant ragweed) and woody plants (mesquite). This herbicide will not harm grasses when used at label-recommended rates. **Transline®** is a low-volatile herbicide, however care must be taken to prevent spray drift and damage to susceptible crops or ornamental plants adjacent to the rights-of-way.

Renumber sections 14.5.4 and 14.5.5 as 14.5.6 and 14.5.7, respectively:

Insert new section 14.5.4 to read:

14.5.4 Mesquite Individual-Plant Leaf Spray Procedures for Transline® (mixed with Garlon 4®)

Mesquite on highway rights-of-way can be controlled by applying a herbicide spray to the foliage of individual plants. This treatment is called a "leaf spray" or "high-volume foliar spray." The most effective leaf spray for mesquite control contains two herbicides, **Garlon 4®** and **Transline®**. The active ingredient in **Transline®** is clopyralid and **Garlon 4®** contains triclopyr ester. Leaf sprays containing 0.5% **Garlon 4®** plus 0.5% **Transline®** are usually highly effective for root-killing mesquite in rights-of way.

Workers should always wear long sleeves, chemical-resistant gloves and eye protection when pouring or mixing these herbicides. When applying the leaf spray to mesquite, wear long sleeves, chemical resistant gloves and long pants over the tops of your boots.

To prepare the spray mix, first fill the spray tank half full of water. Then add **Transline®** and **Garlon 4®** at concentrations of 0.5% each to the spray tank. For each 100 gallons of spray mix this equates to ½ gallon each of **Transline®** and **Garlon 4®**. To ensure a thorough coating of spray on the waxy mesquite leaves, add a surfactant at a concentration of 0.5%. It is also recommended that a dye, such as **Hi-Light®** Spray Marker, be added to the spray to mark plants that have been sprayed. One-third ounce of **Hi-Light®** per gallon of total spray mix is usually sufficient. After all the ingredients are added to the tank, then fill to the desired volume with water under pressure to insure thorough mixing.

The leaf spray can be applied to mesquite using backpack sprayers, sprayers mounted on all-terrain vehicles or other vehicles, or with selective, automated delivery systems. If hand spraying, it is recommended that the sprayer have an adjustable nozzle capable of delivering mostly large spray droplets, such as a **ConeJet®** 5500-PPB-X6 or X8 adjustable cone nozzle.

Leaf spraying of mesquite can begin in the spring after the soil temperature is above 75 degrees at a depth of 1 foot and after the mesquite foliage has changed from a light pea green to a uniform dark green color. Spraying can continue through September. Better control will be achieved as soil temperatures warm and if mesquite that was mowed the previous autumn is allowed to grow through July. Mesquite that has been mowed must be allowed to grow for several months, and preferably for almost two growing seasons to be most susceptible to herbicide leaf sprays. Hot, dry summer weather does not usually reduce the effectiveness of leaf sprays. Mesquite that has been seriously defoliated by insects, disease or hail should not be treated with leaf sprays. Spray the foliage of each mesquite plant until the leaves are wet, almost to the point of dripping. It is important that all leaves on each mesquite plant be sprayed. Discontinue spraying for two to three weeks if significant rainfall is received any time during the summer because the moisture may stimulate new foliage growth at the tips of the mesquite stems. This flush of new growth may seriously reduce downward movement of the herbicides into the root crown and roots.

Garlon 4® is limited on the label to a maximum of 8 quarts per acre when used as either a stem or leaf spray. **Transline®** is limited to 1 and one-third pint per acre. When using individual plant treatments it is possible to exceed these limits when treating dense mesquite. Volumes applied should be monitored to insure label limits are not exceeded.

When using individual plant leaf sprays to control mesquite it is important to keep these points in mind:

- Follow herbicide label directions
- Allow mowed mesquite to grow for several months prior to spraying
- For best results don't spray when:
  - rains have stimulated light-green new growth in tree tops
  - soil temperatures are less than 75 degrees at a depth of 1 foot
  - mesquite leaves are wet
  - mesquite foliage has been significantly damaged by hail, insects or disease
  - you are working immediately upwind of herbicide susceptible trees, shrubs or crops

Insert new section 14.5.5 to read:

14.5.5 Mesquite Broadcast "Overspray" Procedures for Transline® (mixed with Garlon 4®)

When mesquite becomes extremely dense in rights-of-way, it may be necessary to switch from individual plant treatments to a broadcast overspray to avoid violating label limits on herbicide application rates and to maintain cost at an acceptable level. The recommended broadcast rate to control mesquite is ½ pint (1/4 lb. a.e.) of **Garlon 4®** plus 2/3 pint (1/4 lb. a.e.) of **Transline®** per acre. For best results apply these amounts of herbicide in a total spray volume of 20 to 30 gallons per acre, using a 1:5 oil:water emulsion as the carrier.

Always wear eye protection, long sleeves and chemical resistant gloves when pouring and mixing herbicides. To mix the broadcast spray, first fill the spray tank half full of water. Add the desired amount of **Transline®** to the spray tank. Measure the diesel fuel oil required to make a 1:5 oil:water emulsion, which is simply one part diesel fuel oil to 5 parts water in the spray tank. Add an emulsifier such as **Triton X-100®** or **Sponto 712®** and the required amount of **Garlon 4®** to the diesel fuel oil. Shake vigorously, then pour the mixture into the spray tank, and fill the tank with water under pressure. Agitation is required to insure the spray mixture remains in an emulsion.

Broadcast overspraying of mesquite can begin in late spring after soil temperature reaches 75 degrees one foot deep and after the mesquite canopy is a dark green color. Spraying can continue for 45 days thereafter, or until August 1st, whichever is later. This is a much shorter spray season as compared to individual plant leaf sprays. Mesquite should be allowed to grow for at least one full growing season after mowing before applying broadcast oversprays. Each additional growing season for mesquite growth between mowing and treatment will improve control effectiveness. Control using broadcast oversprays will generally be lower than that with individual plant stem or leaf sprays.

When using broadcast "oversprays" to control mesquite it is important to keep these points in mind:

- Follow herbicide label directions
- Allow mowed mesquite to grow for at least 1-2 growing seasons before spraying
- For best results don't spray when:
  - rains have stimulated light-green new growth in mesquite canopies
  - soil temperatures are less than 75 degrees at a depth of 1 foot
  - mesquite leaves are wet
  - mesquite foliage has been significantly damaged by hail, insects or disease
  - you are working upwind of herbicide susceptible trees, shrubs or crops

Rewrite 14.5.7 (old 14.5.5) to read:

14.5.7 Precautions using Transline®

Do not make **Transline®** applications if rainfall is imminent. **Transline®** becomes rainfast in 1 to 2 hours.

Transline® is a low-volatile herbicide (does not readily form a gas), although it can drift and cause damage to adjacent desirable plants. To minimize drift potential, do not spray at high pressures or in windy conditions. Use spray nozzles which produce good coverage with large droplets. A drift control agent such as **Nalcotrol®** or **StaPut®** can be used to reduce herbicide drift (see Section 7). **Transline®** should not be used where it will contaminate irrigation ditches or water used for irrigation or domestic purposes.

<u>*Rewrite 14.6.2 to read:*</u>

14.6.2 Woody Plant Low-Volume Basal Bark (Stem Spray) Application Procedures for Pathfinder II®

Mesquite and many other woody plants can be controlled by the application of the herbicide **Pathfinder II®** to the basal stems. This application technique is commonly called a "stem spray" or "low-volume basal bark application." **Pathfinder II®** is a "ready to use" herbicide, meaning it is applied undiluted to mesquite basal stems. The active ingredient in **Pathfinder II®** is the herbicide triclopyr, which is pre-mixed in a vegetable oil carrier. The triclopyr in **Pathfinder II®** is a low-volatile ester, and can volatilize, damaging sensitive crops and ornamental plants adjacent to highway rights-of-way.

When pouring or applying mesquite stem sprays, personnel must wear chemical-resistant gloves, long sleeves, and long pants over the tops of boots.

Almost any type of pump-up hand sprayer can be used to apply stem sprays to mesquite, but the most efficient way is with a backpack sprayer, or possibly a sprayer mounted on a 4-wheel all-terrain vehicle or similar vehicle. Most importantly, the spray nozzle must have a small orifice that produces a narrow, cone-shaped spray pattern. The nozzle recommended is the **ConeJet®** 5500-X1. This nozzle reduces the quantity of spray applied by 80 percent compared to standard backpack sprayer nozzles. This nozzle reduces damage to grasses and wildflowers and minimizes herbicide deposition in the environment. A 100-mesh screen and check valve should be placed immediately behind the nozzle to prevent dripping and clogging of the nozzle.

Pathfinder II® stem sprays are effective on mesquite throughout the year, but the best time is during the growing season when air temperatures are high. Adjust the **ConeJet®** 5500-X1 nozzle to deliver a narrow, cone-shaped spray pattern. Position the nozzle within an inch or two of the mesquite stem and spray the herbicide mixture lightly but evenly on the plant's stems from ground level to a height of about 12 inches. Apply the mixture to all sides of the stem, but do not spray enough to cause runoff and puddling of the herbicide on the soil surface. Remember, every stem must be treated to kill the entire mesquite plant.

Since the mesquite on highway rights-of-way have been mowed numerous times, they have a very multi-stemmed growth form. Also, tall or dense grass and weeds may be present around mesquite basal stems. These factors restrict the effectiveness of stem sprays and can cause this treatment method to be very slow and labor intensive. Stem sprays are best suited for maintenance control of sparse stands of mesquite in areas with little other plant cover. As density of mesquite increases, herbicide and labor costs for using stem sprays escalate rapidly.

When using **Pathfinder II®** as a stem spray on mesquite, keep these points in mind:

- Follow all directions on the herbicide label
- Do not spray when basal stems are wet
- Dense herbaceous vegetation around basal stems reduces efficiency of this method
- Cost of treatment escalates rapidly as the density of mesquite plants or stems increase
- Do not spray when the wind is blowing toward susceptible crops or ornamental plants near enough to be injured by physical drift of the spray or by volatilization of the herbicide

Add the following sections (14.7, 14.7.1, 14.7.2, 14.7.3 and 14.7.4):

14.7 Garlon 4®

14.7.1 General Characteristics of Garlon 4®

Garlon 4® is a speciality herbicide labeled for control of woody plants and broadleaved weeds on rights-of-way and other non-cropland areas. The active ingredient in **Garlon 4®** is triclopyr ester, which is the also the active ingredient in the ready-to-use (RTU) formulation **Pathfinder II®**. **Garlon 4®** can be mixed with diesel fuel oil and applied as a low-volume basal bark treatment (stem spray). It can also be mixed with the herbicide **Transline®** and a water carrier plus surfactant and applied as an individual plant leaf spray or mixed with **Transline®** and a diesel fuel-water emulsion carrier and be applied as a broadcast overspray to control mesquite.

14.7.2 Woody Plant Low-Volume Basal Bark (Stem Spray) Application Procedures for Garlon 4®

Mesquite and many other woody species can be controlled by the application of **Garlon 4®** mixed with diesel fuel oil to the basal stems. This application technique is commonly called a "stem spray" or "low-volume basal bark application."

Garlon 4® must be mixed with diesel fuel oil before being applied as a stem spray to control mesquite. The diesel fuel oil insures good coverage of the mesquite stems and absorption of the herbicide through the bark. The recommended concentration of **Garlon 4®** to control mesquite on highway rights-of-way is 15% in the diesel fuel oil carrier. This is equivalent to 19 ounces of **Garlon 4®** and 109 ounces of diesel fuel oil to make one gallon of spray mix. An easy way to mix **Garlon 4®** for use as a stem spray is to fill a one-gallon container half full of diesel fuel oil, add 19 ounces of **Garlon 4®** to the container, then fill to volume with diesel fuel oil. The container should then be vigorously agitated before pouring the herbicide:diesel mix into the sprayer.

When pouring, mixing or applying mesquite stem sprays, personnel must wear long sleeves, long pants over the tops of boots and chemical resistant gloves.

Almost any type of pump-up hand sprayer can be used to apply stem sprays to mesquite, but the most efficient way is with a backpack sprayer, or possibly a sprayer mounted on a 4-wheel all-terrain vehicle or similar vehicle. Most importantly, the spray nozzle must have a small orifice that produces a narrow, cone-shaped spray pattern. The recommended nozzle is the **ConeJet®** 5500-X1 adjustable cone nozzle. This nozzle reduces the quantity of spray applied by 80 percent compared to standard nozzles. This nozzle reduces damage to grasses and wildflowers and minimizes herbicide deposition in the environment. A 100-mesh screen and check valve should be placed immediately behind the nozzle to prevent dripping and clogging of the nozzle.

Stem sprays are effective on mesquite throughout the year, but the best time is during the growing season when air temperatures are high. Adjust the 5500-X1 spray nozzle to deliver a narrow, cone-shaped spray pattern. Position the nozzle within an inch or two of the mesquite stem and spray the herbicide mixture lightly but evenly on the plant's stems from ground level to a height of about 12 inches. Apply the mixture to all sides of the stem, but do not spray enough to cause runoff and puddling of the herbicide on the soil surface. Remember, every stem must be treated to kill the entire mesquite plant.

Since the mesquite on highway rights-of-way have been mowed numerous times, they have a very multi-stemmed growth form. Also, tall or dense grass and weeds may be present around mesquite basal stems. These factors restrict the effectiveness of stem sprays and cause this treatment method to be very slow and labor intensive. Stem sprays are best suited for maintenance control of sparse stands of mesquite in areas with little other plant cover. As density of mesquite in the rights-of-way increases, herbicide and labor costs for using stem sprays escalates rapidly.

When using **Garlon 4®** mixed with diesel fuel oil as a stem spray to control mesquite, keep these points in mind:

- Follow all directions on the herbicide label
- Do not spray when basal stems are wet
- Dense herbaceous vegetation around basal stems reduces efficiency of this method
- Cost of treatment escalates rapidly as the density of mesquite plants or stems increase
- Do not spray when the wind is blowing toward susceptible crops or ornamental plants near enough to be injured by physical drift of the spray or by volatilization of the herbicide
- **Garlon 4®** is limited by the label to a maximum of 8 quarts per acre on rights-of-way.

14.7.3 Mesquite Individual Plant Leaf Spray Procedures for Garlon 4® (mixed with Transline®)

See section *"14.5.4 Mesquite Individual Plant Leaf Spray Procedures for* **Transline®** *(mixed with* **Garlon 4®***)*"

14.7.4 Mesquite Broadcast "Overspray" Procedures for Garlon 4® (mixed with Transline®)

See section "*14.5.5 Mesquite Broadcast "Overspray" Procedures for* **Transline®** *(mixed with* **Garlon 4®***)*"