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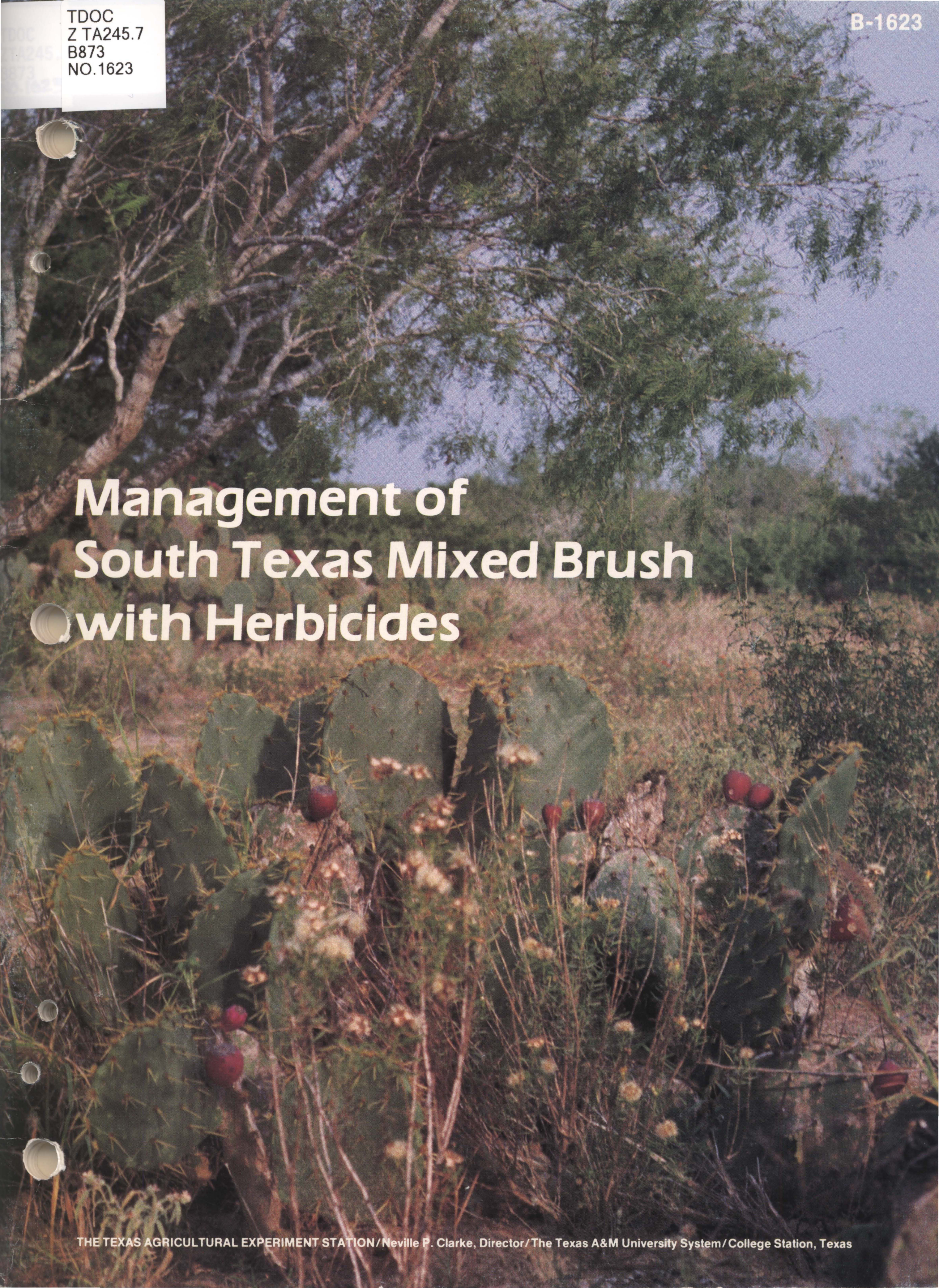

Management of South Texas Mixed Brush with Herbicides

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Management of South Texas Mixed Brush with Herbicides

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I. Background

C. J. Scifres

The Problem

South Texas vegetation is extremely diverse and characterized by assemblages of trees, shrubs, subshrubs, and succulents in varying compositions, which form an almost continuous cover on many sites. Honey mesquite[1], the most cosmopolitan woody species, typifies most brush stands. However, 15 or more species that vary widely in susceptibility to herbicides may be present in any given stand. The specific composition of woody plant stands varies with geographic region, soils, topography, and management history. For example, huisache is more likely to be a component of mixed-brush stands in the eastern half of South Texas than in the west. Twisted acacia, common in the central and western Rio Grande Plains, is less likely to occur in the eastern part. Species commonly associated with honey mesquite throughout the region include spiny hackberry, pricklypear, blackbrush acacia, agarito, tasajillo, lime pricklyash, lotebush, brasil, Texas persimmon, and whitebrush. Whitebrush may develop heavy stands on the more productive soils, especially in more mesic flats and drainages.

The occurrence of other species such as guajillo, Texas colubrina, running mesquite, catclaw acacia, and guayacan is relatively site specific. For example, guajillo generally poses the greatest management problem on shallow ridges, where, in concert with blackbrush acacia and cenizo, it often forms dense, heavy cover.

Because of the typical variation in brush composition associated with sites, not all species occurred in all experiments conducted in this research program. Moreover, the woody plants were rarely distributed evenly throughout a given experiment. Therefore, herbicide responses are reported for selected species, and the species selected for inclusion in this publication vary among the experiments.

Rangeland Herbicides

A great variety of herbicides and formulations have been developed over the last 40 years (Figure 1.1). For many years, 2,4,5-T[2] was the primary herbicide used on rangeland. Broadcast applications of 2,4,5-T controlled honey mesquite but generally did not effectively control most associated species in mixed-brush stands. The introduction of picloram in the early 1960's allowed control, especially with aerial applications, of a broader spectrum of woody plants. After several years of research and development, the 1:1 mixture of 2,4,5-T and picloram applied at 1.1 kilograms/hectare (kg/ha)[3] was merchandised as one of the more effective chemical treatments for mixed-brush control. The herbicide combination, applied in 9.4 liters/hectare (L/ha)[4] of diesel oil and enough water to bring the total carrier solution to 28, 37.4, or 46.8 L/ha, was then routinely used in South Texas for more than 10 years. A 1:1 mixture of dicamba and picloram was found to control brush at levels similar to those of the same rates of the mixture of 2,4,5-T and picloram (Scifres and Hoffman 1972).

The introduction of tebuthiuron improved the potential for control of brush species resistant to other herbicides, especially hard-to-kill species such as whitebrush (Scifres et al. 1979, Scifres et al. 1981). Tebuthiuron pellets, aerially applied at 2.2 kg/ha, effectively controls whitebrush, and prescribed burning at 3- to 5-year intervals thereafter maintains improvement of rangeland previously dominated by whitebrush (Scifres 1987). Because tebuthiuron does not control several major species in mixed-brush stands such as honey mesquite, pricklypear, and lime pricklyash, follow-up measures such as prescribed burning are usually necessary to prevent ultimate domination by these species.

Grid applications of hexazinone pellets were evaluated for mixed-brush control using both ground

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[1]Scientific names of plants and animals are given in Appendix A.
[2]Chemical names of herbicides are given in Appendix B.
[3]In liquid herbicide formulations, herbicide amount refers to acid equivalent; in dry herbicide formulation, herbicide amount refers to active ingredient.
[4]Conversions from metric to English units are given in Appendix C.

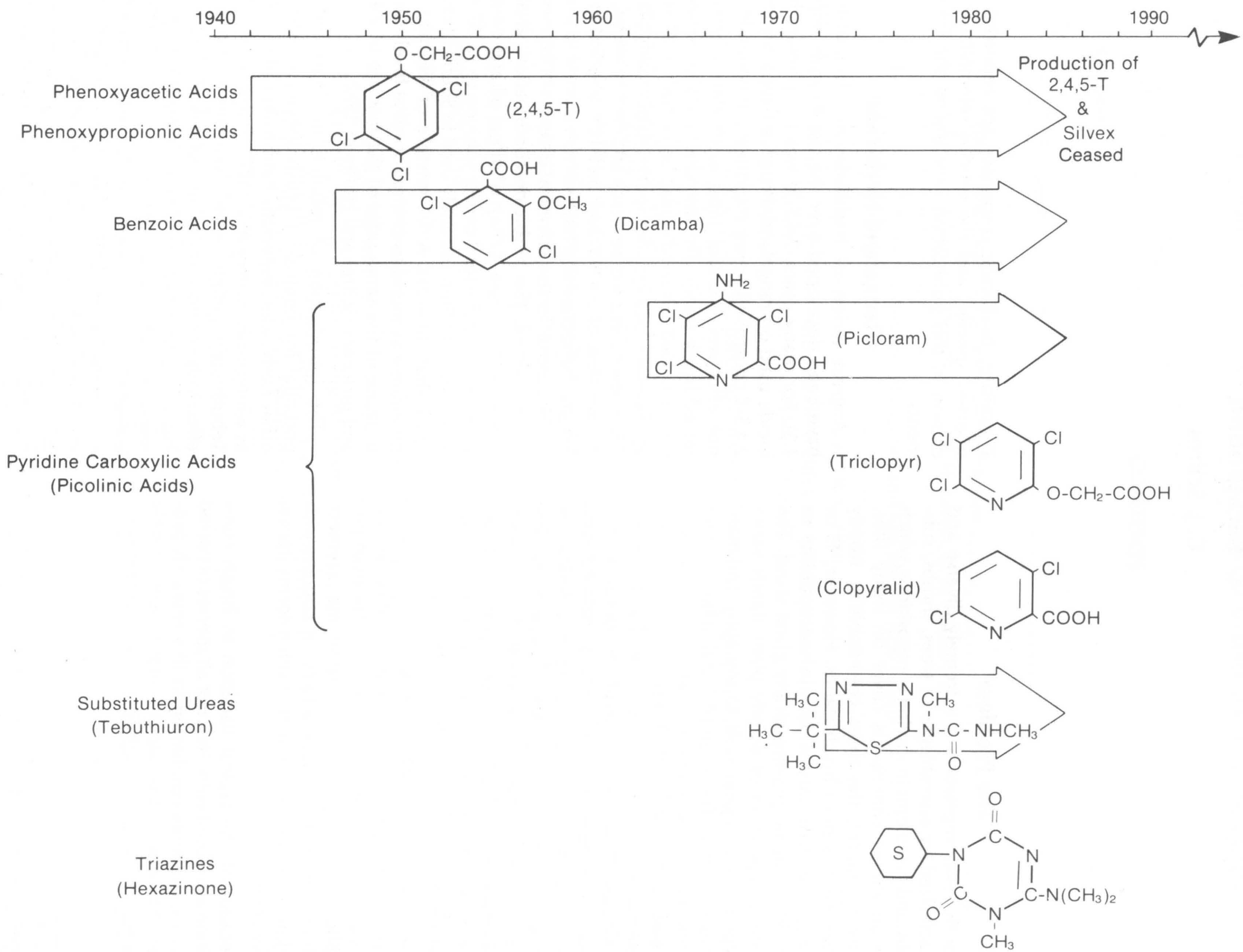

Figure 1.1. A generalized chronology of herbicide availability for brush management.

and aerial applications (Scifres et al. 1984). Grid applications of hexazinone at 2.2 kg/ha or less did not control major mixed-brush species such as honey mesquite, blackbrush acacia, lotebush, spiny hackberry, or twisted acacia on clay or clay loam soils. Apparent mortality of these species was increased, however, when the application rate was increased from 2.2 to 4.5 kg/ha or when 2.2 kg/ha were applied to sandy clay loam. Because hexazinone is not highly effective as a broadcast treatment, it is used primarily for control of individual plants.

Cessation of domestic availability of 2,4,5-T in 1984 provided the impetus for accelerating research on recently developed herbicides for mixed-brush control (Figure 1.1). An array of compounds was evaluated, and subsequently triclopyr was registered in 1985, and clopyralid in 1987. Much of the research reported herein was designed specifically to evaluate triclopyr and clopyralid, each applied alone and in combination with picloram for control of mixed brush (see Figure 1.1 for generalized chronology of the use of herbicides in South Texas).

Research Objectives

Research conducted from 1980 through 1987 in South Texas was organized around several thrusts:

1. With the absence of 2,4,5-T from the marketplace, the commonly used mixture of 2,4,5-T and picloram was lost. Research was designed to evaluate potential alternatives to 2,4,5-T and 2,4,5-T plus picloram over several sites, years, and application methods.
2. Growing interest in herbicides for maintenance control of regrowth brush provided the impetus for evaluating ground-broadcast application of herbicides and their application with the carpeted roller for specific problems such as mesquite and huisache.
3. The availability of herbicides, especially picloram and tebuthiuron in pelleted form, continues to engender questions about their best use. The selection of follow-up treatment to perpetuate effectiveness of herbicide application and the potential influence of disturbance before application of pellets were considered the most important associated research problems.
4. The understanding of the importance of managing brush for game habitat stimulated research on patterned herbicide applications.
5. Recent advances in the ability to evaluate the economic performance of herbicide applications has provided a rational comparative basis for selecting alternative herbicides for range management.

Central to the purpose of this publication is the synthesis of available research information. As a result, both original data and the results of published works are presented.

Research Locations and General Evaluation Procedures

Research was conducted at several sites, on both private and Texas Agricultural Experiment Station properties. Specific locations are given in this text as the various research results are discussed. To facilitate reader orientation and to prevent unnecessary repetition in the remaining text, the various locations are presented on a reference map (Figure 1.2).

The method of evaluating woody plant responses to treatment was common to all experiments. It involved visually categorizing the woody plants into classes according to relative degree of defoliation: 0-25, 26-50, 51-75, 76-90, 91-99, and 100 percent of foliage removed. The workers walked a line down the center of aerially treated plots and recorded the response of woody plants by species within 2 m of the line. The response of all plants was evaluated in the smaller plots treated with ground equipment. A weighted canopy reduction value for each plot was calculated as the sum of the products of the category median value and the number of observations in that category, which was then divided by the total observations. The proportion of plants completely defoliated and without basal regrowth was used as an index of plant kill, especially for evaluations conducted two growing seasons or longer after applications of the herbicides.

Evaluations were normally conducted in late summer or early fall for several years after application. Evaluations at the end of the growing season of application provided an index of the initial impact of treatment. Because such evaluations are usually conducted within 90 to 120 days after spring applications, comparison of average canopy reduction values are most meaningful. For that proportion of plants completely defoliated, apparent mortality rather than "plants killed" is used because basal regrowth may develop in the subsequent growing season. By the third growing season after herbicide application, it becomes progressively difficult to evaluate response of some species. Although honey mesquite wood is highly persistent and dead plants may remain standing for many years, the wood of other species (e.g., huisache) may begin to decompose after the second growing season. The problem of evaluation is compounded and becomes critical on small plots in grazed pastures, which have fewer plants per plot, because livestock may break down and dislodge smaller plants by the end of the second growing season.

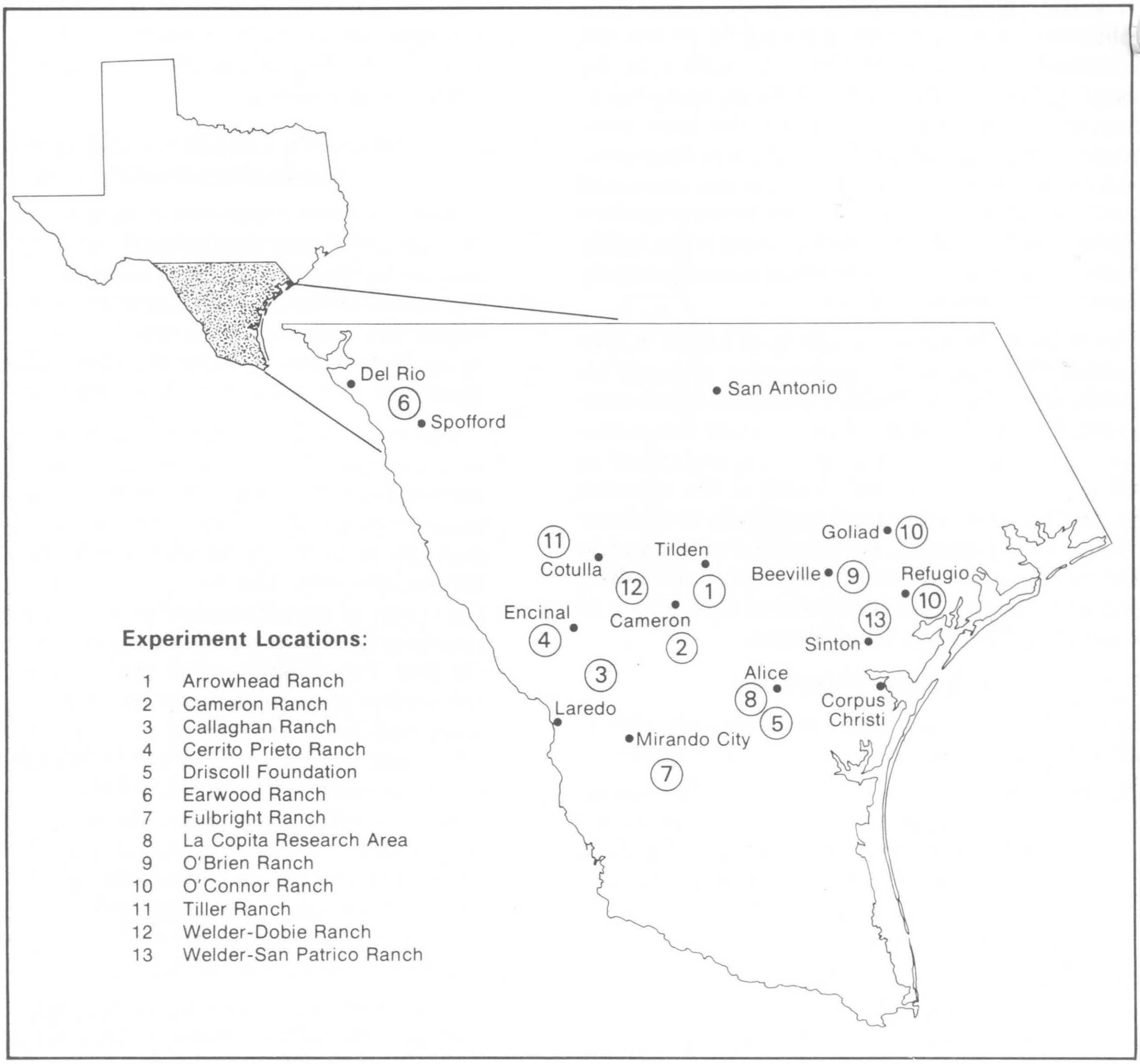

Figure 1.2. Reference map showing research locations in South Texas.

Data Analysis and Interpretation

Data were transformed using the formula $\sqrt{Y + 0.5}$ before being subjected to analysis of variance. Analysis of variance was then conducted on the raw data. In most cases, the transformation made no difference in the conclusions drawn, compared to inferences from analysis of raw data. Therefore, the resulting analyses of raw data are presented. If the treatment mean square was significant ($P \leq 0.05$), a least significant difference (LSD, $P \leq 0.05$) was calculated to allow comparison of treatment means.

Because experimental design varied among studies, they are described for each experiment and location. For the sake of brevity, dates of treatment and evaluation are given in the "Results and Discussion" rather than in the "Materials and Methods" section.

The degree of control deemed "acceptable" varies with objectives for herbicide application and with degree of woody plant problem. However, from consideration of other research and from the perceived general opinion of landowners, we adopted the criteria of canopy reduction of $\geq$80 percent and apparent mortality of $\geq$50 percent at the end of the second growing season to indicate effective control. This standard will be represented throughout the publication when reference is made to acceptable control.

II. Ground Broadcast Application of Herbicides

R. C. Flinn, C. J. Scifres, R. A. Crane, B. H. Koerth,
D. N. Ueckert, and W. T. Hamilton

Introduction

Ground broadcast applications of herbicides are especially amenable to treatment of relatively small areas for control of regrowth and/or invading brush. Some sprayers can be fashioned mostly from materials available on the ranch (Scifres 1980). Although results from ground broadcast applications usually produce results similar to those from aerial applications, a series of experiments were designed specifically to evaluate herbicides for control of brush regrowth and as screening experiments from which promising treatments could be selected for aerial applications.

Materials and Methods

Research was conducted on the Driscoll Foundation near Alice, Texas, and on the Winters Ranch near Brady, Texas (Figure 1.2). Regrowth stands of woody plants to about 1.5 m tall were used in all experiments. Experiments were designed as randomized complete blocks with three or four replications. Herbicides were applied to 18- by 30- or 18-by 60-m plots with rubber-wheeled tractors equipped with a 6.1-m-wide boom. Metsulfuron was applied in 187 to 228 L/ha of water containing 0.5 percent (by volume) of surfactant, depending on experiment and location. Clopyralid, 2,4,5-T, and 1:1 mixtures of dicamba and picloram were applied in 1:3, diesel oil:water emulsions, and 8 ml emulsifier was added for each liter of carrier solution. Application rates of all herbicides except hexazinone varied with the experiment and will be given as results are discussed. Hexazinone pellets (20 percent active ingredient) were applied on 1.8-m centers in a grid pattern to achieve an application rate of 1.1 kg/ha. Because date of application and evaluation varied with experiment and location, that information will be given as results are discussed.

Results and Discussion

Neither 2,4,5-T nor 2,4,5-T plus picloram (1:1) applied at 0.6 kg/ha effectively controlled honey mesquite, huisache, or lime pricklyash after application in June 1981 on the Driscoll Foundation (Table 2.1). Canopy reduction of honey mesquite averaged less than 16 percent at 22 months after application of 2,4,5-T and the combination of 2,4,5-T with picloram. In contrast, canopy reduction exceeded 70 percent and apparent mortality of mesquite averaged 28 percent following application of clopyralid at 0.6 kg/ha. Although canopy reduction differed little following application of clopyralid at 1.1 kg/ha compared with 0.6 kg/ha, mesquite mortality was significantly increased by the higher rate. Moreover, results from application of clopyralid at 1.1 kg/ha essentially met the criteria (see Chapter I) for acceptable honey mesquite control.

Apparent mortality values indicate that metsulfuron at 0.15, 0.3, or 0.6 kg/ha was ineffective for honey mesquite and lime pricklyash control as well as for huisache at 0.3 kg/ha on the Driscoll Foundation (Table 2.1). Huisache mortality, however, averaged 63 percent following application of 0.6 kg/ha of metsulfuron. There was no trend for decreasing huisache canopy with increasing metsulfuron application rate.

As with the experiment established in the spring of 1981, 2,4,5-T at 0.6 kg/ha did not cause significant mortality of honey mesquite, lime pricklyash, or spiny hackberry populations following application in the spring of 1982 on the Driscoll Foundation (Table 2.2). However, 2,4,5-T plus picloram (1:1) at 0.6 kg/ha more effectively controlled honey mesquite than in the previous (1981) experiment and effectively controlled spiny hackberry. As with applications in 1981 (Table 2.1), the most effective treatment for honey mesquite control was clopyralid at 1.1 kg/ha (Table 2.2). Neither rate of clopyralid, however, controlled lime prickly ash or spiny hackberry. Hexazinone at 1.1 kg/ha did not control honey mesquite but effectively controlled spiny hackberry.

Table 2.1. Percentage of canopy reduction (cr) and apparent mortality (am) of honey mesquite, huisache, and lime pricklyash on April 26, 1983, after application of various herbicides on June 24, 1981, on the Driscoll Foundation near Alice, Texas.

Herbicide(s)	Rate (kg/ha)	Species: Honey mesquite		Huisache		Lime pricklyash	
		(cr)	(am)	(cr)	(am)	(cr)	(am)
None	—	4	0	16	13	0	0
2,4,5-T	0.6	12	2	35	0	7	0
2,4,5-T + picloram	0.6	15	9	10	7	47	0
Clopyralid	0.6	73	28	29	0	2	0
Clopyralid	1.1	82	49	61	0	10	0
Metsulfuron	0.15	25	12	95	48	48	0
Metsulfuron	0.3	16	7	67	19	61	0
Metsulfuron	0.6	22	7	58	63	76	6
LSD (0.05)	—	20	11	18	16	7	8

Table 2.2. Percentage of canopy reduction (cr) and apparent mortality (am) of honey mesquite, lime pricklyash, and spiny hackberry on April 27, 1983, after application of several herbicides on April 24, 1982, on the Driscoll Foundation near Alice, Texas.

Herbicide(s)	Rate (kg/ha)	Species: Honey mesquite		Lime pricklyash		Spiny hackberry	
		(cr)	(am)	(cr)	(am)	(cr)	(am)
None	—	0	0	7	0	7	2
2,4,5-T	0.6	27	0	68	0	49	8
2,4,5-T + picloram	0.6	70	29	51	7	85	48
Clopyralid	0.6	70	16	7	0	4	16
Clopyralid	1.1	88	62	39	1	9	0
Hexazinone	1.1	32	27	—	—	93	61
LSD (0.05)	—	19	16	21	9	17	16

Herbicides applied in July 1982 on the Driscoll Foundation did not kill honey mesquite (Table 2.3). In contrast to previous experiments, however, 2,4,5-T plus picloram and clopyralid applied alone at 1.1 kg/ha effectively defoliated lime pricklyash following applications in the summer. Moreover, apparent mortality of lime pricklyash averaged 37 percent where clopyralid had been applied at 1.1 kg/ha. The response of twisted acacia to herbicide application in the summer was similar to that of lime pricklyash. Clopyralid at 0.6 and 1.1 kg/ha and 2,4,5-T plus picloram killed from 10 to 50 percent of the twisted acacia.

Applications of 2,4,5-T in June 1981 at 0.6 kg/ha did not kill honey mesquite on the Winters Ranch near Brady, Texas (Table 2.4). Mixtures (1:1) of 2,4,5-T and picloram and 2,4,5-T with dicamba at 0.6 kg/ha killed only 10 percent of the mesquite population. In contrast, clopyralid at 0.6 kg/ha killed 58 percent of the population, and canopy reduction of mesquite averaged 79 percent at the end of the fourth growing season following application, essentially meeting the criteria for acceptable control. Metsulfuron at 0.07, 0.15, and 0.6 kg/ha and hexazinone at 1.1 kg/ha were ineffective against honey mesquite. Applications of metsulfuron and hexazinone pellets were also ineffective for honey mesquite control after application in October 1981 near Brady (Table 2.5).

Results following herbicide application in June 1982 at Brady were similar to those from experiments in other years at Brady and the Driscoll Foundation.

Table 2.3. Percentage of canopy reduction and apparent mortality of four woody species on April 27, 1983, after application of several herbicides on July 8, 1982, on the Driscoll Foundation near Alice, Texas.

Herbicide(s)	Rate (kg/ha)	Species: Honey mesquite		Lime pricklyash		Spiny hackberry		Twisted acacia	
		(cr)	(am)	(cr)	(am)	(cr)	(am)	(cr)	(am)
None	—	0	0	4	0	2	0	0	0
2,4,5-T	0.6	2	0	37	0	8	0	37	0
2,4,5-T + picloram	0.6	20	0	76	8	13	0	42	10
Clopyralid	0.6	11	0	68	11	13	0	47	25
Clopyralid	1.1	18	2	87	37	27	2	100	50
Hexazinone	1.1	8	0	6	0	58	0	0	0
LSD (0.05)	—	21	NS*	25	17	19	NS	27	26

*NS = Treatment mean square not significant, $P \leq 0.05$.

Table 2.4. Percentage of canopy reduction and apparent mortality of honey mesquite on September 13, 1984, after application of several herbicides on June 10, 1981, on the Winters Ranch near Brady, Texas.

Herbicide(s)	Rate (kg/ha)	Canopy reduction	Apparent mortality
None	—	31	0
2,4,5-T	0.6	30	1
2,4,5-T + picloram (1:1)	0.6	36	10
Clopyralid	0.6	79	58
2,4,5-T + dicamba (1:1)	0.6	43	10
Metsulfuron	0.07	17	0
Metsulfuron	0.15	10	0
Metsulfuron	0.6	18	1
Hexazinone	1.1	23	1
LSD (0.05)	—	10	5

Clopyralid at 0.6 kg/ha killed 28 percent of the mesquite population, whereas 0.15, 0.3, and 0.6 kg/ha of metsulfuron, 0.6 kg/ha of 2,4,5-T, and 1.1 kg/ha of hexazinone were ineffective (Table 2.6).

These experiments indicate that broadcast applications of metsulfuron and hexazinone offer little promise for control of honey mesquite and the associated species lime pricklyash, twisted acacia, and huisache. However, control with clopyralid appears to warrant further research, especially for honey mesquite. Picloram applied in combination with 2,4,5-T effectively controlled spiny hackberry after application in April 1982; however, application in July 1982 did not effectively control this species.

Table 2.5. Percentage of canopy reduction and apparent mortality of honey mesquite on September 13, 1984, after application of hexazinone and metsulfuron on October 1, 1981, on the Winters Ranch near Brady, Texas.

Herbicide	Rate (kg/ha)	Canopy reduction	Apparent mortality
None	—	16	0
Metsulfuron	0.15	21	0
Metsulfuron	0.3	20	0
Metsulfuron	0.6	18	0
Hexazinone	1.1	45	7
LSD (0.05)	—	7	2

Table 2.6. Percentage of canopy reduction and apparent mortality of honey mesquite on September 13, 1984, after application of several herbicides on June 9, 1982, on the Winters Ranch near Brady, Texas.

Herbicide	Rate (kg/ha)	Canopy reduction	Apparent mortality
None	—	8	0
2,4,5-T	0.6	46	1
Clopyralid	0.6	66	28
Metsulfuron	0.15	10	0
Metsulfuron	0.3	25	0
Metsulfuron	0.6	20	2
Metsulfuron	1.1	9	0
Hexazinone	1.1	60	8
LSD (0.05)	—	10	12

III. Control of Honey Mesquite, Huisache, and Blackbrush Acacia with Herbicides Applied by Carpeted Roller

R. A. Crane, C. J. Scifres, B. H. Koerth, and R. C. Flinn

Introduction

For applying herbicide to weeds and brush on rangeland, Mayeux and Crane (1983) described a carpeted roller, a device that is especially useful where plants are 0.25 to 2 m tall and widely spaced. The roller mounts on the front (Mayeux and Crane 1983) or rear (Messersmith and Lym 1985) of a farm tractor and applies herbicide directly onto the foliage and branches of woody plants, an application method that reduces the risk of herbicide drift compared with broadcast sprays. Research with the carpeted roller has emphasized honey mesquite control (Mayeux and Crane 1985) although the technique has also been evaluated for controlling perennial weeds (Mayeux and Crane 1984, Messersmith and Lym 1985).

The carpeted roller used in this research was constructed according to specifications of Mayeux and Crane (1983) and mounted on the front of a 32-kilowatt (kW) farm tractor. Household carpet was attached with metal clamps to a polyvinyl chloride cylinder (2 m long and 25 cm in diameter). The cylinder was rotated continuously by a hydraulic motor at approximately 40 revolutions per minute (rpm) and counterclockwise (opposite to the direction of tractor travel). Roller height could be hydraulically adjusted during travel, allowing treatment of plants 0.25 to 2 m tall. A spray system, mounted 5 cm above the carpeted cylinder, consisted of five nozzles with double-outlet flat spray tips (150° spray angle). Uniform spray solution coverage across the carpet was maintained by wetting as needed with solution under pressure (69 to 104 kiloPascals [kPa]).

Our objectives were to compare clopyralid, a 1:1 mixture of clopyralid plus picloram, picloram, triclopyr, and a 1:1 mixture of triclopyr plus picloram applied in late spring and autumn with the carpeted roller or as broadcast sprays for control of honey mesquite, huisache, and blackbrush acacia.

Materials and Methods

Study Site Descriptions

A series of experiments were conducted on the O'Connor Ranches near Goliad and Refugio, the San Patricio Ranch near Sinton, and La Copita Research Area near Alice (Figure 1.2). The Goliad site was approximately 9.3 km east and 9 km south of Goliad on fine sandy loam of the Papalote series (Aquic Paleustalfs). The Refugio site was approximately 6.9 km east and 4.6 km south of Refugio on a clay of the Victoria series (Udic Pellusterts). Both the Goliad and Refugio study sites were characterized by moderate to dense stands of mesquite with a few scattered huisache plants. Mesquite on the Goliad study site averaged 1.4 m tall at densities of 200 plants/ha. Woody plants on the Refugio site averaged 1.3 m tall at densities of 270 to 600/ha. Interspaces between plants were heavily covered with native herbaceous vegetation. The original brush stands at the two sites had been mechanically removed 15 to 20 years before the study, and the larger plants were multi-stemmed regrowth resulting from shredding several years before the treatments. The smaller mesquite plants, however, were single stemmed.

Research sites on the San Patricio Ranch, 5 km north of Sinton, were on rangeland that had been shredded 4 years previously. Soil is sandy clay loam of the Orelia series (Cumulic Haplustolls). Interspaces between woody plants were heavily covered with native mid- and short grasses. Average plant heights at the San Patricio Ranch at the time of herbicide application were huisache, 0.7 m (range 0.2 to 1.5 m), honey mesquite, 0.5 m (range 0.2 to 0.9 m), and blackbrush acacia, 0.5 m (range 0.2 to 1 m). Average densities ranged from 250 plants/ha for huisache to approximately 300 plants/ha for mesquite and 350 plants/ha for blackbrush acacia.

Study sites on La Copita Research Area, about 18 km southwest of Alice (Figure 1.2), were on a Kleberg bluestem meadow in which the honey mesquite had been shredded several years before application of the treatments. The soil is a fine sandy loam of the Runge series (Typic Argiustolls). Mesquite plants were approximately 0.75 to 1.5 m tall, and the average density was 217 plants/ha.

Treatments and Experimental Design

Broadcast sprays for mesquite control included the potassium salt of picloram at 0.6 and 1.1 kg/ha, monomethylamine salt of clopyralid, clopyralid plus picloram (1:1), butoxyethylester of triclopyr, triclopyr plus picloram (1:1), and 2,4,5-T plus picloram (1:1) at 1.1 kg/ha. Sprays were applied in 187 L/ha of water containing 0.5 percent (by volume) surfactant in three or four 6.2-m-wide swaths. The same herbicides were applied alone and in 1:1 mixtures with the carpeted roller in water containing 0.5 percent surfactant at 12, 24, 48, 60, and 120 grams/L (g/L), depending on experiment and woody species.

Herbicides were applied at the Goliad site on May 29 and 30, 1984, to 23- by 46-m plots, each treatment being replicated twice in a randomized complete block design. Plots were separated by 4.6-m-wide untreated buffer areas.

An experiment was established on the Refugio site on May 29 and 30 and June 13, 1985. Herbicides were also applied on this site on September 18 and 19, 1985. Plots were 23 by 46 m, and each treatment was replicated three times in a randomized complete block design.

Dates of herbicide application on the San Patricio Ranch were October 5, 1983; June 13 and 14, 1984; September 17 and 18, 1984; June 3 and 4 and June 13, 1985; and September 10 and 11 and October 7 and 8, 1985. Experimental design was randomized complete blocks with two or three replications. Plot size was 29 by 29 m, 23 by 46 m, or 46 by 61 m. Where broadcast sprays were directly compared with roller application of herbicides in 1983, plots were split and half were randomly selected to be sprayed or treated with the carpeted roller. In other years, sprays and application with the carpeted roller were randomly allocated to plots within blocks.

Herbicides were applied as broadcast sprays and with the carpeted roller to a pure stand of regrowth mesquite on La Copita Research Area on May 25, 1984. The experiment was designed as a randomized complete block with two replications. Plot size was 31 by 46 m, and treatment procedures were as described previously except that herbicides were broadcast sprayed at 1.1 kg/ha only and carpeted-roller applications were made with herbicide concentrations of 120 g/L.

Results and Discussion

Control of Honey Mesquite

All treatments significantly reduced honey mesquite canopies within 4 months after installation of the experiment in the spring of 1984 near Goliad. Canopy reduction in most treatments exceeded 85 percent (Table 3.1). However, the honey mesquite canopies were progressively replaced through time following application of some treatments, triclopyr being the notable example. Clopyralid and clopyralid plus picloram (1:1) sprays at either rate and the higher dosage applied with the roller applicator provided acceptable levels of control, the selection criterion being 80 percent canopy reduction after 2 years. The higher rates of picloram as broadcast sprays (1.1 kg/ha) or applied with the carpeted roller (60 g/L) also reduced the honey mesquite canopies by at least 80 percent after 27 months. Although canopy reduction 27 months after application of triclopyr plus picloram at 1.1 kg/ha approached 80 percent, no other treatment containing triclopyr resulted in acceptable control.

Fisher et al. (1972) reported an average mortality of honey mesquite populations of 57 percent following aerial application of 2,4,5-T plus picloram (1:1) at 1.1 kg/ha. All spray treatments containing clopyralid effectively controlled honey mesquite, apparent mortality of 50 percent after 2 years being the criterion for acceptable control (Table 3.2). In addition, picloram broadcast sprays applied at 1.1 kg/ha had killed an estimated 50 percent of the honey mesquite after 27 months, and triclopyr plus picloram sprays at either rate killed nearly 50 percent of the honey mesquite population.

Mortality of honey mesquite was not significant after 27 months where triclopyr was applied, regardless of method or rate of application (Table 3.2). Moreover, the lower rates of picloram, whether applied with the roller applicator or as broadcast sprays, clopyralid at 12 g/L with the roller applicator, and triclopyr plus picloram at 12 and 60 g/L did not provide acceptable control of honey mesquite 27 months after application near Goliad.

In general, the relative performance of herbicides applied in September 1985 was the same as that in May 1984 (Table 3.3). Absolute control values, however, were considerably less for autumn than for spring applications. Significant, but unacceptable, levels of apparent mortality at 22 months after autumn applications (July 1987, Table 3.3) occurred only where clopyralid, picloram, or clopyralid plus picloram (1:1) were applied at 60 g/L with the carpeted roller.

Table 3.1. Percentage of honey mesquite canopy reduction at various times after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on May 30, 1984, on the O'Connor Ranch near Goliad, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Months after treatment 4	13	27
None	—	—	—	23	1	10
Clopyralid	Spray	0.6		94	78	82
		1.1		96	83	89
	Roller		12	87	74	64
			60	89	85	93
Picloram	Spray	0.6		83	68	43
		1.1		91	79	88
	Roller		12	79	65	48
			60	98	96	83
Clopyralid + picloram	Spray	0.6		95	88	85
		1.1		98	92	82
	Roller		12	98	90	70
			60	96	95	86
Triclopyr	Spray	0.6		83	61	33
		1.1		92	73	50
	Roller		12	88	60	50
			60	97	75	39
Triclopyr + picloram	Spray	0.6		90	75	69
		1.1		94	86	79
	Roller		12	76	70	54
			60	86	75	57
LSD (0.05)	—	—	—	11	25	26

Table 3.2. Percentage of apparent honey mesquite mortality at various times after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on May 30, 1984, on the O'Connor Ranch near Goliad, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Months after treatment 4	13	27
None	—	—	—	0	0	0
Clopyralid	Spray	0.6		61	53	51
		1.1		81	67	79
	Roller		12	54	46	32
			60	73	66	73
Picloram	Spray	0.6		46	32	17
		1.1		67	52	50
	Roller		12	37	30	17
			60	86	78	35
Clopyralid + picloram	Spray	0.6		71	63	57
		1.1		87	77	67
	Roller		12	83	79	74
			60	91	89	62
Triclopyr	Spray	0.6		32	23	4
		1.1		67	37	18
	Roller		12	48	15	15
			60	87	50	24
Triclopyr + picloram	Spray	0.6		56	46	46
		1.1		78	49	45
	Roller		12	46	43	31
			60	56	40	30
LSD (0.05)	—	—	—	29	33	31

Table 3.3. Percentage of canopy reduction (cr) and apparent mortality (am) of honey mesquite on August 19, 1986, and July 15, 1987, after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on September 19, 1985, on the O'Connor Ranch near Refugio, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	August 1986 (cr)	August 1986 (am)	July 1987 (cr)	July 1987 (am)
None	—	—	—	7	0	2	0
Clopyralid	Spray	1.1		57	2	25	7
	Roller		12	64	3	25	1
			60	84	43	87	36
Picloram	Spray	1.1		47	6	16	1
	Roller		60	91	33	83	32
Clopyralid + picloram	Spray	1.1		55	3	38	0
	Roller		60	95	58	85	47
Triclopyr	Spray	1.1		17	1	5	0
	Roller		60	49	1	13	0
Triclopyr + picloram	Spray	1.1		45	0	16	0
	Roller		60	74	9	38	0
LSD (0.05)	—	—	—	19	21	21	21

With few exceptions, canopy reduction of honey mesquite averaged 90 percent or greater 4 and 13 months following broadcast spray application of herbicides at 0.6- and 1.1-kg/ha rates in the spring 1985 near Refugio (Table 3.4). Canopy reduction after 27 months exceeded 85 percent where sprays of clopyralid, picloram, or clopyralid plus picloram were applied at the same two rates. Canopy reduction exceeded 90 percent where clopyralid, picloram, or clopyralid plus picloram were applied at the 60-g/L rate with the carpeted roller. Individual herbicides or mixtures gave less control at the 12-g/L rate, averaging from a low of 19 percent (triclopyr) to a high of 73 percent (clopyralid plus picloram) after 27 months. Canopy reduction was less than 80 percent 27 months after triclopyr was applied, except where it was applied in combination with picloram as broadcast sprays at 1.1 kg/ha.

Apparent mortality exceeded 50 percent 27 months following application of clopyralid in the spring of 1985 near Refugio except with the lower rate applied with the carpeted roller (Table 3.5). Picloram applied alone or in combination with triclopyr or clopyralid killed more than half of the mesquite population after 27 months only when applied as a broadcast spray at 1.1 kg/ha. Triclopyr alone did not kill a significant proportion of the mesquite population regardless of application method or rate.

Canopy reduction of honey mesquite was less than 80 percent 13 months after application of the various herbicides in June 1984 on the San Patricio Ranch except where clopyralid broadcast sprays were applied at 1.1 kg/ha (Table 3.6). According to evaluations after 13 months, broadcast application of the higher rate of clopyralid was also the most effective treatment relative to percentage of mortality (Table 3.6). However, broadcast applications of clopyralid plus picloram (1:1) at 1.1 kg/ha and application of picloram at 60 g/L killed 51 and 52 percent, respectively, of the mesquite population.

No herbicide treatment effectively controlled honey mesquite after application in October 1983 on the San Patricio Ranch (Table 3.7 and Table 3.8). Likewise, results were variable and control was generally low the year after application of the herbicides in September 1984 (Table 3.9) or in the autumn of 1985 (Table 3.10) near Sinton.

Control of honey mesquite the growing season after application of herbicides in June 1985 on the San Patricio Ranch followed trends similar to other experiments (Table 3.11). In contrast to fall applications, canopy reduction and apparent mortality exceeded 80 percent and 50 percent, respectively, for treatments with clopyralid at the higher rates as a broadcast spray or with the carpeted roller and with clopyralid plus picloram sprays. Triclopyr, and in this test triclopyr and picloram, did not effectively control mesquite.

Broadcast sprays at 1.1 kg/ha of picloram in combination with triclopyr or 2,4,5-T resulted in excellent levels of control and in no difference from that following application of clopyralid plus picloram in the experiment on La Copita Research Area (Table 3.12). Applications of the herbicide mixtures at 120 g/L with the carpeted roller killed 89 percent or more of the mesquite.

A summary analysis was conducted by calculating descriptive statistics for honey mesquite responses to

Table 3.4. Percentage of honey mesquite canopy reduction at various times after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on May 29 and 30 and June 13, 1985, on the O'Connor Ranch near Refugio, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Months after treatment 4	13	27
None	—	—	—	2	6	3
Clopyralid	Spray	0.6		97	98	94
		1.1		99	99	99
	Roller		12	70	71	65
			60	96	95	97
Picloram	Spray	0.6		98	87	86
		1.1		99	97	96
	Roller		12	91	82	56
			60	99	94	91
Clopyralid + picloram	Spray	0.6		95	96	94
		1.1		98	98	99
	Roller		12	91	85	73
			60	99	93	96
Triclopyr	Spray	0.6		87	74	51
		1.1		94	85	68
	Roller		12	68	48	19
			60	92	75	55
Triclopyr + picloram	Spray	0.6		92	89	78
		1.1		99	96	90
	Roller		12	93	72	39
			60	93	85	77
LSD (0.05)	—	—	—	20	10	25

selected treatments at 1.1 kg/ha 1 year after application in the spring (Table 3.13). According to these averages across years, locations, and experiments within locations, neither triclopyr nor picloram at 1.1 kg/ha satisfied the criteria described for effective control (see Chapter I). Both treatments were also associated with variable levels of control. Little difference occurred in the percentage of canopy reduction following application of clopyralid, clopyralid plus picloram, or triclopyr plus picloram, and mean values exceeded 90 percent with relatively small standard deviations. However, average apparent mortality following application of triclopyr plus picloram was much lower than that following application of clopyralid or clopyralid plus picloram and was more variable on a relative basis.

Control of Huisache

Huisache is an aggressive, difficult-to-control woody legume that establishes on native rangelands and tame pastures in South Texas and central Mexico. It occurs as a component of mixed-brush (*Prosopis-Acacia)* stands (Scifres 1980), forms dense, monospecific stands following mixed-brush control on many sites (Mutz et al. 1978), and invades tame pastures, especially coastal bermudagrass. Because of its exceptionally rapid growth rate (i.e., as much as 1 m/yr [Rasmussen et al. 1983]), huisache may limit grazing use and greatly reduce hay quality.

Experiments were conducted in South Texas from 1983 to 1987 to evaluate clopyralid applied by a carpeted roller (Scifres et al. 1988a) for huisache control. Huisache control with clopyralid applied as broadcast sprays or with a carpeted roller was generally equivalent to that of the same rates of picloram or mixtures of clopyralid plus picloram (1:1). Applications of herbicides in the fall generally were more effective than applications in the spring for huisache control, regardless of application method (Bovey et al. 1972). In most cases, application of the herbicides at 48 to 60 g/L with a carpeted roller in the fall killed 90 percent or more of the huisache. No loss of efficacy occurred when huisache plants were cut to within 5 cm of ground line within a week after roller application of clopyralid plus picloram (1:1) at 60 g/L compared with treated plants that were not cut. The treat-and-cut sequence should expedite the improvement and utilization of huisache-infested bermudagrass pastures.

According to results of six experiments conducted on the San Patricio Ranch, triclopyr was ineffective

Table 3.5. Percentage of apparent honey mesquite mortality at various times after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on May 29 and 30 and June 13, 1985, on the O'Connor Ranch near Refugio, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Months after treatment 4	13	27
None	—	—	—	0	0	0
Clopyralid	Spray	0.6		69	74	67
		1.1		90	87	70
	Roller		12	34	23	21
			60	59	67	56
Picloram	Spray	0.6		66	26	24
		1.1		74	58	55
	Roller		12	28	17	9
			60	66	41	38
Clopyralid + picloram	Spray	0.6		77	55	35
		1.1		91	77	79
	Roller		12	47	17	12
			60	76	56	39
Triclopyr	Spray	0.6		34	0	1
		1.1		50	5	0
	Roller		12	12	0	0
			60	44	3	2
Triclopyr + picloram	Spray	0.6		46	26	14
		1.1		49	65	53
	Roller		12	40	11	3
			60	52	19	20
LSD (0.05)	—	—	—	36	21	24

Table 3.6. Percentage of canopy reduction and apparent mortality of honey mesquite at various times after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on June 13, 1984, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Canopy reduction 4	Canopy reduction 13	Apparent mortality 4	Apparent mortality 13
None	—	—	—	13	0	0	0
Clopyralid	Spray	0.6		83	27	73	22
		1.1		97	80	89	80
	Roller		12	64	15	29	12
			60	80	49	64	43
Picloram	Roller		12	77	23	44	17
			60	87	60	68	52
Clopyralid + picloram	Spray	0.6		83	15	75	3
		1.1		100	58	97	51
	Roller		12	61	42	40	25
			60	83	33	69	27
Triclopyr	Roller		12	71	10	39	0
			60	90	28	67	12
Triclopyr + picloram	Roller		12	80	27	60	8
			60	95	39	86	23
LSD (0.05)	—	—	—	19	41	19	42

Table 3.7. Percentage of canopy reduction of honey mesquite at various times after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on October 5, 1983, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Months after treatment 8	12	21
None	—	—	—	1	20	2
Clopyralid	Spray	1.1		6	30	14
	Roller		48	17	34	30
Picloram	Spray	0.6		2	28	3
		1.1		2	16	21
	Roller		24	12	28	4
			48	5	21	13
Clopyralid +	Spray	1.1		5	30	11
picloram	Roller		48	8	49	14
2,4,5-T +	Spray	1.1		4	25	3
picloram	Roller		48	9	27	7
LSD (0.05)	—	—	—	10	25	23

Table 3.8. Percentage of apparent honey mesquite mortality at various times after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on October 5, 1983, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Months after treatment 8	12	21
None	—	—	—	0	0	0
Clopyralid	Spray	1.1		1	0	6
	Roller		48	7	8	19
Picloram	Spray	0.6		1	2	0
		1.1		0	0	0
	Roller		24	1	4	0
			48	0	2	0
Clopyralid +	Spray	1.1		0	4	1
picloram	Roller		48	1	23	2
2,4,5-T +	Spray	1.1		2	0	1
picloram	Roller		48	1	2	5
LSD (0.05)	—	—	—	2	22	19

Table 3.9. Percentage of canopy reduction and apparent mortality of honey mesquite at 10 months after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on September 17 and 18, 1984, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate		Canopy reduction	Apparent mortality
		(kg/ha)	(g/L)		
None	—	—	—	1	0
Clopyralid	Spray	0.6		38	26
		1.1		33	14
	Roller		12	5	2
			60	47	35
Picloram	Spray	0.6		2	0
		1.1		5	0
	Roller		12	11	6
			60	38	32
Clopyralid + picloram	Spray	0.6		20	18
		1.1		19	8
	Roller		12	25	4
			60	37	26
Triclopyr	Spray	0.6		5	0
		1.1		9	3
	Roller		12	5	0
			60	14	3
Triclopyr + picloram	Spray	0.6		3	2
		1.1		12	4
	Roller		12	12	3
			60	29	21
LSD (0.05)	—	—	—	22	27

Table 3.10. Percentage of canopy reduction and apparent mortality of honey mesquite at 12 months after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller from September 10 to October 8, 1985, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate		Canopy reduction	Apparent mortality
		(kg/ha)	(g/L)		
None	—	—	—	10	0
Clopyralid	Spray	0.6		12	0
		1.1		26	1
	Roller		12	34	3
			60	28	5
Picloram	Spray	0.6		9	1
		1.1		31	3
	Roller		12	12	0
			60	45	11
Clopyralid + picloram	Spray	0.6		18	3
		1.1		25	3
	Roller		12	36	5
			60	68	35
Triclopyr	Spray	0.6		13	0
		1.1		14	0
	Roller		12	26	1
			60	38	0
Triclopyr + picloram	Spray	0.6		21	0
		1.1		10	0
	Roller		12	30	1
			60	77	33
LSD (0.05)	—	—	—	26	16

Table 3.11. Percentage of canopy reduction and apparent mortality of honey mesquite at 14 months after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on June 3, 1985, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Canopy reduction	Apparent mortality
None	—	—	—	0	0
Clopyralid	Spray	0.6		77	43
		1.1		92	96
	Roller		12	29	0
			60	81	60
Picloram	Spray	0.6		48	8
		1.1		32	18
	Roller		12	37	6
			60	35	14
Clopyralid + picloram	Spray	0.6		85	61
		1.1		97	72
	Roller		12	61	4
			60	36	14
Triclopyr	Spray	0.6		46	0
		1.1		15	2
	Roller		12	12	0
			60	31	2
Triclopyr + picloram	Spray	0.6		21	6
		1.1		87	21
	Roller		12	46	0
			60	33	17
LSD (0.05)	—	—	—	33	29

for control of huisache (data not shown). However, triclopyr plus picloram (1:1) applied at 1.1 kg/ha as broadcast sprays or at 60 g/L with the carpeted roller in the fall effectively controlled huisache.

Operator effectiveness and shrub density determine herbicide volume and rate/unit area using the carpeted roller. Mayeux (1987) reported that within the range of 50 to 3,260 honey mesquite plants/ha, volume of solution used varied from 3 to 20 L/ha. Amounts of herbicide in solutions of 60 g/L applied to the dense honey mesquite stands, when converted to a unit-area basis, were within the range of rates recommended (0.5 to 1 kg/ha) for broadcast applications.

Although the morphology of huisache is strikingly similar to that of honey mesquite, the power curve of Mayeux (1987) overstated the solution requirements for treating huisache at densities of 200 plants or more. Within the range of 90 to 420 huisache plants/ha, volume of herbicide solution used (Y) was a function of huisache density, with Y = -39.535 plus 21.433(log X) ($r^2 = 0.89$). The log relationship increased the r^2 value somewhat compared with the linear relationship ($r^2 = 0.71$). From the log relationship, the application rate required to treat 100 to 400 plants/ha using 60 g/L ranged from 0.2 to 0.9 kg/ha (Table 3.14). The mixture of 2,4,5-T plus picloram (1:1) broadcast applied at 1.1 kg/ha is normally recommended for huisache control. Treatment of 420 plants/ha with the carpeted roller required about 17 L/ha of solution. This solution volume containing herbicide at 60 g/L corresponds to an application rate on an unit area basis of approximately 1.1 kg/ha.

Control of Blackbrush Acacia

With few exceptions such as picloram spray at 0.6 kg/ha and 2,4,5-T plus picloram at 48 g/L applied with the roller applicator, canopy reduction of blackbrush acacia was 80 percent or greater 12 months after application of herbicides in October 1983 on the San Patricio Ranch (Table 3.15). Picloram as a broadcast spray at 1.1 kg/ha and 2,4,5-T plus picloram applied at 48 g/L with the carpeted roller were the only treatments that did not result in greater than 50 percent apparent mortality a year after application (Table 3.16).

Most herbicides and methods of application had effectively reduced the blackbrush acacia canopies 13 months after application in June 1984 (Table 3.17); however, a notable exception was triclopyr applied with the roller at 12 g/L. Clopyralid applied at 1.1 kg/ha or with the carpeted roller at 60 g/L resulted in apparent mortality greater than 70 percent after 13 months (Table 3.18). The only other treatments that caused 50 percent or greater mortality after 13 months were picloram, clopyralid plus picloram, and triclopyr

Table 3.12. Percentage of canopy reduction and apparent mortality of regrowth mesquite on June 21, 1985 after application of herbicides as broadcast sprays at 1.1 kg/ha or with a carpeted roller at 120 g/L on May 1984, on the La Copita Research near Alice, Texas.

Herbicide(s)	Application method	Canopy reduction	Apparent mortality
None	—	9	0
Clopyralid + picloram	Spray	99	99
Clopyralid + picloram	Roller	98	91
Triclopyr + picloram	Spray	99	97
Triclopyr + picloram	Roller	97	97
2,4,5-T + picloram	Spray	98	97
2,4,5-T + picloram	Roller	97	89
LSD (0.05)	—	5	5

plus picloram applied at 60 g/L with the carpeted roller.

Of the treatments applied on the San Patricio Ranch on September 12-18, 1984, all, except (1) 0.6 kg/ha of clopyralid as a broadcast spray, (2) 12 g/L of clopyralid, picloram, and clopyralid plus picloram applied with the carpeted roller, and (3) triclopyr, regardless of application method or rate, effectively controlled the blackbrush acacia 10 months after application (Table 3.19). Although triclopyr applied alone was ineffective for blackbrush acacia control, the mixture of triclopyr plus picloram resulted in acceptable control levels.

Compared with results from other experiments at the same location, blackbrush acacia control was low following application of herbicides in June 1985 (Table 3.20). At 14 months after application, only clopyralid applied with the roller applicator at 60 g/L achieved an acceptable level of control as indicated by apparent mortality. In contrast, applications of various treatments in the fall of 1985 (Table 3.21) effectively controlled blackbrush acacia. In general, treatments with clopyralid, picloram, or clopyralid plus picloram (1:1) were highly effective except where 12 g/L were applied with the carpeted roller. Triclopyr applied alone did not effectively control blackbrush acacia. However, the combination of triclopyr and picloram as a broadcast spray at 1.1 kg/ha or applied at 60 g/L with the carpeted roller effectively controlled blackbrush acacia.

Although no direct measurements were taken, heavy stands of regrowth blackbrush acacia apparently required considerably more herbicide solution with the carpeted roller than did huisache or honey mesquite at the same densities. Regrowth of blackbrush acacia tended to develop laterally, and several plants had coalesced into large clumps. Where high densities of these clumps occur over relatively large areas, broadcast spraying would probably be more advantageous than would herbicide application with the carpeted roller.

Summary

Results of this research indicate that herbicide application with a carpeted roller can be used effectively to control low densities of regrowth honey mesquite, huisache, and blackbrush acacia. Where nearly pure stands of honey mesquite present the primary management problem, clopyralid, clopyralid plus picloram, or triclopyr plus picloram applied in the spring at 48 to 60 g/L with the carpeted roller will result in effective control. For moderate to dense stands, broadcast sprays of the herbicides at 1.1 kg/ha will result in effective honey mesquite control. Application of herbicides in the autumn will not effectively control honey mesquite.

Huisache and blackbrush acacia may be controlled with clopyralid, clopyralid plus picloram, picloram, or triclopyr plus picloram applied in autumn or spring with the carpeted roller or as broadcast sprays. Applications in September and October, however, appear to be more effective than do treatments in the spring, especially for huisache control. From empirical evidence, it appears that substantially more herbicide solution is required to treat blackbrush acacia with the carpeted roller than is required for honey mesquite or huisache at comparable densities. More research will be required to clarify this field observation.

Table 3.13. Summary analysis of descriptive statistics for honey mesquite responses to selected treatments at 1.1 kg/ha 1 year after application in the spring.

Herbicide(s)	Canopy reduction	Apparent mortality
	(% ± SD)	
Clopyralid	91 ± 6	78 ± 14
Picloram	69 ± 27	43 ± 18
Clopyralid + picloram	96 ± 3	75 ± 3
Triclopyr	63 ± 23	14 ± 16
Triclopyr + picloram	90 ± 5	45 ± 18

Table 3.14. Predicted requirements of carrier solution (L/ha) and herbicide (kg/L) to treat various densities of huisache with 60 g/L of herbicide using the carpeted roller.

Huisache density (plants/ha)	Volume of solution (L/ha)	Application rate (kg/ha)
100	3.3	0.2
200	9.8	0.6
300	13.6	0.8
400	16.2	0.9

Table 3.15. Percentage of canopy reduction of blackbrush acacia at 8 and 12 months after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on October 5, 1983, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate		Months after treatment	
		(kg/ha)	(g/L)	8	12
None	—	—	—	38	20
Clopyralid	Spray	1.1		100	100
	Roller		48	96	92
Picloram	Spray	0.6		100	78
		1.1		94	89
	Roller		24	97	82
			48	99	91
Clopyralid +	Spray	1.1		99	93
picloram	Roller		48	99	85
2,4,5-T +	Spray	1.1		95	85
picloram	Roller		48	91	53
LSD (0.05)	—	—	—	13	35

Table 3.16. Percentage of apparent mortality of blackbrush acacia at various times after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on October 5, 1983, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Months after treatment 8	Months after treatment 12
None	—	—	—	0	0
Clopyralid	Spray	1.1		96	95
	Roller		48	83	88
Picloram	Spray	0.6		60	57
		1.1		36	43
	Roller		24	95	72
			48	82	73
Clopyralid +	Spray	1.1		79	73
picloram	Roller		48	82	66
2,4,5-T +	Spray	1.1		54	54
picloram	Roller		48	33	20
LSD (0.05)	—	—	—	49	56

Table 3.17. Percentage of canopy reduction of blackbrush acacia at 4 and 13 months after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on June 13, 1984, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Months after treatment 4	Months after treatment 13
None	—	—	—	16	5
Clopyralid	Spray	0.6		92	96
		1.1		96	92
	Roller		12	73	68
			60	98	96
Picloram	Roller		12	80	79
			60	93	77
Clopyralid +	Spray	0.6		94	94
picloram		1.1		97	84
	Roller		12	76	83
			60	98	99
Triclopyr	Roller		12	68	27
			60	95	93
Triclopyr +	Roller		12	74	80
picloram			60	98	94
LSD (0.05)	—	—	—	12	21

Table 3.18. Percentage of apparent blackbrush acacia mortality at 4 and 13 months after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller on June 13, 1984, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Months after treatment 4	Months after treatment 13
None	—	—	—	0	0
Clopyralid	Spray	0.6		65	42
		1.1		71	72
	Roller		12	8	14
			60	84	76
Picloram	Roller		12	25	24
			60	70	59
Clopyralid + picloram	Spray	0.6		59	23
		1.1		74	21
	Roller		12	15	48
			60	80	87
Triclopyr	Roller		12	26	5
			60	57	38
Triclopyr + picloram	Roller		12	24	33
			60	83	70
LSD (0.05)	—	—	—	32	40

Table 3.19. Percentage of canopy reduction and apparent mortality of blackbrush acacia at 10 months after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller from September 12 to 18, 1984, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Canopy reduction	Apparent mortality
None	—	—	—	17	0
Clopyralid	Spray	0.6		90	38
		1.1		96	78
	Roller		12	78	43
			60	90	73
Picloram	Spray	0.6		92	68
		1.1		98	85
	Roller		12	84	48
			60	98	89
Clopyralid + picloram	Spray	0.6		97	75
		1.1		97	94
	Roller		12	76	21
			60	94	79
Triclopyr	Spray	0.6		68	15
		1.1		72	0
	Roller		12	65	9
			60	83	22
Triclopyr + picloram	Spray	0.6		91	59
		1.1		96	83
	Roller		12	87	50
			60	96	79
LSD (0.05)	—	—	—	17	28

Table 3.20. Percentage of canopy reduction and apparent mortality of blackbrush acacia at 14 months after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller June 3, 1985, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Canopy reduction	Apparent mortality
None	—	—	—	0	0
Clopyralid	Spray	0.6		68	2
		1.1		60	3
	Roller		60	77	57
Picloram	Spray	0.6		43	10
		1.1		44	16
	Roller		12	35	2
			60	55	30
Clopyralid + picloram	Spray	0.6		29	0
		1.1		78	26
	Roller		12	30	3
			60	62	33
Triclopyr	Spray	0.6		16	0
		1.1		17	0
	Roller		12	7	0
			60	14	5
Triclopyr + picloram	Spray	0.6		36	7
		1.1		23	3
	Roller		12	48	0
			60	43	22
LSD (0.05)	—	—	—	40	28

Table 3.21. Percentage of canopy reduction and apparent mortality of blackbrush acacia at 12 months after application of selected herbicides and mixtures (1:1) as broadcast ground sprays or with a carpeted roller from September 12 to October 8, 1985, on the San Patricio Ranch near Sinton, Texas.

Herbicide(s)	Application method	Rate (kg/ha)	Rate (g/L)	Canopy reduction	Apparent mortality
None	—	—	—	5	1
Clopyralid	Spray	0.6		77	40
		1.1		89	67
	Roller		12	70	15
			60	93	90
Picloram	Spray	0.6		93	67
		1.1		99	88
	Roller		12	74	28
			60	99	91
Clopyralid + picloram	Spray	0.6		89	48
		1.1		98	90
	Roller		12	71	23
			60	100	100
Triclopyr	Spray	0.6		16	1
		1.1		20	0
	Roller		12	17	3
			60	52	2
Triclopyr + picloram	Spray	0.6		78	47
		1.1		80	55
	Roller		12	68	14
			60	94	55
LSD (0.05)	—	—	—	21	30

IV. Aerial Application of Selected Herbicides for Mixed Brush Control

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Introduction

Aerial application of herbicides became increasingly popular in South Texas after the introduction of picloram, which broadened the spectrum of species controlled in mixed-brush stands. Compared with applications of 2,4,5-T alone, the combination of 2,4,5-T and picloram (1:1) at 1.1 kg/ha increased control of cactus species, blackbrush acacia, twisted acacia, spiny hackberry, guajillo, and other species associated with honey mesquite (Fisher et al. 1972). In addition, levels of the mesquite population killed were increased from 34 percent with application of 2,4,5-T to 52 percent following treatment with 2,4,5-T plus picloram.

Cessation in availability of 2,4,5-T caused concomitant loss of the mixture of 2,4,5-T and picloram. Thus, research was initiated to evaluate alternative compounds to be aerially applied alone or in combination with other herbicides such as picloram for mixed-brush control. Clopyralid and triclopyr, having chemical structures somewhat similar to picloram, received much of the research attention.

This chapter presents the results of aerial application of clopyralid, dicamba, and triclopyr, applied alone and in combination with picloram and, where possible, compares these data with those for efficacy of 2,4,5-T plus picloram. Otherwise, comparisons of the compounds for honey mesquite control include reference to historical performance of 2,4,5-T plus picloram (i.e., canopy reduction ≥80 percent and apparent mortality ≥50 percent after two growing seasons [Fisher et al. 1959, 1972]; see also discussion in Chapter 1).

Materials and Methods

Experiments established on the Welder Dobie Ranch in 1983 and on the Driscoll Foundation in 1984 and 1985 were designed as randomized complete blocks with two replications. Other locations with single plots receiving each treatment and established in 1985 included the Arrowhead Ranch near Tilden, Earwood Ranch near Spofford, O'Brien Ranch near Beeville, Tiller Ranch near Cotulla, Callaghan Ranch near Encinal, and Fullbright Ranch near Mirando City (Figure 1.2).

Herbicides were applied on the Welder Dobie Ranch from a 485-kW monowing aircraft and at a rate of 19 L/ha of a 1:4, oil:water emulsion. A helicopter was used to apply herbicides in 19 L/ha total solution, including 0.9 L/ha of diesel fuel at all other locations. Treatments were evaluated in late summer - early fall each year after application, resulting in data collections at 3-4, 14-15, and 26-27 months after treatment of most experiments. An effort was made to evaluate at least 50 plants of each species in each plot. After transformation as necessary, data from the Welder Dobie Ranch and the Driscoll Foundation were subjected to two-way analysis of variance. Data from the six other locations were pooled before conducting two-way analysis of variance to evaluate the effect of treatment and location. Soils, application dates, and environmental conditions during treatment for the various locations are given in Table 4.1.

Various herbicides and herbicide mixtures were aerially applied to 3- to 9-ha strips on the La Copita Research Area on May 13, 1986. A helicopter was used to apply treatments as described for the Driscoll Foundation. Responses of woody plants in the strips were evaluated on August 13, 1987.

Results and Discussion

Control of Honey Mesquite

All treatments reduced the canopy cover of honey mesquite by 94 percent or more 6 months after application on the Welder Dobie Ranch near Cotulla in 1983 (Table 4.2). Canopy cover reduction was 89 percent or greater at the 38-month evaluation on plots treated with picloram and the herbicide mixtures, whereas average canopy reduction was less than 80 percent where 2,4,5-T or triclopyr were applied.

Table 4.1. Locations, soils, application dates, and environmental particulars for experiments with treatments aerially applied from 1983 through 1985.

	Ranch								
	Arrowhead	Callaghan	Driscoll	Earwood	Fulbright	O'Brien	Tiller	Welder-Dobie	La Copita
County	McMullen	Webb	Jim Wells	Kinney	Jim Hogg	Bee	LaSalle	LaSalle	Jim Wells
Nearest town	Tilden	Encinal	Ben Bolt	Spofford	Mirando City	Beeville	Cotulla	Freer	Alice
Range site	Clay Loam	Clay Loam	Sandy Loam, Tight Sandy Claypan Prairie	Clay Loam, Shallow Ridge	Shallow Sandy Loam, Loamy Sand	Claypan Prairie	Shallow Sandy Loam, Sandy Loam	Clay Loam	Sandy Loam, Clay Loam, Gray Sandy Loam
Soil series/ association	Houla-Salco-Soledad	Moglia	Czar Delfina Opelika	Knippa Uvalde Kimbrough-Ector	Cuevitas Delfina	Orelia	Dilly Duval	Bookout Caid	Runge Opelika
Date applied	5-24-85	5-27-85	5-24-84 5-15-85	6-12-85	5-31-85	6-11-85	5-9-85	5-18-83	5-24-86
Wind speed (mph)	0-6	3-9	0-6 0-10	0-5	5-9	0-9	2-4	0-8	0-10
Relative humidity (%)	83-90	79-90	49-100 61-78	36-37	—	73-88	90-94	78-91	70-90
Air temperature (°C)	24-27	23-27	22-32 21-24	31-34	27	27-29	23-24	24-28	27-34
Soil temperature (°C)	28	26	26	26	—	—	26	—	30

Table 4.2. Percentage of canopy reduction and apparent mortality of honey mesquite at various times after aerial application of selected herbicides and herbicide mixtures (1:1) at 1.1 kg/ha to mixed-brush stands on May 18, 1983, on the Welder Dobie Ranch near Cotulla, Texas.

	Canopy reduction				Apparent mortality			
	Months after treatment							
Herbicide(s)	6	15	27	38	6	15	27	38
None	2	33	2	3	0	0	0	0
2,4,5-T	94	80	56	70	61	13	10	10
Triclopyr	97	81	75	76	46	19	17	9
Picloram	99	88	86	93	90	43	45	40
2,4,5-T + picloram	97	84	89	89	61	45	40	25
Triclopyr + picloram	98	94	92	92	70	38	45	45
Clopyralid + picloram	99	96	96	96	92	48	63	59
LSD (0.05)	15	20	10	14	28	31	20	15

Mortality of honey mesquite was not significant ($P \leq 0.05$) at 15 months after application or at later evaluations following aerial application of 2,4,5-T or triclopyr on the Welber Dobie Ranch (Table 4.2). Apparent mortality, however, was generally 40 percent or greater at 15 and 27 months after aerial application of picloram at 1.1 kg/ha or at 0.6 kg/ha combined with 0.6 kg/ha of 2,4,5-T, triclopyr, or clopyralid. This trend held at 38 months after application of the herbicides, except where picloram was applied in combination with 2,4,5-T.

Honey mesquite canopies were reduced by 80 percent or more 4 months after aerial application of herbicides in May 1984 on the Driscoll Foundation (Table 4.3). Canopy reductions were maintained through 27 months after application of the herbicides, defoliation being 90 percent or greater in most plots. Dry growing conditions at 27 months after initiation of the experiment caused canopy reduction of honey mesquite in untreated plots to approach 50 percent.

Apparent mortality values were highly variable within years, but several conclusions could be drawn from evaluations at 15 and 27 months after application of herbicides in 1984 on the Driscoll Foundation (Table 4.3). Triclopyr at either rate, picloram at 0.3 kg/ha, and dicamba plus triclopyr at 0.6 kg/ha of each herbicide were the least effective treatments. Mixtures of triclopyr or clopyralid at 0.6 kg/ha with equal amounts of picloram killed more than 60 percent of the honey mesquite. In general, honey mesquite control with clopyralid or triclopyr in combination with picloram did not differ compared with application of 2,4,5-T plus picloram. Moreover, honey mesquite control did not differ whether the clopyralid plus picloram mixture was applied at 0.3 kg/ha or 0.6 kg/ha of each herbicide or whether 0.3 kg/ha of clopyralid was applied with 0.6 kg/ha of picloram.

Results of the experiment established in 1985 on the Driscoll Foundation (Table 4.4) were similar to those described following herbicide applications in 1984 (Table 4.3). Canopy reduction 15 months after aerial application of herbicides in 1985 was 80 percent or greater on all treatments and 90 percent or greater with most treatments (Table 4.4). Apparent mortality after 15 and 26 months was not significant where triclopyr at 0.6 kg/ha and 1.1 kg/ha, dicamba at 1.1 kg/ha, or dicamba plus triclopyr at 0.6 kg/ha of each herbicide were applied. However, apparent mortality after 15 and 26 months was significant for all the other treatments, being greater where clopyralid plus picloram was applied at 0.6 kg/ha of each herbicide.

All treatments significantly reduced honey mesquite canopies the growing season following application on La Copita Research Area (Table 4.5). There was no difference in apparent mortality among treatments, and mean apparent mortality was 67 percent or greater.

Results of honey mesquite control on the Arrowhead Ranch near Tilden, Callaghan Ranch near Encinal, Earwood Ranch near Spofford, O'Brien Ranch near Beeville, and the Tiller Ranch near Cotulla were pooled for presentation (Table 4.6). Data from the Fullbright Ranch near Mirando City were not included in the analysis pool because all treatments applied at the other five locations were not applied on the Fullbright Ranch. This analysis included an estimate of variation in honey mesquite control among ranches. In no case did variation differ significantly among ranch locations. The herbicide treatments reduced honey mesquite canopies by 79

Table 4.3. Percentage of canopy reduction and apparent mortality of honey mesquite at various times aft aerial application of selected herbicides and herbicide mixtures to mixed-brush stands on May 24, 1984, o the Driscoll Foundation near Alice, Texas.

		Canopy reduction			Apparent mortality		
		Months after treatment					
Herbicide(s)	Rate(s) (kg/ha)	4	15	27	4	15	27
None	—	12	13	49	6	8	17
Triclopyr	0.6	88	91	98	61	39	34
Triclopyr	1.1	94	94	98	44	41	14
Clopyralid	0.3	80	94	84	53	76	52
Clopyralid	0.6	99	89	98	89	67	63
Picloram	0.3	95	92	90	47	38	40
Picloram	0.6	93	97	98	57	47	50
Triclopyr + picloram	0.6 + 0.6	96	99	99	77	80	66
Clopyralid + picloram	0.3 + 0.3	95	99	98	80	81	66
Clopyralid + picloram	0.3 + 0.6	97	97	98	81	70	79
Clopyralid + picloram	0.6 + 0.6	97	96	96	83	65	67
2,4,5-T + picloram	0.6 + 0.6	99	98	99	91	44	76
Dicamba + triclopyr	0.6 + 0.6	99	99	82	68	42	36
LSD (0.05)		23	21	20	38	33	32

Table 4.4. Percentage of canopy reduction and apparent mortality of honey mesquite at various times after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands on May 15, 1985, on the Driscoll Foundation near Alice, Texas.

		Canopy reduction			Apparent mortality		
		Months after treatment					
Herbicide(s)	Rate(s) (kg/ha)	3	15	26	3	15	26
None	—	18	12	5	0	0	0
Triclopyr	0.6	84	89	84	25	16	8
Triclopyr	1.1	98	93	86	68	24	29
Clopyralid	0.6	78	88	89	28	39	49
Dicamba	1.1	89	80	66	18	8	7
Picloram	0.6	84	93	84	39	38	40
Dicamba + triclopyr	0.6 + 0.6	88	90	88	22	17	14
Triclopyr + picloram	0.6 + 0.6	98	97	94	56	44	56
Dicamba + picloram	0.6 + 0.6	96	95	96	58	31	51
Clopyralid + picloram	0.3 + 0.3	93	90	88	53	44	40
Clopyralid + picloram	0.3 + 0.6	92	93	97	52	42	57
Clopyralid + picloram	0.6 + 0.6	90	98	99	64	74	81
LSD (0.05)	—	16	11	10	31	23	17

Table 4.5. Percentage of canopy reduction and apparent mortality of honey mesquite on August 13, 1987, following aerial application of selected herbicide mixtures (1:1) at 1.1 kg/ha to mixed-brush stands on May 13, 1986, on La Copita Research Area near Alice, Texas.

Herbicide(s)	Canopy reduction	Apparent mortality
None	6	0
2,4,5-T + picloram	100	68
Dicamba + picloram	98	67
Triclopyr + picloram	100	82
Clopyralid + picloram	100	83
LSD (0.05)	2	20

Table 4.6. Percentage of canopy reduction and apparent mortality of honey mesquite at various times after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands in 1985 at five locations in South Texas.

		Canopy reduction			Apparent mortality		
		Months after treatment					
Herbicide(s)	Rate(s) (kg/ha)	2	14	26	2	14	26
None	—	8	26	2	0	0	0
Triclopyr	1.1	79	93	96	57	26	35
Clopyralid	0.6	82	91	85	35	53	29
2,4,5-T + picloram	0.6 + 0.6	97	98	96	64	51	63
Triclopyr + picloram	0.6 + 0.6	99	98	98	89	61	72
Clopyralid + picloram	0.3 + 0.6	99	94	92	82	63	67
Clopyralid + picloram	0.6 + 0.6	99	99	99	91	82	85
Dicamba + picloram	0.6 + 0.6	97	95	96	87	51	62
LSD (0.05)	—	15	3	7	33	13	35

percent or more 2 months after aerial application; average defoliation exceeded 90 percent after 14 and 26 months, regardless of treatment. Apparent mortality values after 14 months indicate that triclopyr at 1.1 kg/ha was the least effective treatment for honey mesquite control. Clopyralid alone at 0.6 kg/ha, clopyralid plus picloram at 0.3 + 0.6 kg/ha, triclopyr plus picloram at 0.6 kg/ha of each, and dicamba plus picloram at 0.6 kg/ha of each herbicide were roughly equivalent to 2,4,5-T plus picloram at 0.6 + 0.6 kg/ha according to average apparent mortality of honey mesquite after 14 months. By 26 months after application, the percentage of honey mesquite killed by triclopyr at 1.1 kg/ha or clopyralid at 0.6 kg/ha was not significant. However, mortality following application of picloram in combination with the other herbicides averaged 60 percent or greater. The greatest level of honey mesquite control resulted when clopyralid plus picloram was applied at 0.6 kg/ha of each herbicide.

Since a major objective of this research was to evaluate potential alternative herbicides for control of honey mesquite using results from aerial applications of 2,4,5-T plus picloram as the standard for comparison, data were pooled across locations for inspection. From data taken at 12 to 15 months after aerial application of alternative herbicides and combinations, means and standard deviations were calculated for selected treatments applied at 1.1 kg/ha (Table 4.7).

Several inferences may be drawn from the contrasts although the number of locations used in the analysis is relatively small, not all treatments occurred at all locations, and the influence of year of application is confounded with location. First, all the alternatives were relatively effective in reducing honey mesquite canopies. Except for triclopyr, the average canopy reduction was 95 percent greater and varied from only 2 to 4 percent by the end of the second growing season following herbicide application. Second, equal-ratio mixtures of triclopyr or dicamba with picloram were equivalent to 2,4,5-T plus picloram applied at 1.1 kg/ha relative to expected mortality of honey mesquite at 1 year after application. Third, the

Table 4.7. Summary analysis of descriptive statistics for honey mesquite responses to aerial application of selected herbicides and herbicide mixtures (1:1) at 1.1 kg/ha from data taken at 12 to 15 months after treatment.

Herbicide(s)	Location	Canopy reduction	Apparent mortality
		(% ± SD)	
2,4,5-T + picloram	7	96 ± 4	49 ± 23
Triclopyr + picloram	8	98 ± 2	58 ± 21
Dicamba + picloram	6	95 ± 2	48 ± 26
Clopyralid + picloram	8	98 ± 2	74 ± 14
Triclopyr	8	92 ± 6	27 ± 18

combination of clopyralid plus picloram at 1.1 kg/ha was superior to the other alternatives when apparent mortality of honey mesquite at 14-15 months after application was used as the criterion for comparison. Although these values may be reduced somewhat after 24 months, results of the older experiments indicate that the relative standing among treatments will probably remain the same. Finally, triclopyr alone is less effective for honey mesquite control than are the combinations of alternative herbicides with picloram. These general conclusions agree with summary comparisons of treatment response following ground broadcast applications (see Chapter III).

Clopyralid was not aerially applied alone at 1.1 kg/ha, but the same analysis of 0.6 kg/ha applied to six locations indicates average values for canopy reduction of 92 ± 4 percent and apparent mortality of 58 ± 15 percent, roughly equivalent to results from application of 1:1 kg/ha of mixtures of triclopyr, 2,4,5-T, or dicamba with picloram at 1.1 kg/ha total herbicide.

Control of Blackbrush Acacia

Apparent mortality values 38 months after aerial application of herbicides in May 1983 on the Welder Dobie Ranch near Cotulla indicate that 2,4,5-T and triclopyr were the least effective of the treatments for blackbrush acacia control (Table 4.8). Further, apparent mortalities did not differ whether picloram was applied alone at 1.1 kg/ha or at 0.6 kg/ha in mixtures with the same rate of 2,4,5-T, triclopyr, or clopyralid.

Response of blackbrush acacia to aerial application of sprays in 1984 on the Driscoll Foundation varied highly (Table 4.9). Defoliation rarely exceeded 70 percent after the first growing season, and treatment effects were confounded with defoliation imposed by lowerthan-normal winter temperatures and dry summers. Except for clopyralid at 0.3 kg/ha plus picloram at 0.6 kg/ha at 4 months after treatment, no herbicide treatment killed a significant percentage of the blackbrush acacia. Mortality from the same treatment was not significant in subsequent evaluations.

Response of blackbrush acacia to treatments applied in May 1985 on the Driscoll Foundation also varied highly (Table 4.10). All treatments, except triclopyr at 0.6 kg/ha, significantly defoliated blackbrush acacia after 3 months; however no treatment caused significant mortality after 3, 15, or 26 months.

Responses averaged over the five locations that were aerially sprayed in 1985 indicate that a significant difference occurred among locations and among treatments within locations. Triclopyr reduced the canopy cover of blackbrush acacia by 80 percent after 14 months and 65 percent after 26 months, but the percentage of the population completely defoliated and showing no regrowth (apparent mortality) was not significant (Table 4.11). Apparent mortalities 14 months after application of the herbicides indicate that triclopyr plus picloram (1:1) at 1.1 kg/ha and clopyralid plus picloram (1:2) at 0.9 kg/ha were no more effective than was triclopyr at 1.1 kg/ha. Combinations of 0.6 kg/ha of clopyralid, dicamba, or 2,4,5-T with an equal amount of picloram killed a statistically significant proportion of the blackbrush acacia at both evaluation dates. According to averages across the five locations, clopyralid at 0.6 kg/ha was as effective as were the mixtures with picloram for blackbrush acacia control.

Control of Spiny Hackberry

Triclopyr or 2,4,5-T at 1.1 kg/ha did not effectively control spiny hackberry after aerial application on the Welder Dobie Ranch in 1983 (Table 4.12). In contrast, picloram at 1.1 kg/ha and at 0.6 kg/ha combined with equal amounts of 2,4,5-T, triclopyr, or clopyralid were more effective in reducing spiny hackberry canopies. Further, the herbicide mixtures tended to result in higher levels of control, especially when apparent mortality after 38 months was used as the evaluation criterion. The most effective treatment, however, was picloram at 1.1 kg/ha.

Results from herbicide applications in 1984 on the Driscoll Foundation near Alice (Table 4.13) partly confirmed the results from the experiment initiated in 1983 on the Welder Dobie Ranch (Table 4.12). The reduction of spiny hackberry canopies indicates that triclopyr and clopyralid were ineffective. On the other hand, picloram or herbicide combinations containing picloram significantly reduced spiny hackberry. However, no treatment caused significant mortality in the spiny hackberry population.

Except for triclopyr plus picloram, the herbicide mixtures containing 0.6 kg/ha of picloram and picloram alone at 0.6 kg/ha effectively controlled spiny hackberry, as indicated by apparent mortalities after 26 months, in the experiment established in 1985 on the Driscoll Foundation (Table 4.14). All treatments effectively controlled spiny hackberry, according to evaluation in 1987 after application in 1986 on La Copita Research Area (Table 4.15). Canopy reductions averaged 84 percent or greater, and apparent mortality ranged from 42 to 72 percent.

According to averages across three ranch locations, herbicide mixtures containing picloram killed a significant proportion of the spiny hackberry population (Table 4.16). The mixtures containing picloram were more effective than were triclopyr or clopyralid applied alone.

Because of the uniformly low control following aerial applications of herbicides in 1984 on the Driscoll Foundation, the results with spiny hackberry appear mixed. In all other experiments, however, herbicide mixtures containing 0.6 kg/ha of picloram were relatively effective for controlling spiny hackberry.

Response of Lime Pricklyash

Relatively high densities of lime pricklyash occurred in both experiments on the Driscoll Foundation. Although canopy reduction averaged 60 to 70 percent during the 1984 growing season, no treatment resulted in effective and consistent control (Table 4.17). By 15 months after application, 5 percent or less of the plants were completely defoliated by any treatment, and canopy reduction did not average 50 percent for most treatments. Results following application of the herbicides in 1985 were similar to those in 1984 (Table 4.18). Some treatments reduced lime pricklyash canopies by more than 70 percent in the same growing season that treatments were applied; however, no treatment effectively caused plant mortality at either the 3- or 15-month evaluation dates.

Average canopy reduction values for lime pricklyash were significant the year following aerial spraying of mixtures containing picloram on La Copita Research Area in May 1986 (Table 4.19). As with experiments at other locations, however, mean apparent mortality was generally not significant, and recovery of the lime pricklyash population can be expected in subsequent years. Thus, according to results from these experiments, no herbicide or herbicide combination effectively controlled lime pricklyash.

Response of Brasil to Herbicides

Herbicide mixtures containing picloram significantly reduced canopy covers of brasil the season of treatment on the Driscoll Foundation in 1984, but essentially no mortality occurred and canopy reduction was not maintained through later evaluations (Table 4.20). Results from applications in 1985 followed the same trend (data not shown). According to average data across three other locations, herbicide mixtures containing 0.6 kg/ha of picloram reduced brasil canopies into the second growing season following application, but as in other experiments, canopies were replaced after 27 months and few plants were killed (Table 4.21).

Results from aerial application of herbicide mixtures on La Copita Research Area confirmed those from other experiments (Table 4.22). Canopy reduction of brasil averaged 21 percent or less, and the sprays caused no apparent mortality of brasil.

Control of Pricklypear

Pricklypear response, whether indicated by reduction in live cladophylls (pads) or by percentage of plants killed, depended on the presence of picloram in the herbicide mixtures. At 38 months after aerial application of herbicides on the Welder Dobie Ranch near Cotulla, 0.6 kg/ha of picloram alone or in combination with other herbicides killed 89 to 97 percent of the pricklypear (Table 4.23). This observation was supported by results on the Driscoll Foundation 27 months after application of the herbicides in 1984 (Table 4.24).

Response of Whitebrush and Texas Persimmon to Herbicides

Results of aerial application of herbicides to whitebrush are inconclusive. Whitebrush is a drought-deciduous shrub, so seasonal patterns of natural defoliation confounded the evaluations within all experiments. In addition, whitebrush occurred only in widely scattered patches and did not occur on all plots. As a general observation, however, it appears that only picloram or herbicide mixtures containing picloram at 0.6 kg/ha partly controlled whitebrush. Other herbicides were ineffective.

No herbicide or herbicide combination significantly reduced Texas persimmon canopies (data not shown). Picloram at 0.6 kg/ha or herbicide mixtures containing picloram caused minor defoliation the growing season of application. Little damage, however, was evident by the growing season after herbicide application.

Table 4.8. Percentage of canopy reduction and apparent mortality of blackbrush acacia at various times after aerial application of selected herbicides and herbicide mixtures (1:1) at 1.1 kg/ha to mixed-brush stands on May 18, 1983, on the Welder Dobie Ranch near Cotulla, Texas.

Herbicide(s)	Canopy reduction			Apparent mortality		
	Months after treatment					
	15	27	38	15	27	38
None	64*	12	25	6	0	5
2,4,5-T	82	62	82	13	3	18
Triclopyr	82	56	74	14	5	14
Picloram	94	80	96	36	49	38
2,4,5-T + picloram	94	90	93	32	54	32
Triclopyr + picloram	96	94	92	26	35	40
Clopyralid + picloram	92	94	95	39	56	40
LSD (0.05)	5	17	12	31	19	16

* Canopy reduction of untreated blackbrush attributed to lower-than-normal winter temperatures, winter 1983-84.

Table 4.9. Percentage of canopy reduction and apparent mortality of blackbush acacia at various times after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands on May 24, 1984, on the Driscoll Foundation near Alice, Texas.

Herbicide(s)	Rate(s) (kg/ha)	Canopy reduction			Apparent mortality		
		Months after treatment					
		4	15	27	4	15	27
None	—	22	8	43	2	1	1
Triclopyr	0.6	78	10	39	0	0	9
Triclopyr	1.1	43	38	14	5	0	4
Clopyralid	0.3	62	68	56	2	0	0
Clopyralid	0.6	63	76	48	19	10	11
Picloram	0.3	64	47	66	10	6	2
Picloram	0.6	65	46	38	18	15	6
Triclopyr + picloram	0.6 + 0.6	64	68	48	21	19	24
Clopyralid + picloram	0.3 + 0.3	85	60	54	35	5	2
Clopyralid + picloram	0.3 + 0.6	88	55	38	62	0	5
Clopyralid + picloram	0.6 + 0.6	90	67	30	28	2	8
2,4,5-T + picloram	0.6 + 0.6	90	75	34	22	0	20
Dicamba + triclopyr	0.6 +0.6	78	70	4	5	30	2
LSD (0.05)	—	35	33	NS	41	NS	NS

NS = no significant differences among treatments.

Table 4.10. Percentage of canopy reduction and apparent mortality of blackbrush acacia at various times after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands on May 15, 1985, on the Driscoll Foundation near Alice, Texas.

		Canopy reduction			Apparent mortality		
		Months after treatment					
Herbicide(s)	Rate(s) (kg/ha)	3	15	26	3	15	26
None	—	11	19	1	0	0	0
Triclopyr	0.6	30	24	16	0	0	0
Triclopyr	1.1	68	68	52	50	6	1
Clopyralid	0.6	86	78	26	37	20	2
Dicamba	1.1	70	36	5	36	5	0
Picloram	0.6	45	44	39	25	6	0
Dicamba + triclopyr	0.6 + 0.6	90	60	80	32	15	39
Triclopyr + picloram	0.6 + 0.6	94	84	76	22	28	25
Dicamba + picloram	0.6 + 0.6	87	77	56	33	6	6
Clopyralid + picloram	0.3 + 0.3	81	74	70	54	46	5
Clopyralid + picloram	0.3 + 0.6	88	67	57	28	15	17
Clopyralid + picloram	0.6 + 0.6	100	88	74	50	59	30
LSD (0.05)	—	33	25	39	NS	NS	NS

NS = no significant differences among treatments.

Table 4.11. Percentage of canopy reduction and apparent mortality of blackbrush acacia at 14 and 26 months after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands in 1985 at five locations in South Texas.

		Canopy reduction		Apparent mortality	
		Months after treatment			
Herbicide(s)	Rate(s) (kg/ha)	14	26	14	26
None	—	6	14	0	1
Triclopyr	1.1	80	65	19	4
Clopyralid	0.6	96	76	41	30
2,4,5-T + picloram	0.6 + 0.6	93	—	42	—
Triclopyr + picloram	0.6 + 0.6	93	91	25	32
Clopyralid + picloram	0.3 + 0.6	92	84	25	28
Clopyralid + picloram	0.6 + 0.6	97	93	39	30
Dicamba + picloram	0.6 + 0.6	74	85	36	23
LSD (0.05)	—	21	19	26	22

Table 4.12. Percentage of canopy reduction and apparent mortality of spiny hackberry at various times after aerial application of selected herbicides and herbicide mixtures (1:1) at 1.1 kg/ha to mixed-brush stands on May 18, 1983, on the Welder Dobie Ranch near Cotulla, Texas.

	Canopy reduction			Apparent mortality		
	Months after treatment					
Herbicide(s)	15	27	38	15	27	38
None	59*	7	21	0	0	9
2,4,5-T	36	6	36	0	0	8
Triclopyr	51	11	21	0	3	0
Picloram	90	49	94	42	34	74
2,4,5-T + picloram	67	62	56	10	25	18
Triclopyr + picloram	80	55	80	0	3	32
Clopyralid + picloram	100	79	74	86	12	40
LSD (0.05)	38	32	33	3	NS	27

NS = no significant difference among treatments.

*Canopy reduction of untreated spiny hackberry attributed to lower-than-normal winter temperatures, winter 1983-84.

Table 4.13. Percentage of canopy reduction and apparent mortality of spiny hackberry at various times after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands on May 24, 1984, on the Driscoll Foundation near Alice, Texas.

		Canopy reduction			Apparent mortality		
		Months after treatment					
Herbicide(s)	Rate(s) (kg/ha)	4	15	27	4	15	27
None	—	9	14	19	0	0	0
Triclopyr	0.6	16	8	14	0	0	2
Triclopyr	1.1	28	37	5	3	11	0
Clopyralid	0.3	32	24	33	1	0	3
Clopyralid	0.6	34	32	24	0	0	2
Picloram	0.3	57	42	36	11	1	0
Picloram	0.6	70	55	28	15	0	4
Triclopyr + picloram	0.6 + 0.6	58	50	34	4	11	6
Clopyralid + picloram	0.3 + 0.3	59	34	25	8	0	0
Clopyralid + picloram	0.3 + 0.6	64	72	31	8	0	0
Clopyralid + picloram	0.6 + 0.6	62	59	44	14	0	5
2,4,5-T + picloram	0.6 + 0.6	78	58	45	18	1	4
Dicamba + triclopyr	0.6 + 0.6	52	20	8	0	0	0
LSD (0.05)	—	27	NS	14	19	NS	NS

NS = no significant differences among treatments.

Table 4.14. Percentage of canopy reduction and apparent mortality of spiny hackberry at various times after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands on May 15, 1985, on the Driscoll Foundation near Alice, Texas.

		Canopy reduction			Apparent mortality		
		Months after treatment					
Herbicide(s)	Rate(s) (kg/ha)	3	15	26	3	15	26
None	—	17	11	8	0	1	0
Triclopyr	0.6	29	15	17	1	0	0
Triclopyr	1.1	56	35	31	4	1	4
Clopyralid	0.6	14	14	9	0	0	0
Dicamba	1.1	67	28	20	6	0	0
Picloram	0.6	70	74	83	25	12	60
Dicamba + triclopyr	0.6 + 0.6	48	20	11	2	0	0
Triclopyr + picloram	0.6 + 0.6	93	75	66	49	35	16
Dicamba + picloram	0.6 + 0.6	87	87	80	52	41	59
Clopyralid + picloram	0.3 + 0.3	90	70	80	59	26	43
Clopyralid + picloram	0.3 + 0.6	97	74	92	82	48	88
Clopyralid + picloram	0.6 + 0.6	97	92	98	82	59	93
LSD (0.05)	—	19	28	16	26	15	18

Table 4.15. Percentage of canopy reduction and apparent mortality of spiny hackberry on August 13, 1987, following aerial application of selected herbicide mixtures (1:1) at 1.1 kg/ha to mixed-brush stands on May 13, 1986, on La Copita Research Area near Alice, Texas.

Herbicide(s)	Canopy reduction	Apparent mortality
None	5	0
2,4,5-T + picloram	84	42
Dicamba + picloram	98	70
Triclopyr + picloram	93	72
Clopyralid + picloram	91	62
LSD (0.05)	13	32

Table 4.16. Percentage of canopy reduction and apparent mortality of spiny hackberry at 15 and 27 months after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands in 1985 at three locations in South Texas.

		Canopy reduction		Apparent mortality	
		Months after treatment			
Herbicide(s)	Rate(s) (kg/ha)	15	27	15	27
None	—	15	6	0	6
Triclopyr	1.1	56	9	2	—
Clopyralid	0.6	54	30	5	2
Triclopyr + picloram	0.6 + 0.6	97	83	47	47
Clopyralid + picloram	0.3 + 0.6	92	99	48	—
Clopyralid + picloram	0.6 + 0.6	99	99	44	84
Dicamba + picloram	0.6 + 0.6	98	85	46	56
LSD (0.05)	—	14	21	17	32

Table 4.17. Percentage of canopy reduction and apparent mortality of lime pricklyash at various times after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands on May 24, 1984, on the Driscoll Foundation near Alice, Texas.

Herbicide(s)	Rate(s) (kg/ha)	Canopy reduction			Apparent mortality		
		Months after treatment					
		4	15	27	4	15	27
None	—	14	7	13	0	0	0
Triclopyr	0.6	55	16	12	6	1	0
Triclopyr	1.1	62	21	11	4	0	0
Clopyralid	0.3	71	17	30	13	0	3
Clopyralid	0.6	22	26	18	0	0	0
Picloram	0.3	50	35	27	1	1	0
Picloram	0.6	75	47	18	7	0	0
Triclopyr + picloram	0.6 + 0.6	65	60	20	15	1	2
Clopyralid + picloram	0.3 + 0.3	62	46	32	18	3	2
Clopyralid + picloram	0.3 + 0.6	61	32	25	4	0	0
Clopyralid + picloram	0.6 + 0.6	60	38	15	3	0	0
2,4,5-T + picloram	0.6 + 0.6	76	74	32	0	5	2
Dicamba + triclopyr	0.6 + 0.6	76	30	14	8	0	0
LSD (0.05)	—	17	19	33	15	7	7

Table 4.18. Percentage of canopy reduction and apparent mortality of lime pricklyash at various times after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands on May 15, 1985, on the Driscoll Foundation near Alice, Texas.

Herbicide(s)	Rate(s) (kg/ha)	Canopy reduction			Apparent mortality	
		Months after treatment				
		3	15	26	3	15
None	—	17	8	3	0	0
Triclopyr	0.6	76	24	10	8	1
Triclopyr	1.1	82	39	19	0	0
Clopyralid	0.6	11	6	10	0	0
Dicamba	1.1	44	18	10	8	2
Dicamba + triclopyr	0.6 + 0.6	59	35	18	6	8
Triclopyr + picloram	0.6 + 0.6	92	47	40	28	2
Dicamba + picloram	0.6 + 0.6	73	44	11	6	1
Clopyralid + picloram	0.3 + 0.3	51	24	21	2	1
Clopyralid + picloram	0.3 + 0.6	72	34	14	25	1
Clopyralid + picloram	0.6 + 0.6	75	44	28	8	4
Picloram	0.6	47	45	16	7	3
LSD (0.05)	—	27	22	13	NS	7

NS = no significant difference among treatments.

Table 4.19. Percentage of canopy reduction and apparent mortality of lime pricklyash on August 13, 1987, following aerial application of selected herbicide mixtures (1:1) at 1.1 kg/ha to mixed-brush stands on May 13, 1986, on La Copita Research Area near Alice, Texas.

Herbicides	Canopy reduction	Apparent mortality
None	3	0
2,4,5-T + picloram	52	9
Dicamba + picloram	69	11
Triclopyr + picloram	77	19
Clopyralid + picloram	43	5
LSD (0.05)	20	13

Table 4.20. Percentage of canopy reduction and apparent mortality of brasil at various times after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands on May 24, 1984, on the Driscoll Foundation near Alice, Texas.

		Canopy reduction			Apparent mortality		
		Months after treatment					
Herbicide(s)	Rate(s) (kg/ha)	4	15	27	4	15	27
None	—	9	4	10	0	0	0
Triclopyr	0.6	16	4	6	0	0	0
Triclopyr	1.1	26	12	5	1	0	0
Clopyralid	0.3	44	10	16	3	0	0
Clopyralid	0.6	7	8	13	0	0	0
Picloram	0.3	25	7	21	1	0	1
Picloram	0.6	30	12	11	0	0	0
Triclopyr + picloram	0.6 + 0.6	46	14	10	13	0	0
Clopyralid + picloram	0.3 + 0.3	48	17	23	10	0	1
Clopyralid + picloram	0.3 + 0.6	38	17	18	0	0	0
Clopyralid + picloram	0.6 + 0.6	41	15	6	3	4	0
2,4,5-T + picloram	0.6 + 0.6	63	41	14	13	0	0
Dicamba + triclopyr	0.6 + 0.6	36	26	19	0	0	4
LSD (0.05)	—	29	NS	NS	NS	NS	NS

NS = no significant differences among treatments.

Table 4.21. Percentage of canopy reduction and apparent mortality of brasil at 15 and 27 months after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands in 1985 at three locations in South Texas.

		Canopy reduction		Apparent mortality	
		Months after treatment			
Herbicide(s)	Rate(s) (kg/ha)	15	27	15	27
None	—	5	2	1	0
Triclopyr	1.1	9	7	0	0
Clopyralid	0.6	2	1	0	0
2,4,5-T + picloram	0.6 + 0.6	20	—	0	—
Triclopyr + picloram	0.6 + 0.6	31	4	0	0
Clopyralid + picloram	0.3 + 0.6	40	7	1	0
Clopyralid + picloram	0.6 + 0.6	37	9	4	0
Dicamba + picloram	0.6 + 0.6	29	7	4	0
LSD (0.05)	—	12	NS	NS	—

NS = no significant differences among treatments.

Table 4.22. Percentage of canopy reduction and apparent mortality of brasil on August 13, 1987, following aerial application of selected herbicide mixtures (1:1) at 1.1 kg/ha to mixed-brush stands on May 13, 1986, on La Copita Research Area near Alice, Texas.

Herbicides	Canopy reduction	Apparent mortality
None	0	0
2,4,5-T + picloram	4	0
Dicamba + picloram	21	0
Triclopyr + picloram	18	0
Clopyralid + picloram	5	0
LSD (0.05)	6	NS

NS = no mean significantly different (LSD = 0.05) from mean of untreated plots.

Table 4.23. Percentage of reduction in green cladophylls and apparent mortality of pricklypear at various times after aerial application of selected herbicides and herbicide mixtures (1:1) at 1.1 kg/ha to mixed-brush stands on May 18, 1983, on the Welder Dobie Ranch near Cotulla, Texas.

	Canopy reduction		Apparent mortality		
	Months after treatment				
Herbicide(s)	15	27	15	27	38
None	0	0	0	0	6
2,4,5-T	15	25	0	20	58
Triclopyr	15	22	0	1	35
Picloram	92	70	0	43	90
2,4,5-T + picloram	95	85	0	65	93
Triclopyr + picloram	85	84	0	40	89
Clopyralid + picloram	96	71	0	74	97
LSD (0.05)	13	19	—	18	21

Table 4.24. Percentage of reduction in green cladophylls and apparent mortality of pricklypear at various times after aerial application of selected herbicides and herbicide mixtures to mixed-brush stands on May 24, 1984, on the Driscoll Foundation near Alice, Texas.

		Canopy reduction			Apparent mortality	
		Months after treatment				
Herbicide(s)	Rate(s) (kg/ha)	4	15	27	15	27
None	—	6	17	50	2	14
Triclopyr	0.6	30	40	77	4	15
Triclopyr	1.1	27	46	35	12	10
Clopyralid	0.3	21	40	68	8	26
Clopyralid	0.6	50	42	74	8	33
Picloram	0.3	50	75	93	16	59
Picloram	0.6	61	78	99	42	90
Triclopyr + picloram	0.6 + 0.6	42	70	94	40	82
Clopyralid + picloram	0.3 + 0.3	42	69	96	34	75
Clopyralid + picloram	0.3 + 0.6	59	92	97	57	81
Clopyralid + picloram	0.6 + 0.6	51	82	94	41	71
2,4,5-T + picloram	0.6 + 0.6	70	77	99	44	84
Dicamba + triclopyr	0.6 + 0.6	28	22	14	2	1
LSD (0.05)	—	36	37	17	34	22

V. Influence of Pre- and Post-Application Management Practices on Efficacy of Pelleted Herbicides

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Introduction

Many of the woody plants that dominate rangeland on the South Texas Plains aggressively resprout following top removal. No technology offers effective long-term, broad-spectrum brush control as a one-time treatment. Furthermore, the effective lifespan of many first-time brush control treatments is not long enough to pay for the initial investment (Whitson and Scifres 1980). Therefore, low-cost follow-up treatments must be periodically applied to maintain improvement attained with the initial treatment.

Brush is a fundamental element of wildlife habitat (Inglis et al. 1986), although wildlife species may differ in their requirements for height, amount, and interspersion of brush cover. Leasing trespass rights for hunting can be a significant source of income from Texas rangeland (Whitson et al. 1977). Wildlife habitat concerns need to be carefully planned into the chronology of brush treatments along with livestock grazing.

Our objectives were to compare a series of follow-up treatments on mixed-brush regrowth to create alternative management scenarios depending upon the management objectives for the area.

Materials and Methods

The experimental area near Cotulla (approximately 175 km south of San Antonio, Texas; Figure 1.2) was characterized by undisturbed and roller-chopped brush dominated by blackbrush acacia and pricklypear and by lesser amounts of screwbean mesquite, honey mesquite, tasajillo, and several other species. Roller chopping was completed approximately 1 year before herbicide applications, and brush regrowth was about 0.6 m tall at the time of application. Treatments applied to both undisturbed and roller-chopped brush included none, picloram as a foliar spray at 1.1 kg/ha, picloram pellets at 2.2 kg/ha, and tebuthiuron pellets at 2.2 kg/ha. Pelleted herbicides were applied on May 11, and the foliar spray was applied on June 1, 1983. Percentage of brush canopy change was monitored using the line intercept method (Canfield 1941) along a permanent 30.4-m transect established across the diagonal of each plot.

Experiments were established in 1983 and 1984 on La Copita Research Area in brush stands characterized by regrowth resulting from chaining two ways and stacking and burning of stacked brush piles in the winter of 1978-79. Dominant brush species on areas treated in 1983 were honey mesquite, lime pricklyash, and false broomweed. Several scenarios were evaluated to determine the best approach to continued management relative to pasture objectives. Treatments included none, tebuthiuron pellets at 2.2 kg/ha, picloram as a foliar spray at 1.1 kg/ha, and shredding to a 5-cm stubble height. Two replicates of each treatment were applied to 61- by 122-m plots in spring 1983. Herbicide-treated and shredded plots were subsequently divided, and prescribed burns were applied to half of each plot. Percentage of brush canopy change was monitored using the line intercept method along a permanent 30.4-m transect in each plot. No pretreatment data were taken on the 1983 experiment, so means from treatments were compared with untreated plots. Evaluation dates were October 1984, June 1985, and August 1986.

Dominant brush species on the area treated in 1984 included honey mesquite, spiny hackberry, and whitebrush. Treatments were tebuthiuron pellets at 2.2 kg/ha, picloram as a foliar spray at 1.1 kg/ha, shredding at 4 and 6 years after chaining, burning at 4 and 6 years after chaining, and shredding and burning in combination with all the aforementioned treatments, each applied to two replicates on 45- by 61-m plots. Herbicides were applied in spring 1984. Shredding and burning treatments were applied during the winter of their respective treatment years. Percentage of brush canopy change was monitored using the line intercept method along two permanent 30.4-m transects in each plot. Percentage of live brush canopy intercept was measured before treatment and again in October 1984, May 1985, and July 1986. Means for treatments were compared with pretreatment data for each plot.

In addition, herbaceous standing crop was estimated by clipping 10 equidistantly spaced, 0.25-m^2 quadrats along the diagonal of all plots in October 1984 and May 1985. Quadrats were clipped to a uniform 2.5-cm stubble height, separated into grasses and forbs, oven dried, and weighed.

Previous research demonstrated that regrowth brush was more desirable for production and hunting of bobwhite quail compared with mature, undisturbed mixed brush (Lovestrand 1986). Lovestrand's (1986) research report was published after the inception of our primary studies but before our evaluations of quail habitat. Quail density was higher, more coveys were flushed, and more quail were harvested with fewer shots fired in the chained pasture (Lovestrand 1986). This study, however, was conducted when the regrowth brush was at or near optimal stage for these activities (i.e., less than 1.5 m tall and easily walked through). Continued management is necessary to maintain regrowth brush in an optimal state (Scifres 1980).

All plots within the 1984 experiment were evaluated in the summer of 1986 for habitat quality for bobwhite quail. Two workers ranked each plot according to structure criteria adapted from Guthery (1986) (Table 5.1). Scores for each category were averaged between replicates for each treatment. Recommendations derived from this survey were based on an entire pasture being treated and the landscape taking on the perspective of a treated plot.

Results and Discussion

Change in Woody Canopy Cover

Roller chopping alone was the only treatment that increased canopy cover of woody plants during the 3-year evaluation of the experiment near Cotulla (Table 5.2). Simple top removal of most woody plants causes resprouting from remaining stem segments, roots, and crowns. These resprouts typically increase stem density and canopy cover of resprouting species (Scifres 1980). However, total canopy cover and cover of blackbrush acacia did not differ among herbicide treatments or between treated and undisturbed brush during 1984. The lack of differences in woody cover among herbicide treatments in another study was attributed to an extended dry period in South Texas during 1983 and through part of 1984 (Scifres and Koerth 1986). Drought conditions also probably account for the lack of difference in treatments in this study during 1984.

Picloram pellets effectively controlled pricklypear and prevented resprouting or re-establishment for the duration of the evaluations (Table 5.2). This supports previous research showing that broadcast applications of picloram pellets at 1.1 to 2.2 kg/ha are effective for controlling pricklypear (Scifres 1980).

Table 5.1. Evaluation criteria of quail habitat structure used to assess the impact of various brush management treatments on quail habitat on La Copita Research Area near Alice, Texas.

Structure	Habitat value	Category	Score
Bare ground—free of growing plants and litter			
	<	<30%	1
	Optimum	30-60%	2
	>	>60%	3
Brush cover—percentage of area covered by woody canopy			
	<	<5%	1
	Optimum	5-15%	2
	>	15-25%	3
	Excessive	>25%	4
Brush height—amount of woody species from 0.3 to 1.5 m tall with low, spreading branches			
	<	<5%	1
	Optimum	5-15%	2
	>	15-25%	3
	Excessive	>25%	4
Nesting cover—grass clumps at least 20 cm high and 30 cm in diameter			
	<	<1%	1
	Optimum	1-3%	2
	>	>3%	3
Brush diversity—number of brush species			

Pricklypear was unaffected by picloram the year after foliar application but was effectively removed by the second year.

Picloram was equally effective as a foliar spray or when applied as pellets to undisturbed blackbrush acacia (Table 5.2). Conversely, pelleted formulations of picloram and tebuthiuron were superior to picloram sprays for blackbrush canopy reduction in 1986 on areas that had been roller chopped the year before herbicide application.

Because no pretreatment data were taken on the experiment established in 1983 on La Copita, differences in canopy cover after treatment could be a result of different amounts of each brush species that were available in each plot for treatment. However, the experimental area was chosen in part because of its uniformity of brush coverage; therefore, relative species composition probably was basically the same for each plot.

By October 1984, only picloram alone and prescribed burning treatments had not reduced total woody canopy cover on plots treated in 1983 on La Copita (Table 5.3). We attributed this primarily to the large amount of false broomweed apparently unaffected by these treatments. False broomweed was not reduced by burning alone until June 1985. On the picloram treatment, false broomweed significantly increased in canopy coverage by August 1986 compared with untreated plots. All treatment effectively reduced lime pricklyash cover through the second growing season, but the woody plant had recovered by subsequent evaluation dates. Honey mesquite appeared to be effectively controlled by picloram, picloram followed by burning, and tebuthiuron followed by burning. Because of the relatively small amount of mesquite coverage, however, slight reading errors would magnify apparent differences and make these results inconclusive.

Because of low amounts of fine standing fuel, the prescribed burn was spotty and did little damage to the brush canopy in the experiment established in 1984 on La Copita. A continuous flame front could not be sustained, and clumps of grass surrounding brush had to be ignited separately. As a result, brush canopy actually increased in total cover compared with untreated areas by May 1985, and this increase continued through July 1986 (Table 5.4). Whitebrush appeared especially stimulated by the spotty burn and increased by more than 150 percent of the pretreatment cover by July 1986. A burn in January 1986, on the areas previously burned in 1984, was more successful because of better fuel conditions; thus the total woody cover was reduced to near the level of untreated sites. Conversely, the single burn in January 1986 of previously untreated areas reduced total canopy cover significantly compared with burning in 1984 only and burning in 1984 and 1986 and was equal to shredding of the plots that had been burned in 1984, relative to brush cover reduction.

Table 5.2. Percentage of change in brush canopy cover following various brush management treatments applied to undisturbed brush and brush roller chopped in spring 1983 on the Cameron Ranch near Cotulla, Texas. Data are shown in sets for 1984, 1985, and 1986.

	Undisturbed*				Roller chopped				
Species	None	PS	PP	TB	None	PS	PP	TB	LSD (0.05)
(1984)									
Blackbrush	-52.2	-75.3	-79.9	-64.0	+8.4	-67.5	-80.1	-81.4	35.4
Pricklypear	+407.8	+272.9	-100	+293.3	+65.3	+335.5	-100	+35.6	39.1
Other spp.	-6.7	-22.7	-34.5	+6.2	+124.8	+39.0	-6.7	+10.1	82.7
Total cover	-38.9	-61.9	-67.8	-36.9	+39.7	-33.9	-54.4	-43.9	40.6
(1985)									
Blackbrush	-4.3	-61.8	-64.8	-48.6	+58.4	-48.3	-16.1	-46.9	68.5
Pricklypear	+165.2	-100	-100	+549.6	+114.1	-100	-100	+185.1	43.1
Other spp.	+8.3	-55.6	-12.8	+50.9	+70.7	-38.9	-23.5	+220.8	64.9
Total cover	+2.1	-63.9	-51.8	-9.8	+65.4	-43.9	-55.2	-18.9	46.4
(1986)									
Blackbrush	-28.3	-64.8	-61.8	-24.4	+9.9	-46.7	-90.7	-77.1	34.4
Pricklypear	+553.7	-100	-93.7	+529.9	+345.3	-100	-100	+280.5	43.2
Other spp.	+19.0	-31.3	-1.1	+24.4	+34.3	-37.8	-29.7	+241.5	73.9
Total cover	-6.0	-62.8	-57.8	-3.9	+59.0	-41.1	-69.1	-14.3	49.9

* PS = picloram spray; PP = picloram pellet; TB = tebuthiuron pellet.

Table 5.3. Percentage of brush canopy cover following various brush management treatments in spring 1983 for control of regrowth brush on La Copita Research Area near Alice, Texas.

Treatment*	October 1984				June 1985				August 1986			
	FB	LPA	HM	Total	FB	LPA	HM	Total	FB	LPA	HM	Total
None	22.4	8.1	3.0	39.5	28.7	14.0	6.9	58.7	30.0	16.0	2.3	56.1
Shred	4.0	2.7	1.1	15.5	9.6	3.6	2.8	26.9	8.1	8.9	5.1	35.3
Picloram	27.9	2.3	0	33.0	39.9	6.6	1.6	53.7	49.7	6.8	0	62.3
Tebuthiuron	0.4	1.4	2.0	4.2	0.7	1.8	6.3	10.4	0	9.2	7.6	20.6
Burn	15.5	3.0	3.8	28.1	16.5	4.9	9.8	36.5	17.9	6.5	7.5	37.3
Shred burn	1.5	3.9	2.0	10.4	3.0	3.7	2.6	11.9	4.4	2.3	2.0	10.0
Picloram burn	5.3	3.1	0.3	13.4	5.0	9.5	0	18.8	7.3	4.8	0	17.3
Tebuthiuron burn	0	1.7	1.0	3.2	0	1.3	0	2.0	0.4	3.5	0	4.8
LSD (0.05)	8.9	3.9	2.3	9.3	8.4	8.7	5.5	14.6	8.7	10.5	5.4	16.2

*FB = false broomweed; LPA = lime pricklyash; and HM = honey mesquite.

The tebuthiuron treatment reduced total brush canopy to about one-third of the pretreatment cover, and woody cover remained at that level through May 1985 following establishment of the experiment in 1984 (Table 5.4). By July 1986, there was a slight trend toward increasing shrub cover, primarily mesquite, which is resistant to tebuthiuron at 2.2 kg/ha or less (Scrifres et al. 1979). Subsequent burning or shredding or tebuthiuron-treated areas tended to further reduce the canopy, but differences were not significant. Both spiny hackberry and whitebrush were effectively controlled by tebuthiuron 2 years after treatment, similar to results reported by Scifres et al. (1979).

Picloram reduced total canopy cover by more than 90 percent through May 1985 (Table 5.4). Canopy cover reduction was significantly greater than with any other treatment throughtout this period. By July 1986, canopy cover had begun to recover and was no longer significantly different from that on plots treated with tebuthiuron. Burning or shreddding of the picloram-treated areas in the winter of 1986 tended to reduce further the woody canopy, but cover was not significantly different from that on plots treated with picloram alone. Picloram is an effective herbicide for controlling a broad spectrum of woody plants, particularly if applied as a foliar spray (Scifres 1980), which most likely accounts for the high initial defoliation.

Shredding in 1984 reduced total canopy cover more than 52 percent by the first growing season, but a quick recovery was evident by May 1985 extending through July 1986 (Table 5.4). Shredding removes only the aerial part of the plant and kills few if any plants. Hamilton et al. (1981) showed that honey mesquite can regain 50 percent of its original height in less than 5 months following shredding and that spiny hackberry and whitebrush attain more than 50 percent pretreatment height within 10 months. Subsequent burning or shredding in 1986 of areas shredded in 1984 decreased canopy cover, but results were not significant.

Repeated top removal by shredding induces a change in the growth form of woody plants capable of resprouting (Scifres 1980). Specifically, the number of stems typically increases and the plant assumes a more decumbent growth form, thereby increasing the amount of canopy cover. Although shredding may produce short-term beneficial effects (e.g., sprouts become more accessible to livestock and wildlife, and some herbaceous vegetation is released), these effects are short lived depending upon site potential, species composition, and rainfall (Mutz et al. 1978). For example, shredding in 1984 and 1986 increased whitebrush canopy by July 1986 to more than 400 percent compared with pretreatment levels

Table 5.4. Percentage of change in brush canopy cover following various brush management treatments in spring 1983 for control of regrowth brush on La Copita Research Area.

	October 1984				May 1985				July 1986			
Treatment*	SH	WB	HM	Total	SH	WB	HM	Total	SH	WB	HM	Total
None					-12.1	-17.3	15.3	0.6	20.7	16.2	24.5	22.4
Burn 1984	15.9	7.8	-15.7	-0.9	16.4	36.0	36.0	20.2	21.3	154.8	22.1	46.3
Burn 1986									-26.5	0.9	-59.7	-19.5
Burn 1984, 1986									19.4	16.4	25.7	29.5
Burn 1984, shred 1986									40.0	36.1	-36.3	-25.0
Tebuthiuron 1984	-77.7	-95.7	-61.2	-66.2	-99.4	-100	-25.0	-65.6	-89.0	-100	-52.1	-50.3
Tebuthiuron 1984, burn 1986									-100	-98.2	-52.2	-52.7
Tebuthiuron 1984, shred 1986									-98.6	-100	-97.3	-88.2
Picloram 1984	-99.2	-100	-100	-91.8	-97.0	-95.5	-95.6	-91.7	-91.6	-93.8	-81.8	-72.8
Picloram 1984, burn 1986									-96.4	-100	-99.1	-90.6
Picloram 1984, shred 1986									-95.9	-81.0	-100	-89.0
Shred 1984	-47.2	-43.4	-55.0	-52.8	-49.2	30.4	20.9	-37.9	-47.5	63.8	51.4	-21.2
Shred 1986									-58.6	-10.7	-30.8	-39.7
Shred 1984, burn 1986									-49.7	79.9	-65.5	-38.3
Shred 1984, shred 1986									-54.5	401.9	-49.3	-60.5
LSD (0.05)	22.4	40.4	81.5	12.4	16.2	25.1	14.2	19.4	13.8	58.2	44.7	15.5

*SH = spiny hackberry; WB = whitebrush; HM = honey mesquite; total = total live woody canopy cover.

(Table 5.4). Shredding, however, may be an acceptable alternative to suppress brush for a short period until financial or time constraints can be overcome to apply a more effective treatment.

Follow-up treatment interval also varies with range site, species composition, and rainfall. These data, however, suggest that a 2-year interval may be too short to obtain significant results compared with the original treatment. Mutz et al. (1978) suggested shredding at 3- to 5-year intervals for maintenance of mixed-brush stands after mechanical treatment on the Coastal Prairie. Because of better initial control with herbicide treatments compared with shredding, a 5- to 6-year interval may be appropriate for prescribed burning following herbicide application.

Production of Herbaceous Vegetation

Picloram was the only treatment that significantly increased grass standing crop the first growing season following application in 1984 on La Copita (Figure 5.1). By May 1985, however, both herbicide treatments produced significantly more grass, picloram-treated areas maintaining the highest production. There was no advantage to burning and shredding relative to grass production over no treatment either the first or second growing season.

Forb standing crop was significantly increased by shredding during both the first and second growing season following treatment (Figure 5.1). Tebuthiuron application and burning tended to reduce forb production the first growing season although results were not significantly different from no treatment. Picloram significantly reduced forb production the first growing season. Most broadleaf plants are highly susceptible to picloram although effects are not as long lasting for forbs as for woody species (Scifres 1980). By the second growing season in May 1985, forb standing crop on picloram-treated plots was no different from that on untreated plots. Burned plots and shredded plots produced significantly more forbs than did untreated plots.

Picloram-treated plots clearly produced more herbage (grass plus forbs), primarily attributable to increased grass production, than did other treatments (Figure 5.2). Standing crops of total herbage on tebuthiuron-treated plots were the next greatest by the second growing season. Burning and shredding treatments yielded equal total herbage standing crops and significantly increased herbage production over no treatment during the second growing season.

Treatment Effects on Quail Habitat

Herbicide treatments in the experiment installed in 1984 on La Copita tended to reduce brush diversity, whereas mechanical and burning treatments maintained species numbers very near that of untreated plots except for the shred/burn sequence (Table 5.5). Possibly some mortality of species was caused by burning the smaller regrowth plants following shred-

Table 5.5. Evaluation of bobwhite quail habitat structure following various brush management treatments in spring 1984 for control of regrowth brush on La Copita Research Area near Alice, Texas.

Treatment	Habitat structure				
	Bare ground	Nesting cover	Brush cover	Brush height	Brush species (no.)
None	2-*	2+	4	4	10
Burn 1984	2-	2+	4	4	8
Burn 1986	2	2	4	4	8
Burn 1984, 1986	2	2-	4	3+	12
Burn 1984, shred 1986	1	3	3+	3+	9
Tebuthiuron 1984	1	3	2+	2+	7
Tebuthiuron 1984, burn 1986	2	2+	2+	2+	6
Tebuthiuron 1984, shred 1986	1	3	3	2-	7
Picloram 1984	1	3	2+	2	8
Picloram 1984, burn 1986	2-	3	2-	2-	8
Picloram 1984, shred 1986	1	3	2	2	5
Shred 1984	1	3	4	4	11
Shred 1986	2-	2+	3+	3	10
Shred 1984, burn 1986	2	2+	3+	3+	7
Shred 1984, 1986	1	3	3	3	8

* Minus values are low within the range of values for that category. Plus values are high within the range of values for that category (see Table 5.1).

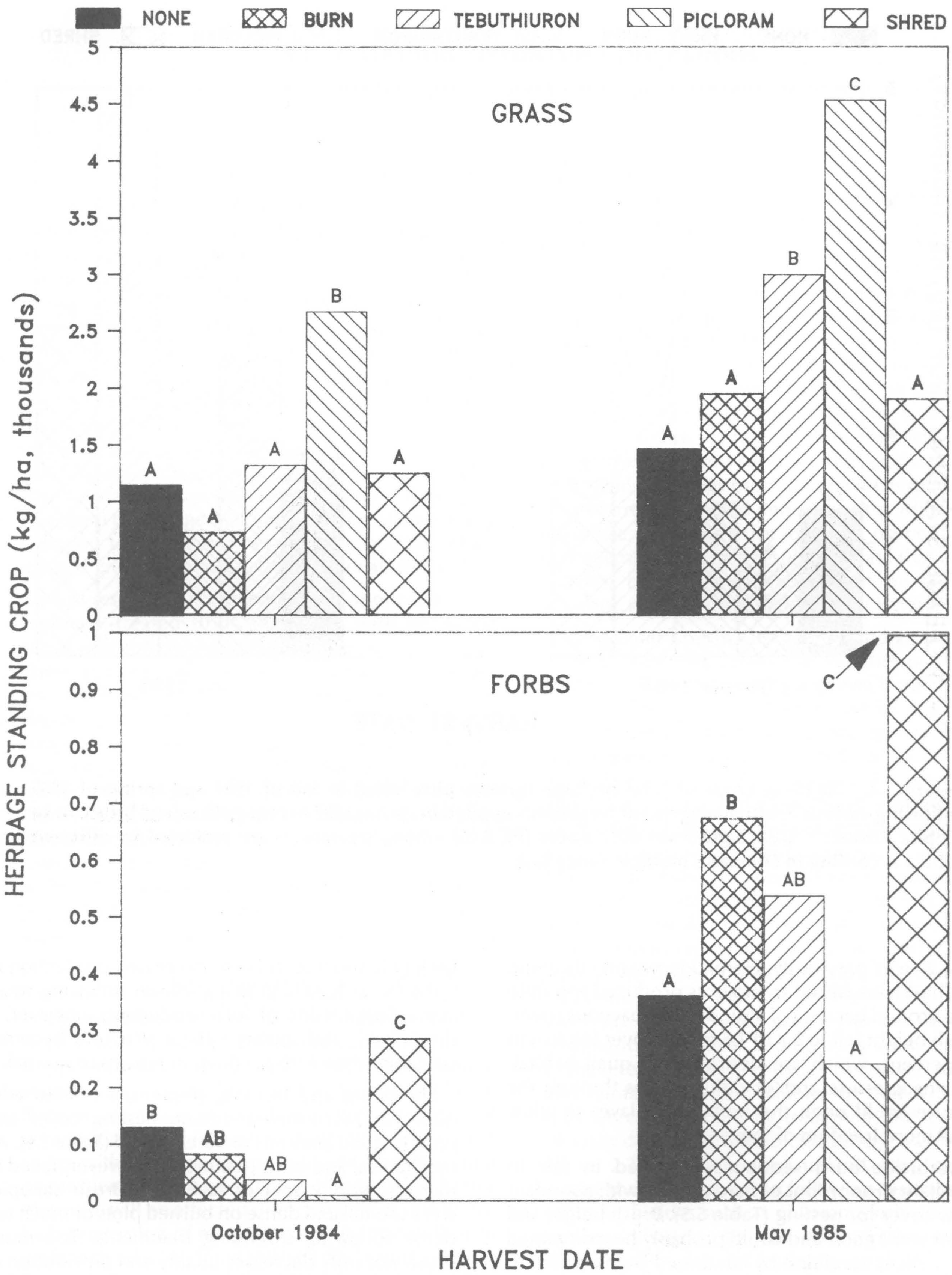

Figure 5.1. Standing crops of grasses and forbs following various brush management treatments in spring of 1984 for control of regrowth brush on La Copita Research Area. Significant differences ($P \leq 0.05$) among treatments are represented by different letters according to Duncan's multiple range test.

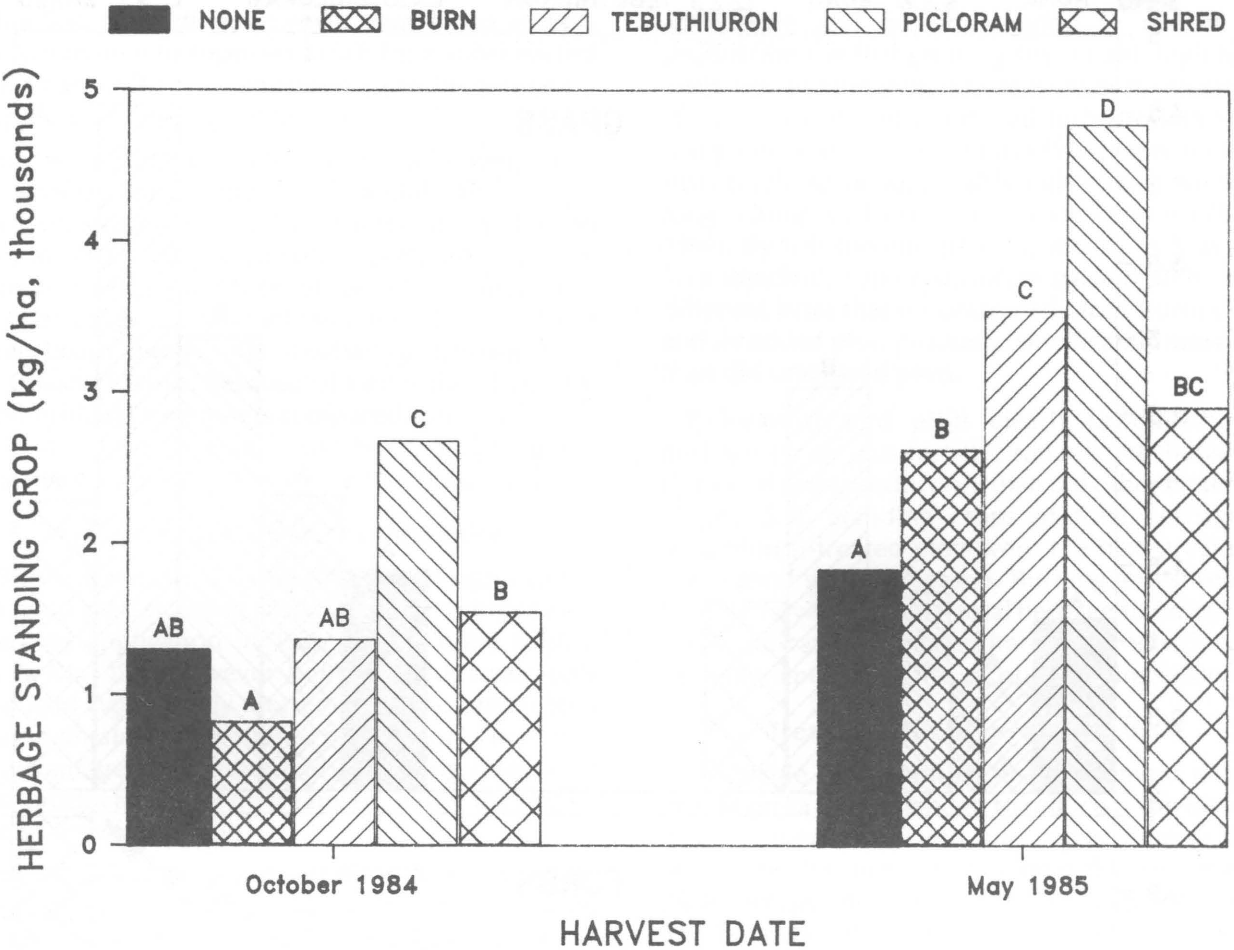

Figure 5.2. Standing crops of total herbage (grasses plus forbs) in fall of 1984 and spring of 1985 following various brush management treatments applied in spring 1983 to regrowth mixed brush on La Copita Research Area. Significant differences (P≤0.05) among treatments are indicated by different letters according to Duncan's multiple range test.

ding 2 years previously. Herbicide treatments alone and herbicide/shred treatments produced too little bare ground because of abundant herbaceous cover. Brush height fell to 0.3 to 1.5 m and cover fell to 5 to 15 percent, which are desirable for quail habitat. Grazing pressure and/or disking strips through the pasture could open the herbaceous layer to allow quail more freedom of movement.

Herbicide/burn sequences resulted in fair to excellent proportions of bare ground with abundant grass cover for nesting (Table 5.5). Brush height and cover were good and could probably be maintained in excellent condition by continued burning at 3- to 5-year intervals. Overall, herbicide/burn sequences resulted in the highest quality habitat according to our structure criteria, except for a lower species diversity of woody plants. The major limitation to herbicide treatments is the decreased production of forbs for at least a growing season following treatment. Suppression of forb production, however, is short lived, and quality habitat structure becomes available when forb production returns to normal.

Shredding and burning sequences yielded adequate to more-than-adequate nesting cover and poor to good amounts of bare ground (Table 5.5). All mechanical and burn treatments, however, failed to manage woody species favorably. Brush canopies were too tall and dense on burned plots or much too dense following shredding treatments. Too much brush not only decreases quality and distribution of nesting cover and production of seeds by forbs but also detracts from the quality of the hunting experience (Guthery 1986).

VI. Patterned Herbicide Applications

C. J. Scifres and B. H. Koerth

Introduction

After decades of controversy over the compatibility of herbicidal brush control and wildlife management, the belief that herbicides may be used for wildlife management without long-term detrimental effects is now generally accepted. The key to successful use of herbicides on areas where wildlife management is an objective is development of the appropriate pattern of treatment. As much as 80 percent of a given management unit may be treated with herbicides without lasting negative effects on populations of white-tailed deer and various other game species (Beasom and Scifres 1977). More importantly, part treatment of management units is often economically superior to complete treatment, especially when game is given a real value (Whitson et al. 1977).

Most research has compared strip application (i.e., herbicide-treated strips alternating with untreated strips) with complete treatment of management units. These patterns are designed to achieve maximum possible brush control in the treated strips, and their design is regular (i.e., predetermined widths for treated strips regularly alternated with untreated strips of predetermined widths). Any given management unit is composed of several to many range sites (i.e., varying vegetation-soil-topographic combinations). Because strip patterns are site indiscriminate, treatment does not depend upon their location within the management unit. Thus, the optimum balance of treated and untreated sites may not be achieved, even with careful planning.

Site Interactions

The importance of site can be couched in terms of the habitat needs of both wild and domestic animals. Range sites vary in their capability to produce vegetation that provides food and cover for animals. Because vegetation on specific sites varies in botanical composition, the impact of herbicide application varies with site. For example, a site having a high proportion of the woody cover composed of honey mesquite will be affected differently from one with a high proportion of mixed-shrub species if both sites were sprayed with clopyralid (see discussion, Chapter IV). In addition, as soil characteristics (e.g., fertility, depth, water-holding capacity) vary with site, so varies the potential for producing both kinds and amounts of grasses and forbs.

In many cases, sites that provide the best habitat for game animals are also desirable for livestock production. Beasom et al. (1982) investigated the impact of site-discriminate treatments on white-tailed deer response by spraying a drainage bounded by upland sites of lesser potential productivity. Discriminate treatment of the honey mesquite drainage neither caused consistent differences in deer use of that habitat nor changed deer use of the pasture containing the sprayed drainage. The authors concluded that the spray had minor impacts on forb populations, did not seriously reduce cover screen, and promoted grass production, which reduced use of preferred deer food items by cattle. Although the drainage accounted for only 20 percent of the management unit, the results indicate that at least a portion of preferred habitat can be sprayed if adjacent, albeit less desirable, habitat is not disturbed.

Scifres and Koerth (1986) proposed an alternative to strip spraying, called the variable-rate pattern (VRP). A VRP is installed by applying herbicide strips in two directions, the second set of strips being applied over the same area but at a right angle to the first (Figure 6.1). They evaluated VRPs using 0, 1.1, and 2.2 kg/ha of tebuthiuron applied to one location and 0, 1.1, 2.2, 3.3, and 4.4 kg/ha to another, both in the Rio Grande Plains. These application rates created an interspersion of shrub-dominated (untreated blocks), shrub-herbaceous (half herbicide rate), and herbaceous-dominated (full herbicide rate) patches across the landscape. Botanical composition and relative ground cover of herbaceous vegetation varied among herbicide dosages, range site, time after treatment, and rainfall. The greatest change within a given site was increased grass cover as a function of treatment. Forb cover and diversity were a function of the interaction of herbicide dosage with range site and rainfall. Forb populations on shallow, gravelly sites were unaffected by treatment, but cover and diversity decreased as herbicide dosage was increased above 2.2 kg/ha on deep upland sites, especially during the growing season following treatment. With other herbicides such as picloram, forb populations can be expected to be reduced at all rates, especially if rates greater than 0.6 kg/ha are applied.

Not all changes in forb populations can be attributed to direct effects of herbicides. On some sites, increase in grass production in response to

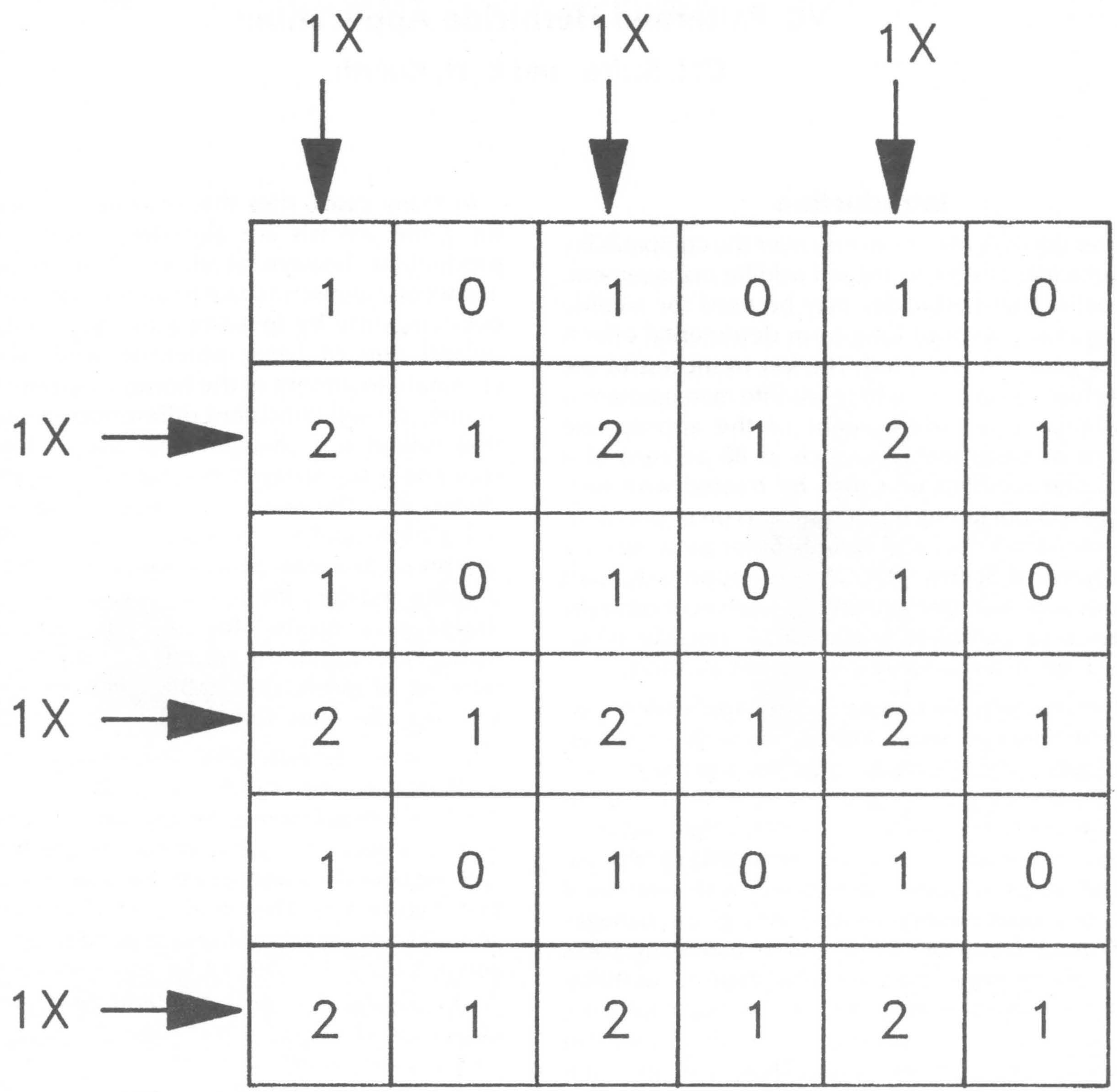

Figure 6.1. Example of generic three-rate variable rate pattern for herbicide application. In this case, 1X equals 1.1 kg/ha.

treatment may also cause some reduction in forb populations (Beasom et al. 1982, Scifres and Koerth 1986). However, forb populations are typically restored within 2 or 3 growing seasons after application of most herbicides.

Figure 6.1 illustrates a generic VRP with treated blocks as squares. Depending on distribution of habitat across the landscape and on objectives for its treatment, treated areas may be rectangular or square. Cost of applying VRPs vary with specific herbicide and design (e.g., block size, distribution of herbicide rates, etc.). Figure 6.1 may be used as an example to contrast costs of herbicide applications. The design includes 36 blocks, 9 of which are treated with the high herbicide rate (2x), 18 treated with the lower rate (1x), and 9 left untreated. Assume a total area of 360 ha (i.e., 36 blocks at 10 hectare each), herbicide cost of $50/ha for the 1x rate, and $12.35/ha for flying cost. Application of the 1x rate in strips to treat 75 percent of the hypothetical pasture would cost $16,834.50 ($62.35 per treated hectare, $46.76/ha pasture wide). Application of the 2x rate in strips (the usual case) would cost $30,334.50 ($84.26/ha on a pasture-wide basis). The VRP would be applied in six strips of 60 ha each at the 1x rate for a cost of $22,446, or $62.35/ha pasture wide. Thus, for this particular case, the VRP on a per-hectare basis would cost 25 percent more than application of strips using the lower rate but 26 percent less than for strips using the higher rate.

Design Considerations

The first consideration in designing a pattern is the distribution of habitats and their relative importance to the targeted management unit. For example, a management unit may be composed of habitats ranging from mesic drainages to shallow ridges separated by upland (intermediate) sites. Each of these sites have specific utilities for different species, and their use may depend on the relative positions of one site to the other. All wildlife species considered for management must be identified before the treatment is implemented because each species has individual habitat needs and responds to specific changes in varying ways. Given that most rangeland supports a variety of wildlife species, both game and nongame, the needs of each species under consideration may have to be prioritized. Treatments that benefit one species may negatively impact another.

Animals do not distribute themselves randomly or regularly across an area. They tend to cluster in and around areas that provide for their needs. These critical areas may be filled to capacity. In such cases, for a treatment to do no harm to a population, critical habitat needs to be preserved. To increase populations, beneficial areas must be created from suboptimal habitat. Thus, some index of habitat based on objective censusing of the population provides information for the decision about the proportion of site to be treated, the kind of treatment, and the location of treatments. During this planning phase, the expertise of a wildlife biologist is needed.

Once the areas for treatment have been selected and located on a working map, ground vegetation surveys should be conducted to ascertain the general composition and structure of the woody stands. Measurements should be of (1) kind and amount of each species because each species differs in its value for rangeland uses as well as its susceptibility to different treatments; (2) stature and growth form because this affects accessibility and nutritive value of the plant as well as its ultimate reaction to a given treatment and indicates kind and amount of screening and shading value; and (3) maturity with respect to mast and browse production. This information is critical to matching treatments to site conditions.

Objectives for treating selected sites may vary considerably. For example, drainage sites with heavy stands of whitebrush may be selected for treatment to thin the understory shrubs and promote herbaceous cover. In such a hypothetical case, it may be desirable to control whitebrush, wolfberry, and shorter-statured shrubs but to leave the overstory species such as honey mesquite and Texas persimmon undamaged. The ultimate goal is to create a more parklike appearance but in a discrete patch. Tebuthiuron pellets applied at 2.2 kg/ha controls whitebrush and various other shrubs but does not damage mesquite, Texas persimmon, pricklypear, and various other species. In most cases, however, selectivity is not perfect, and certain compromises must be considered. For example, tebuthiuron also controls spiny hackberry, a valuable browse species. Thus, the wildlife biologist should consult with a range scientist having expertise in herbicide use during the planning of specific treatments.

If control of honey mesquite is one of the objectives, aerial sprays of dicamba plus picloram, triclopyr plus picloram, or clopyralid plus picloram may be considered. These herbicide mixtures will also control several associated species in mixed-brush stands including pricklypear, spiny hackberry, tasajillo, and, to a lesser extent, blackbrush acacia. From recent research results (see previous chapters), the clopyralid plus picloram mixture controls a higher percentage of honey mesquite than do the other mixtures and may be more appropriate for dense stands of mixed brush where maximum control is desired.

In the study of VRPs by Scifres and Koerth (1986), a constant strip width was used to achieve treated blocks of minimum size to test specific hypotheses. However, design flexibility of VRPs is almost limitless. Different widths of treated and untreated strips, different herbicides applied to different strips, spraying strips in different years, and combinations of herbicide-treated strips with mechanically cleared strips are some alternative patterns that may be considered to take full advantage of the interaction of site features with herbicide selectivity. The ultimate goal in designing any pattern is to promote diversity both structurally and botanically within the treated area.

Specific herbicide and species susceptibility are of paramount importance. Herbicides that are species specific may be used to thin stands of mixed brush or to provide a high level of control on sites dominated by a few species that are highly susceptible to that herbicide. One example is the application of tebuthiuron at 2.2 kg/ha to whitebrush-dominated sites. Herbicides such as picloram plus clopyralid that control a broader spectrum of brush species may be used at low rates to thin patches of brush or to provide maximum control at higher rates in areas dominated by mixed species of brush.

Changes induced by herbicide application are also much more subtle than those induced by mechanical clearing. The most rapid changes occur after application of foliar-active herbicides. Plants defoliate within about 30 days after application; however, branches and trunks of defoliated species remain to provide screening cover and shade. Soil-active herbicides depend upon soil water for transport to the root system and for absorption and translocation to aerial parts of the plant. Defoliation does not adequately occur until rain moves the herbicide into the soil. Furthermore, activity of soil-applied herbicides may be mediated by soil characteristics. Organic matter and clay content greatly affect the response of susceptible plants to tebuthiuron (Duncan and Scifres 1983). Herbicides may also be leached below the rooting zone in very sandy soils. Therefore, timeliness and extent of rainfall combined with site characteristics ultimately determine the extent and activity of soil-applied herbicides. Defoliation may not be complete until two growing seasons following application of tebuthiuron. Advantages of soil-applied herbicides include reduced drift, negligible volatilization, and long application season (Scifres 1980). In addition, cattle tend to prefer grazing tebuthiuron-treated sites (Scifres et al. 1983), so possible interactions of grazing livestock and wildlife need to be considered in pattern design.

Because of the high proportion of resprouting species, rangeland in South Texas has a strong tendency to revert back to a shrub-dominated complex following any brush management method. The need for follow-up treatments should be considered as part of the initial planning. For example, prescribed burning may be selected with anticipated application of burning at 3 to 5 years after herbicide treatment and periodically thereafter as needed. Provisions for proper application of the burns should include distribution and size of patches to be burned. It may be that only those patches treated with herbicide will be capable of producing enough fuel to carry a fire. Deferment from grazing before burning, to build fuel to carry the fire, and after burning, to protect the area until green-up, needs to be built into the grazing program for the treated area. Areas to be burned should be deferred for at least 3 months preburn and 6 weeks to 3 months postburn depending upon rainfall. Animals, both domestic and wild, can be expected to concentrate on the burned areas for at least a growing season following the fires. Therefore, it may be necessary to defer grazing or at least shift some livestock from burned areas to lighten grazing pressure during the hot, dry part of summer. Regrowth on burned areas tends to demand much water and may degrade faster than unburned areas when soil water is deficient.

Economic considerations for herbicide application are discussed in Chapter VII. An objective analysis of expected, comparative returns on the investment in alternative patterning strategies from cattle and deer can be developed for an array of scenarios.

VII. Factors Affecting Economic Performance of Herbicides

C. J. Scifres and W. T. Hamilton

Introduction

Before the 1980's, evaluating potential herbicide treatments on economic bases was relatively difficult. Discussion and decisions to adopt a specific treatment centered largely on treatment cost. Major limitations to developing research information in this regard were size of experiments required, number of studies needed to adequately represent various brush problems, and length of time required (10 or more years) to conduct such research. The scrutiny of 2,4,5-T and the potential for its removal from the marketplace catalyzed interest in developing techniques for evaluating economic performance of herbicides for brush control. As a result, research activity was directed toward creating a production response model that could use expert opinion as well as quantitative data to objectively analyze projected results from herbicide applications.

The Model

The model consists of a production response curve that projects change in livestock production through time following herbicide application (Figure 7.1). The first series of calculations are based on estimates of changes in livestock carrying capacity and include the following:

1. The initial carrying capacity (P_o), which may be used as the real-time value (carrying capacity actually used) or an estimated value that represents appropriate carrying capacity.
2. The maximum expected level of production (P_{max}) and the expected longevity of maximum production (TP_{max}).
3. The time (T_r) required to reach P_{max} after application of a given herbicide at P_o.
4. The expected point in time at which treatment effect is exhausted (TE_o), i.e., carrying capacity returns to pretreatment level (P_o). Time required to reach TE_o is the treatment life, TL.

Thus, the model takes into account the maximum potential change in carrying capacity, the annual change through time, and the length of treatment effectiveness. The investment in treatment must also take into account the impact of time. This is accommodated in analytical terms by applying net-present value analysis to the data, which allows discounting all monetary inputs/outputs to the present time.

Data Needs

Net-present value analysis is employed via partial budgeting techniques, which require two kinds of data. All costs (fixed and variable) and returns are associated with adopting a given alternative.

Examples of costs include the following:

1. Cost of applying the herbicide, including not only herbicide and application but any necessary practices (e.g., grazing deferment) for proper implementation of the practice.
2. Cost of obtaining additional livestock and cost of their maintenance to take advantage of forage released by treatment. This cost may be accrued in purchasing additional animals and/or by retaining additional animals (i.e., reducing sales of animals).
3. Reduced revenues as a result of treatment. A common consideration is potential reduction in hunting revenues precipitated by herbicide application.
4. Interest charged for investment costs in the treatment.

Examples of increased revenues include the following:

1. Increased sales of livestock. Increased product attributable to treatment includes the following:
   a. Increased number of calves for sale arising from the addition of cows and, potentially, from the increase in the number of calves weaned from the cow herd resident at the time of treatment.
   b. Increase in the average selling weight attributable to treatment (i.e., any increment

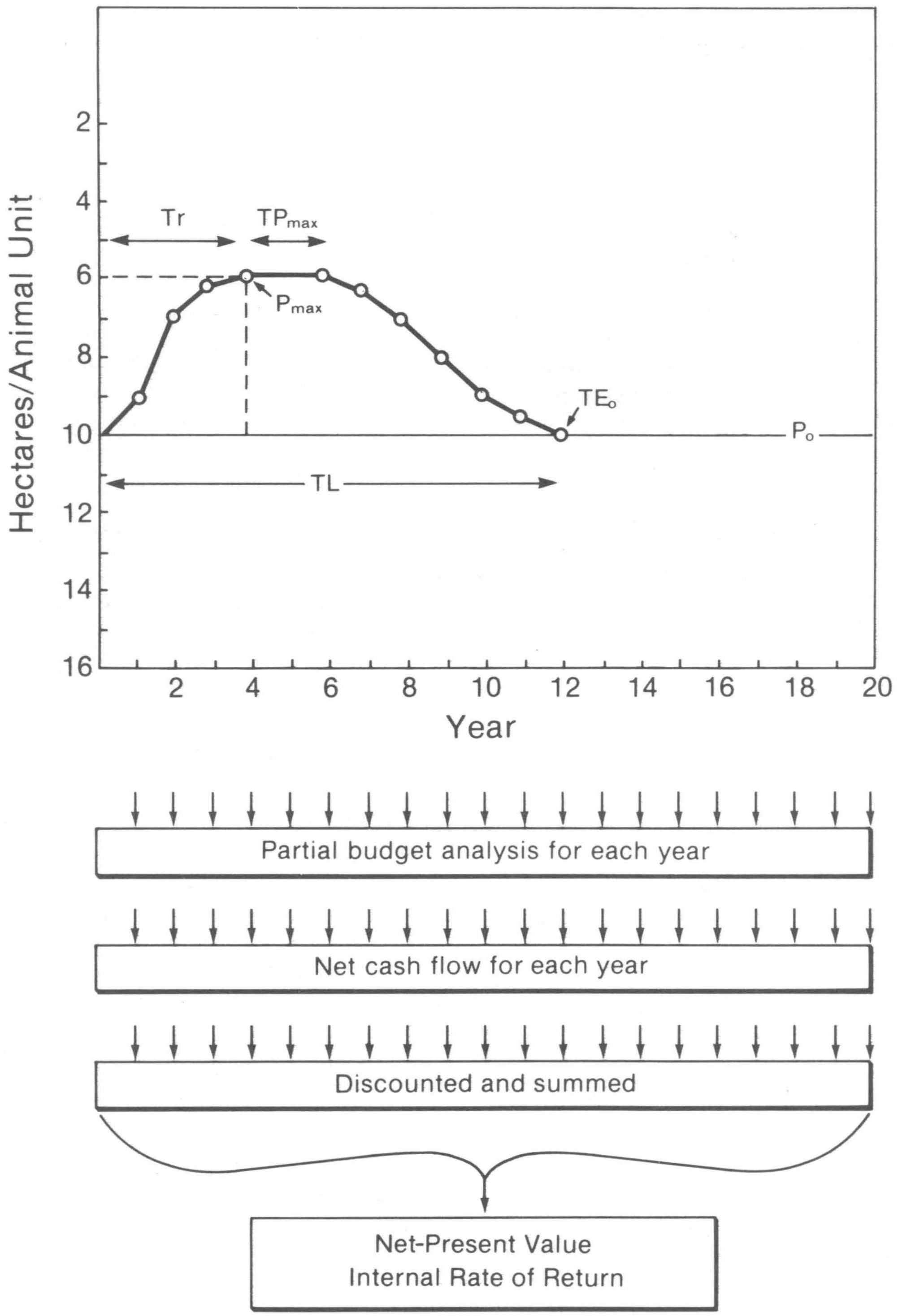

Figure 7.1. Production response curve used to project change in livestock production through time following application of a range improvement method, such as herbicide treatment, and a flow chart of the economic analysis.

increase in weaning weight in contrast to weaning weights from the herd resident at the time of treatment).

2. Other increases in revenue. An example might be increased revenues from quail hunting following spraying.
3. Decreased costs. An example would be reduction in annual variable costs per cow attributable to treatment.

Results of Analyses

Net-present value analyses offer a number of variables important to decision making when selecting an alternative herbicide for brush management:

1. Magnitude, timing, and sources of investments.
2. Magnitude of annual returns through the cash-flow stream.
3. Annual present value and accumulated present value of treatment (technique discounts values to present based on the selected discount rate).
4. Net-present value of treatment at the end of the project (including salvage value) and internal rate of return.

The rate of return is selected according to preference, which is often based on potential returns from alternative investments. To illustrate use of the economic analyses, results from hypothetical case studies are presented as follows.

Hypothetical Case Studies

Scenario 1: Aerial Spraying in Strips

The study area is a 364-ha pasture in the western part (19-31 Precipitation Evaporation Zone) of the South Texas Plains. The range site is all sandy loam in fair range condition.The resource manager perceives that brush is the primary constraint to meeting his/her objective for range improvement to increase herbaceous forage production for livestock. The manager, however, desires to maintain or improve white-tail deer habitat in the pasture.

A survey of the woody plants was conducted to quantify the total brush canopy cover and relative canopy cover by species (Table 7.1). On the basis of the woody species present, their relative importance in the stand, and estimated susceptibility to aerial application of picloram and triclopyr (1:1) at 1.1 kg/ha in the spring, this treatment was selected as a technically feasible alternative for consideration (see Chapters II, III, and IV for discussion of herbicide alternatives).

The decision was made to strip spray 60 percent of the pasture (see Chapter VI for discussion of patterns) in the current year, and a 15-year planning horizon was used to evaluate economic performance of the alternative. No follow-up or maintenance practices were planned. Therefore, no salvage value of the treatment remained after the fifteenth year (Figure 7.2).

Assumptions in the scenario are that one bull will be used to breed 20 cows, replacement cows are valued at $400, and bulls are valued at $800. An average price for steer and heifer calves of $1.764/kg is used each year of the planning horizon. An 8 percent discount rate is used in the analysis.

The economic performance of the treatment based on internal rate of return (IRR) is shown for scenario 1 in Table 7.2. The treatment resulted in an IRR of less than 0 at any cost of the herbicide and application above about $65/ha. The target IRR (discount rate) of 8 percent was not reached at a cost for herbicide and application greater than approximately $44/ha.

Scenario 2: Aerial Spraying and Retreatment

It is common practice in some areas to reapply herbicide treatments at the end of their effective life (TL) or at the point that benefits from the treatment have diminished to pretreatment levels (TE_O).

Scenario 2 assumes the same range site, brush complex, and treatment as those of scenario 1, but the treatment is reapplied in year 10 (Figure 7.2). Carrying capacity, livestock performance, and variable cost benefits are accrued to the end of the planning horizon and beyond as a result of the second treatment. The salvage value of the second treatment is approximately 30 percent at the end of the fifteenth year. Salvage value was calculated as the percentage of benefits from the second treatment that remained at the end of the planning horizon.

Scenario 2 performed slightly better economically than did scenario 1 (Table 7.2). The IRR was positive when treatment cost was about $80/ha; however, the desired 8 percent return on investment was not reached at a cost for the herbicide and application of greater than about $47/ha.

Scenario 3. Aerial Spraying Followed by Prescribed Burning

Two reasons for the economic performance of scenarios 1 and 2 are that benefits from the treatment expired before the end of the planning horizon (scenario 1) and that costs of the second herbicide application were too great to be offset by benefits during the planning horizon and post-planning horizon salvage value (scenario 2).

An alternative to initial treatment only or retreatment with the herbicide would be to use some other low-cost alternative to extend the benefits over a greater portion of the planning horizon. Scenario 3 considers the use of prescribed, cool-season burns in years 5, 9, and 13 to maintain benefits of the herbicide treatment over a 15-year planning horizon. Treatments and costs for scenario 3 are shown in Table 7.3.

We anticipated that the initial burn would not require pre-burn deferment but that the second and third burns would require fall and winter pre-burn deferments (3.5 months). All burns would require 2.5-month post-burn deferments.

Scenario 3 was used to illustrate inputs and outputs for the economic analyses. The response in hectares required per animal unit (ha/AU) and the changes in livestock production expected on the treated portion of the pasture over the planning horizon are shown in Table 7.4. Table 7.5 integrates the treated and untreated portions of the pasture to produce a weighted ha/AU carrying capacity for each year of the planning horizon. Note that the carrying capacity of the untreated portion of the pasture (P_O of 10.12 ha/AU) is assumed to remain stable over the planning horizon. The combined estimated carrying capacity and livestock production response on treated and untreated areas of the pasture are shown in Table 7.6. An average price of $1.764/kg is assumed over the planning horizon for all economic analysis.

Table 7.1. Hypothetical brush complex in the 19-31 PE Zone of the South Texas Plains and estimated susceptibility to picloram and triclopyr (1:1) at 1.1 kg/ha.

Species	Composition (%)	Susceptibility*
Honey mesquite	18	VH
Twisted acacia	8	M
Blackbrush acacia	7	M
Pricklypear	3	VH
Spiny hackberry	3	M-H
Lime pricklyash	2	L
Guayacan	2	L
Texas colubrina	2	L
Whitebrush	1	L
Desert yaupon	1	M
Lotebush	1	M-L
Guajillo	1	M-H
Shrubby blue sage	1	M-L
	50	

*VH = very high (>50% mortality expected), H = high (40-50% mortality expected), M = moderate (20-40% mortality expected), L = low (10-20% mortality expected); see chapter IV.

Table 7.2. Internal rates of return for various costs of the applied herbicide, derived on the basis of responses from the case study scenarios.

Herbicide and application ($/ha)	Scenarios 1	2	3	4	5	6
	%					
98.84	<0	<0	<0	<0	<0	<0
93.90	<0	<0	<0	0.22	<0	<0
88.96	<0	<0	0.07	0.81	<0	<0
84.01	<0	<0	0.81	1.54	<0	<0
79.07	<0	0.07	1.54	2.27	<0	<0
74.13	<0	0.95	2.27	3.00	<0	<0
69.19	<0	1.83	3.15	3.88	<0	<0
64.25	0.59	3.00	4.03	4.91	<0	<0
59.30	2.12	4.17	5.05	5.93	<0	0.95
54.36	3.74	5.49	6.23	7.10	<0	2.12
49.42	5.64	7.10	7.54	8.42	<0	3.44
44.48	7.69	9.01	9.16	9.89	<0	4.91
39.54	10.18	11.21	10.91	11.65	2.27	6.67

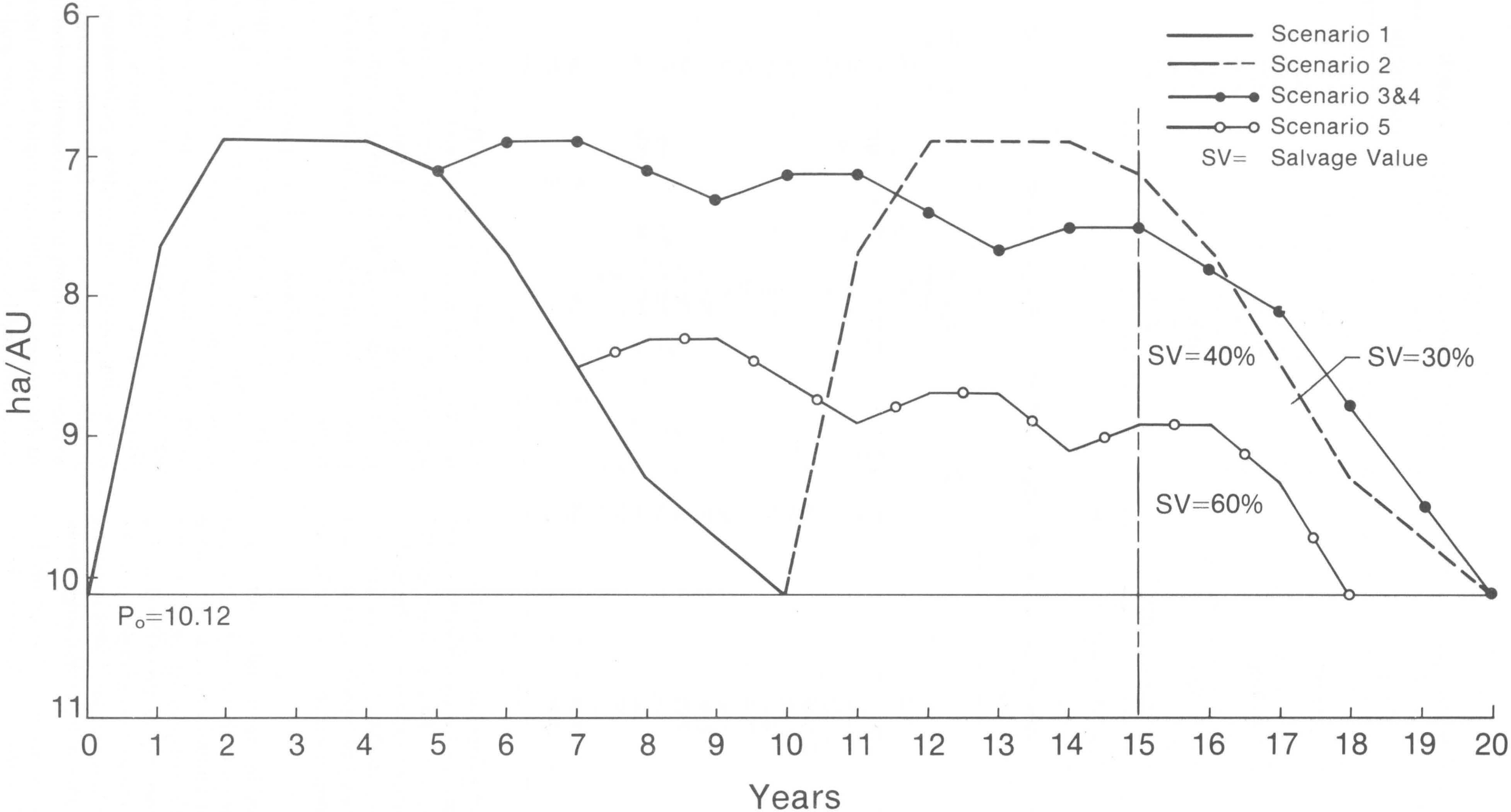

Figure 7.2. Production response curves for various treatment scenarios discussed in text (scenario 1: aerially spraying in strips; scenario 2: aerially spraying with retreatment with same herbicide; scenario 3: aerial spraying followed by prescribed burn; scenario 4: importance of area treated; and scenario 5: importance of treatment life on outcome of economic analysis).

Table 7.3. Sequence and estimated cost of treatments for the hypothetical case study, scenario 3.

Year	Treatment	Units	Cost/unit ($)
0	Spray*	218 ha	64.25
5	Cut firelanes	218 ha	7.41
5	Burn	218 ha	6.18
5	Defer (post-burn)	114 AUM	6.67
9	Run firelines	218 ha	3.71
9	Burn	218 ha	6.18
9	Defer (pre- and post-burn)	266 AUM	6.67
13	Run firelines	218 ha	3.71
13	Burn	218 ha	6.18
13	Defer (pre- and post-burn)	257 AUM	6.67

*Triclopyr plus picloram (1:1) at 1.1 kg/ha total herbicide.

Table 7.4. Estimated carrying capacity and livestock production changes on the treated areas of the hypothetical case study, scenario 3.

Year	ha/AU	Conception rate (%)	Weaning weight (kg)	Variable cost/cow ($)
0	10.12	82	192.8	89
1	7.69	83	195.1	86
2	6.88	84	197.3	84
3	6.88	85	199.6	84
4	6.88	85	199.6	84
5	7.08	85	199.6	84
6	6.88	85	199.6	84
7	6.88	85	199.6	84
8	7.08	85	199.6	84
9	7.29	84	197.3	85
10	7.08	84	197.3	85
11	7.08	84	197.3	85
12	7.41	83	195.1	86
13	7.69	83	195.1	86
14	7.49	83	195.1	86

The salvage value of the final burn (year 13) at the end of the 15-year planning horizon is estimated to be 40 percent (Figure 7.2). This is based on the assumption that no further treatments will be applied after the fifteenth year and that salvage value of the year 13 burn is composed of benefits accrued after the end of the planning horizon until production returns to P_O.

These data were used in the model to determine an annual net cash flow for each year of the planning horizon. The resultant annual net cash flows were used to calculate the net-present value of the treatment alternative over the length of the planning horizon at the discount rate selected (8 percent). The IRR on the investment was also used for comparing the economic performance of treatment alternatives.

The data generated for scenario 3 were used to produce the economic analysis in Appendix D. An accumulated net-present value at the end of the planning horizon of -$3,523 (Appendix D, page 66) indicates that the treatment did not achieve the objective of an 8 percent return on the money invested. The actual IRR for the treatment was 4.03 percent at a cost of $64.25/ha for the herbicide and application (Table 7.7).

Computer software makes it possible to run net-present value analyses and calculate IRR very quickly. This means that several technically feasible alternatives can be compared almost as fast as elements of the partial budget can be determined. Different versions of the same treatment can also be compared, that is, different price levels, costs, levels of change in carrying capacity or livestock performance, and lengths of planning horizon. Such analyses are useful to show the sensitivity of the economic performance of the treatment to different input levels. Table 7.7 was developed by conducting the same analysis as

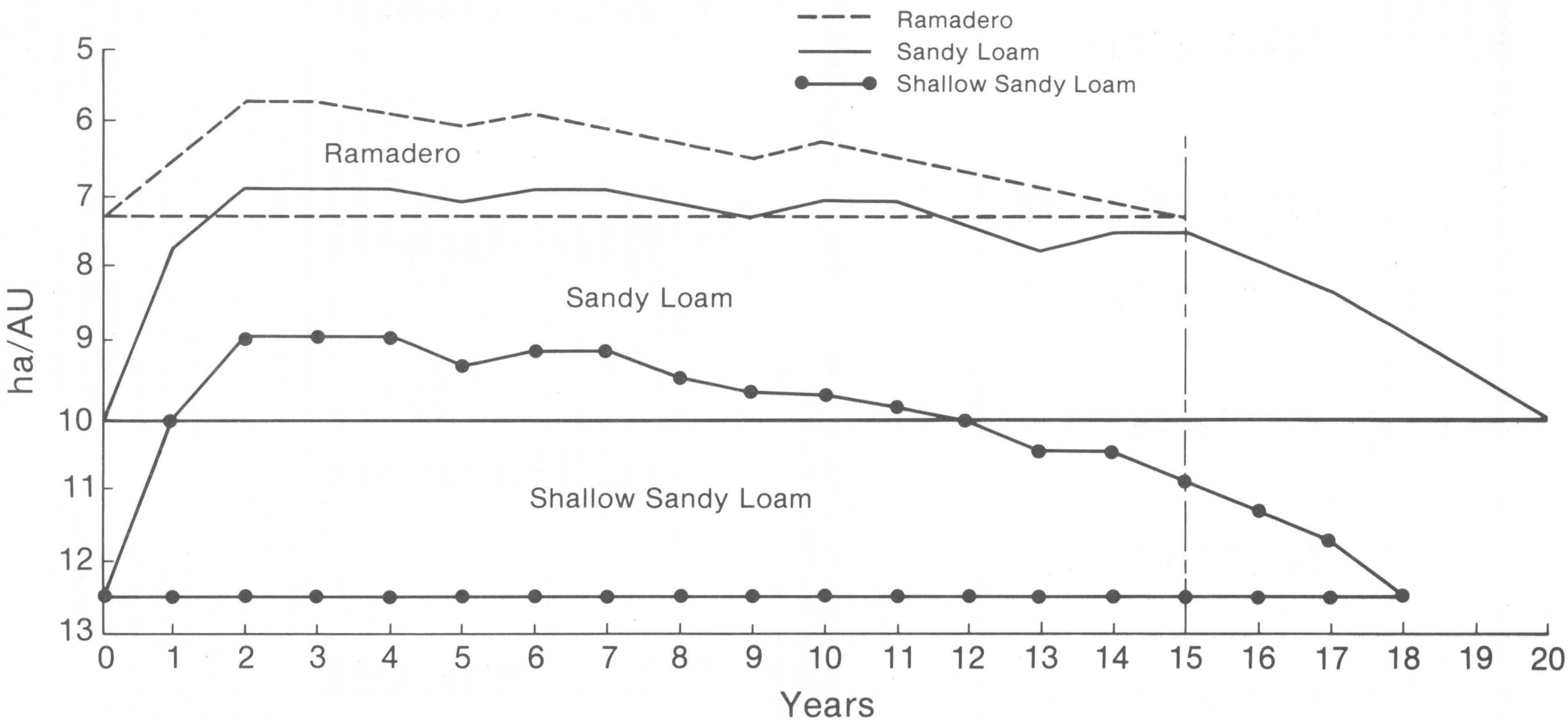

Figure 7.3. Contrasting production response curves for three range sites important in South Texas following aerial application of herbicide.

Table 7.5. Combined carrying capacity response for the treated and untreated areas in the hypothetical case study, scenario 3.

	Untreated			Treated			Combined	
Year	ha/AU	ha	AU	ha/AU	ha	AU	AU	ha/AU
0	10.12	146	14.4	10.12	218	21.6	36.0	10.12
1	10.12	146	14.4	7.69	218	28.4	42.8	8.50
2	10.12	146	14.4	6.88	218	31.8	46.2	7.89
3	10.12	146	14.4	6.88	218	31.8	46.2	7.89
4	10.12	146	14.4	6.88	218	31.8	46.2	7.89
5	10.12	146	14.4	7.08	218	31	45.4	8.01
6	10.12	146	14.4	6.88	218	31.8	46.2	7.98
7	10.12	146	14.4	6.88	218	31.8	46.2	7.98
8	10.12	146	14.4	7.08	218	31	45.4	8.01
9	10.12	146	14.4	7.29	218	30	44.4	8.22
10	10.12	146	14.4	7.08	218	31	45.4	8.01
11	10.12	146	14.4	7.08	218	31	45.4	8.01
12	10.12	146	14.4	7.41	218	29.5	43.9	8.30
13	10.12	146	14.4	7.69	218	28.4	42.8	8.50
14	10.12	146	14.4	7.49	218	29.2	43.6	8.34

Table 7.6. Combined estimated carrying capacity and livestock production changes on the treated and untreated areas of the hypothetical case study, scenario 3.

Year	ha/AU	Conception rate (%)	Weaning weight (kg)	Variable cost/cow ($)
0	10.12	82	192.8	89
1	8.50	83	194.1	87.2
2	7.89	83.2	195.5	86
3	7.89	83.8	196.9	86
4	7.89	83.8	196.9	86
5	8.01	83.8	196.9	86
6	7.89	83.8	196.9	86
7	7.89	83.8	196.9	86
8	8.01	83.8	196.9	86
9	8.22	83.2	195.1	86.6
10	8.01	83.2	195.5	86.6
11	8.01	83.2	195.5	86.6
12	8.30	83	194.1	87.2
13	8.50	83	194.1	87.2
14	8.34	83	194.1	87.2

shown in Appendix D but by changing only the cost of the herbicide and application ($64.25/ha in the original analysis, Appendix D) in each subsequent analysis.

The cost of the herbicide and application would have to be about $48/ha for the treatment to produce an 8 percent IRR, assuming all other variables to be constant. The cost of the herbicide and application could, however, go as high as about $89/ha before IRR dropped below zero. A positive IRR is relatively insensitive to cost changes of the herbicide and application in this particular scenario.

Scenario 4: Importance of Area Treated

A logical alternative to scenario 3 would be to increase the percentage of the pasture treated. Research in South Texas by Beasom and Scifres (1977) and Tanner et al. (1978) indicates that more than 60 percent of a pasture can be treated in strips without detrimental effects on white-tailed deer populations (see also Chapter IV). Scenario 4 assumes that the percentage of the pasture treated was increased from 60 percent (218 ha) to 80 percent (291 ha). The maintenance burn treatments were applied as described for scenario 3. The response curve for the treated area of the pasture is the same as for scenario 3 (Figure 7.2). Carrying capacity, livestock performance, and variable cost per cow were adjusted to reflect the increase in treated versus untreated area. Costs of the deferments were increased to reflect the increased number of animal units in years 5, 9, and 13. Calf prices and all other assumptions were the same as those for scenario 3. At the same treatment cost of $64.25/ha for the herbicide and application, IRR increased from 4.03 percent for 60 percent treated to 4.91 percent for 80 percent treated (Table 7.2).

Scenario 5: Importance of Treatment Life

Another variable that affects economic outcome of treatment alternatives is the life of treatment (TL). Although TL is defined as the time required for treatment effect to be exhausted (TE_O), it could also be considered as the level of treatment effect remaining at the end of the planning horizon. Where maintenance practices are used to extend effects of the original treatment indefinitely, TE_O may not be reached during the planning horizon.

Scenario 5 is an example of the effect of reduced treatment benefits over a portion of the planning horizon (years 6-14) and uses the same treatment alternative as that of scenario 3 (60 percent sprayed plus cool-season burns). The assumption is made, however, that the burn, scheduled for year 5 to capture the fine fuel load and fuel continuity before they diminished owing to brush regrowth, was not applied. This can be the result of drought, unfavorable weather conditions during the time for the burn, inadequate deferment to protect the fuel bed, or managerial choice to use forage (fuel) for livestock instead of for prescribed burning. Scenario 5 assumes that the first maintenance burn was not applied until year 7 and that subsequent burns were applied in years 11 and 14 (Figure 7.2). The impact of reduced total benefits that are accrued over the planning horizon by missing a critical burn are shown in Table 7.2. In this scenario, IRR would be less than 0 for the entire range of costs of herbicide and application that were analyzed above about $43/ha.

Scenario 6: Importance of Range Site

Scenarios 1 through 5 assume that the entire pasture in the case study was a sandy loam range site. However, it would be unusual for a 364-ha pasture in South Texas to contain only one range site. Scenario 6 is an example of the effect of multiple range sites on economic performance of treatments. Sites chosen for the analysis are typical for the region and include sandy loam, ramadero (wide, flat drainages), and shallow sandy loam. The scenario assumes the same application design for the herbicide in alternating treated and untreated strips and a ratio of 60 percent treated (218 ha) and 40 percent untreated (146 ha). It also assumes that the three range sites make up equal portions of treated and untreated areas.

The same treatment set of picloram plus triclopyr (1:1) at 1.1 kg/ha applied in year 0 and prescribed cool-season burns in years 5, 9, and 13 is used. The same response curve for this treatment set on the sandy loam site used in the previous scenarios is used in scenario 6. Figure 7.3 shows response curves for all three range sites.

The major differences between range sites affecting response to treatments are woody plant composition and productivity potential of the sites (Scifres et al. 1988). For example, the ramadero site is more productive than are the other two sites. The initial recommended stocking rate for the ramadero site in fair range condition is 7.3 ha/AU compared with 10.12 ha/AU for the sandy loam site and 12.6 ha/AU for the shallow sandy loam. Response to the herbicide treatment on the ramadero is greatly reduced, however, by the composition of the woody stand on the site. Whitebrush, which has low susceptibility to the herbicide combination, dominates the ramadero site. Large honey mesquite trees, which are susceptible to the herbicides, also occur on the site, but the overall efficacy of treatment is constrained by its ineffectiveness on whitebrush and other species of moderate to low susceptibility, such as lime pricklyash. Reduced herbicide efficacy also limits the accumulation of fine fuel load on portions of the area so that burns would tend to be patchy, thus providing less opportunity to extend herbicide benefits on the ramadero than on the sandy loam site. It should be noted that the ramadero sites in South Texas are considered prime white-tailed deer habitat and are often left out of brush treatment designs.

Woody species composition on the shallow sandy loam site is similar to that of the sandy loam site, and the herbicide treatment would be similar in efficacy on the two sites. The shallow sandy loam site is inherently less productive, however, and although magnitude of improvement from the herbicide treatment as a percentage of initial carrying capacity would be similar, fine fuel load and continuity would consistently be less. This would reduce effectiveness of maintenance burns to suppress brush regrowth and result in a lesser proportion of benefits from the herbicide treatment being carried to the end of the planning horizon.

Response of treated areas must be determined for each of the sites separately and integrated with the different carrying capacities of the untreated areas of the sites to yield a single, weighted response curve for the pasture. Livestock responses (conception rates, weaning weights, and variable costs) are calculated in the same way.

The IRR for scenario 6, based on various costs of the herbicide and application, is shown in Table 7.2. The IRR was less than 0 for herbicide costs greater than about $64/ha.

From the positive attributes of herbicide application in strips, an alternative approach, referred to generically as variable-rate patterning (VRP), was recently described (Scifres and Koerth 1986; see also Chapter VI). Scifres et al. (1988b) found that economic response to VRP treatments in South Texas differed among sites of differing forage production capabilities and between otherwise similar sites because of variation in botanical composition of the brush stands. For example, according to economic assumptions used in the study, IRR at two locations were 6.3 and 1.3 percent, respectively, when 2.2 kg/ha of tebuthiuron were applied to sites with deep soils (drainages), 3.1 and less than 0 percent following treatment of uplands, and was negative following application to shallow ridges. Sites with a greater proportion of the woody cover being tebuthiuron-susceptible species such as whitebrush yielded greater IRR from the investment in treatment than did sites with heavy cover of honey mesquite, a tebuthiuron-tolerant species. Figure 7.4 shows the variation in IRR plotted against treatment cost for three range sites at the study location near Pearsall, Texas. Maximum investments in treatments of sites with the expectation of generating a 10 percent IRR were $99.25/ha for drainages, $74.70/ha for upland sites, and $43.05/ha for ridges. These data clearly indicate that site productivity potential and botanical composition of woody plants should be considered when designing VRP or other herbicide applications to optimize herbicide efficacy and economic performance.

Summary

According to the hypothetical scenarios, the sandy loam site is best matched to the technical alternative being considered, that of aerial spraying picloram plus triclopyr at 1.1 kg/ha. Return on investment increased with percentage of the site treated, assuming no reduction in revenue resulting from loss of hunting income or other causes. Species composition of the site is well matched to the herbicide in terms of susceptibility, and productivity of the site is great enough to create herbaceous fine fuel load required for effective maintenance burns. This is contrasted with the ramadero site, which is highly productive but has a poor match of woody species with the herbicide, and with the shallow sandy loam site, which has good species susceptibility but lacks productivity potential to develop adequate fuel loads and continuity for burning. According to the assumptions and the IRR generated in the scenarios, the sandy loam site presents the best opportunity for successful economic performance of the treatment alternative.

Length of treatment life, or the level of initial benefits maintained to the end of the planning horizon, is critical to successful economic performance. Missing a critical burn in year 5 of scenario 5 and allowing initial benefits from the herbicide treatment to deteriorate until year 7 when the first burn was applied also greatly reduced IRR.

These case studies indicate the importance of matching available herbicide technology with the woody plant problem according to species present and relative composition in the stand. In many situations, this means that range site selection is important and that the same treatment alternative does not have uniform efficacy across all sites. Research results from the study by Scifres and Koerth (1986) show the importance of designing VRPs that consider the variation in site potential and brush composition when assigning dosages of the herbicide.

The analyses also indicate that maintenance of a high proportion of the initial benefits from the herbicide treatment is necessary for successful economic performance over planning horizons greater than the treatment life of the the herbicide alone.

Table 7.7. Internal rates of return of various cost levels for the applied herbicide according to responses in scenario 3.

Herbicide application ($/ha)	Internal rate of return (%)
93.90	< 0
88.96	0.07
84.01	0.81
79.07	1.54
74.13	2.27
69.19	3.15
64.25	4.03
59.30	5.05
54.36	6.23
49.42	7.54
44.48	9.16
39.54	10.91

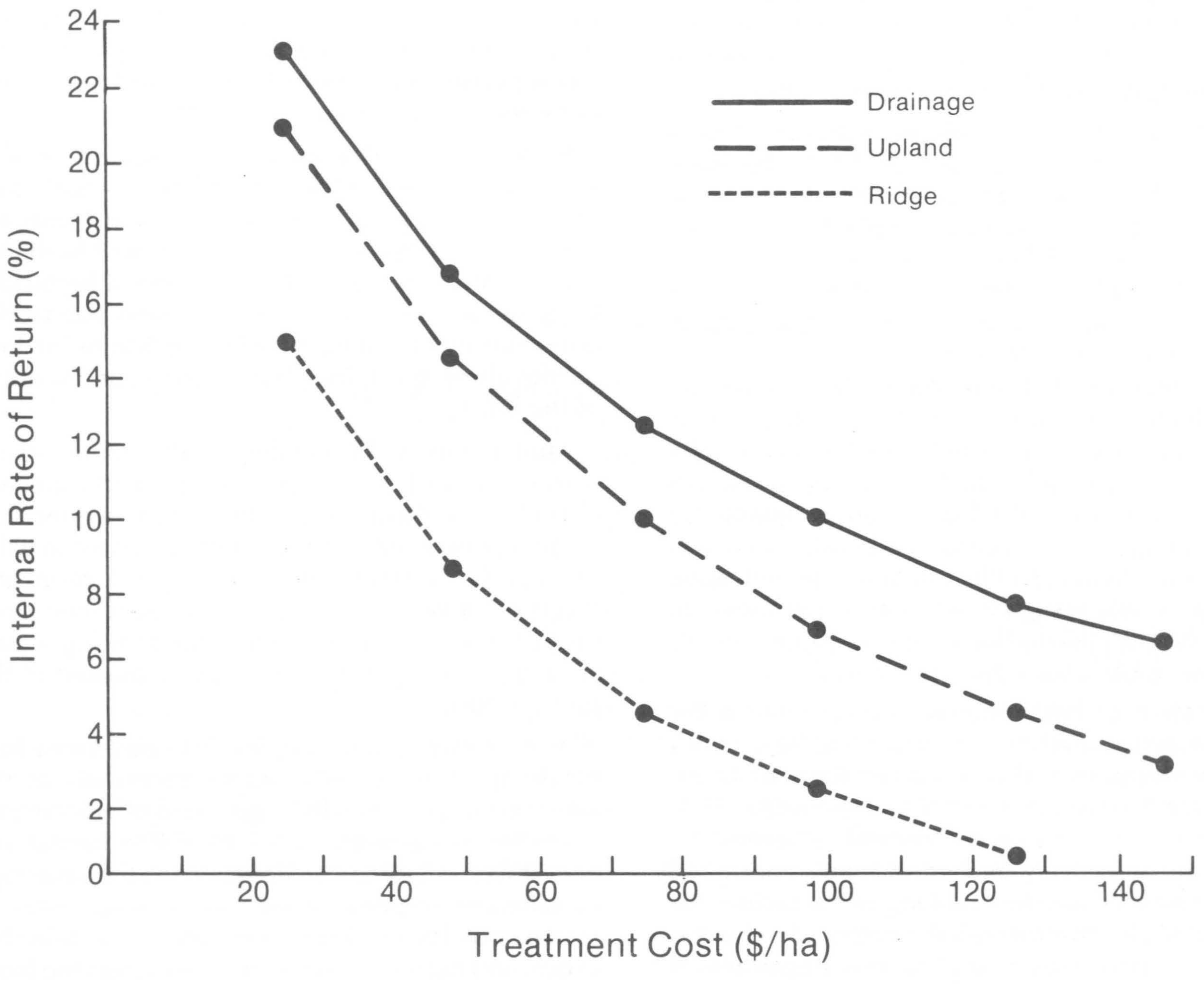

Figure 7.4. Contrast of internal rates of return on the investment in tebuthiuron application given varying costs of treatment for three sites of differing potential for forage production (adapted from Scifres et al. 1988b).

VIII. Highlights of Research Findings

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Research was conducted from 1980 through 1987 at 12 locations to evaluate various herbicides, application methods, and patterns of application for managing South Texas mixed brush. The herbicide mixture 2,4,5-T plus picloram, previously the most widely used spray for brush management, was used as the standard of comparison for efficacy evaluations. Although several brush species were evaluated, control of honey mesquite was emphasized. Research and commercial results indicate that acceptable control was set at $\geq$80 percent canopy reduction and mortality of $\geq$50 percent of the population during the growing season after herbicide application.

The experimental herbicide metsulfuron at rates to 0.6 kg/ha and hexazinone at 1.1 kg/ha were ineffective for honey mesquite control. The most effective treatments, broadcast applied at 1.1 kg/ha with ground or aerial equipment, were clopyralid and clopyralid plus picloram (1:1). These treatments exceeded the control levels achieved with the same rate of 2,4,5-T plus picloram. The 1:1 mixture of triclopyr plus picloram was generally only slightly more effective than the 1:1 mixture of 2,4,5-T plus picloram at 1.1 kg/ha, and the 1:1 mixture of dicamba plus picloram was equivalent to 2,4,5-T plus picloram at 1.1 kg/ha. Triclopyr at 1.1 kg/ha did not effectively control honey mesquite, and, from results of ground broadcast applications only, picloram applied alone at 1.1 kg/ha was less effective than when picloram was applied at 0.6 kg/ha with the same rate of clopyralid, 2,4,5-T, triclopyr, or dicamba.

Application of herbicides with a carpeted roller was an effective method for controlling light stands of honey mesquite, 0.25 to 1.5 m tall. Rates of 12, 24, 48, and 60 g/L were evaluated. The lower rate did not result in effective mesquite control, whereas the higher rate effectively and consistently controlled honey mesquite. Relative ranking of herbicides for honey mesquite control with the carpeted roller was the same as for broadcast applications. Regardless of application method, honey mesquite was not controlled by applications of herbicides in the fall.

Huisache was effectively controlled by broadcast applications of clopyralid, picloram, and 1:1 mixtures of clopyralid plus picloram and triclopyr plus picloram at 1.1 kg/ha or by the same herbicides at 48 or 60 g/L with the carpeted roller. Regardless of herbicide, rate, or method of application, applications in the autumn (September-October) were more effective than treatment in the spring. In a series of studies, all top growth was removed from huisache within a week after application of clopyralid plus picloram at 60 g/L without loss of efficacy.

Blackbrush acacia was effectively controlled by the herbicide mixtures containing picloram. Twisted acacia and spiny hackberry were partly controlled. Texas persimmon, lime pricklyash, and brasil were not effectively controlled.

Prescribed burning within two growing seasons after application of picloram pellets or tebuthiuron pellets at 2.2 kg/ha to regrowth mixed brush expedited range improvement compared with herbicide application alone. Overall, application of herbicide-burn sequences resulted in improved habitat for bobwhite quail compared with application of herbicides alone, prescribed burning only, or shredding of the brush.

Application of herbicides in alternating strips, treating as much as 80 percent of the landscape, will result in only short-term, if any, negative effects on wildlife populations. The greatest detriment to wildlife habitat is reduction in forb production and diversity for the growing season of application. Forb production is normally restored the growing season after application of the herbicides evaluated in the present study.

A recently described approach to patterning herbicide applications, referred to generically as the variable-rate pattern (VRP), appears to offer increased flexibility in herbicide use for wildlife habitat enhancement. A VRP can be designed to take advantage of different response potentials of range sites to create mosaics of shrub-dominated, shrub-herbaceous, and herb-dominated patches across the landscape.

The development of a production response model and the accumulated research results, observations, and experience were used with net-present value analysis to allow projection of the economic performance of herbicides applied to South Texas brushlands. Results of these analyses indicate the importance of several variables, in addition to treatment cost and product price (the traditional major considerations affecting decision making), in determining economic performance of herbicide application for brush management. Range site, as it determines composition of the brush stand and potential for herbaceous production, is critical to determining the magnitude of return on investment. Herbicide alternatives must be properly matched with composition of the brush stand for optimum effectiveness of herbicide treatment as well as for designing follow-up treatments. Length of effective range improvement is also critical to maximum economic performance, and the lifespan of treatment effect from herbicide application may be inadequate to provide acceptable economic performance. Well-planned and well-executed follow-up treatments such as prescribed burning may be employed to effectively extend herbicide treatment life, increase economic performance, and enhance wildlife habitat.

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APPENDIX A

Scientific Names of Plants and Animals Mentioned in Text

Plants

Common name	Scientific name
Agarito	*Berberis trifolialata*
Bermudagrass	*Cynodon dactylon*
Blackbrush acacia	*Acacia rigidula*
Brasil	*Condalia obovata*
Catclaw acacia	*Acacia greggii*
Cenizo	*Leucophyllum frutescens*
Desert yaupon	*Schaefferia cuneifolia*
False broomweed	*Ericameria austrotexana*
Guajillo	*Acacia berlandieri*
Guayacan	*Porlieria angustifolia*
Honey mesquite	*Prosopis glandulosa* var. *glandulosa*
Huisache	*Acacia farnesiana*
Lime pricklyash	*Zanthoxylum fagara*
Lotebush	*Zizyphus obtusifolia*
Pricklypear	*Opuntia spp.*
Running mesquite	*Prosopis spp.*
Screwbean	*Prosopis reptans*
Shrubby blue sage	*Salvia ballotaeflora*
Spiny hackberry	*Celtis pallida*
Tasajillo	*Opuntia leptocaulis*
Texas colubrina	*Colubrina texensis*
Texas persimmon	*Diospyros texana*
Twisted acacia	*Acacia tortuosa*
Whitebrush	*Aloysia gratissima*

Animals

Common name	Scientific name
White-tailed deer	*Odocoileus virginianus*
Bobwhite quail	*Colinus virginianus*

APPENDIX B

Chemical Names of Herbicides Mentioned in Text

Common name	Chemical name
Clopyralid	3,6-dichloro-2-pyridinecarboxylic acid
Dicamba	3,6-dichloro-2-methoxybenzoic acid
2,4,5-T	(2,4,5-trichlorophenoxy)acetic acid
Hexazinone	3-cycolhexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H, 3H)-dione
Metsulfuron	2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)-amino]carbonyl]amino]sulfonyl]benzoic acid
Picloram	4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid
Tebuthiuron	N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea
Triclopyr	[(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid

APPENDIX C

Conversion from Metric to English Units

Metric unit	English equivalent
Hectare (ha)	2.47 acres
Liter (L)	0.26 gallon
Degree centigrade (°C)	(degrees Farenheit -32) 0.56
Centimeter (cm)	0.394 inch
Meter (m)	3.28 feet
Kilometer (km)	0.621 statute mile
Kilopascal (kPa)	0.14 pound per square inch
Gram (g)	0.0022 pound, 0.0353 ounce

APPENDIX D

Economic Analysis of Scenario 3 of the Case Studies: Economic Performance of Herbicides for Brush Management in South Texas

Investment Report

Year	Animal units (no.)	Additional animal investment ($)	Treatment investment ($)	Total annual investment ($)	Total accumulated investment ($)
0	36.0	0	14,007	14,007	14,007
1	42.9	2400	0	2400	16,407
2	46.2	1600	0	1600	18,007
3	46.2	0	0	0	18,007
4	46.2	0	0	0	18,007
5	45.5	-400	2963	2563	20,569
6	46.2	400	0	400	20,969
7	46.2	0	0	0	20,969
8	45.4	-400	0	-400	20,569
9	44.3	-400	2156	1756	22,325
10	45.5	400	0	400	22,725
11	45.5	0	0	0	22,725
12	43.9	-800	0	-800	21,925
13	42.9	-400	2156	1756	23,681
14	43.7	400	0	400	24,081
Salvage		2800	943	3743	

Variable Cost Report

Year	Total head (no.)	Total added head (no.)	Variable cost per head ($)	Variable cost for added head ($)	Variable cost savings from present herd ($)	Total increase in variable costs ($)
0	36	0	89.0	0	0	0
1	42	6	87.2	523	65	458
2	46	10	86.0	860	108	752
3	46	10	86.0	860	108	752
4	46	10	86.0	860	108	752
5	45	9	86.0	774	108	666
6	46	10	86.0	860	108	752
7	46	10	86.0	860	108	752

APPENDIX D (Continued)

Year	Total head (no.)	Total added head (no.)	Variable cost per head ($)	Variable cost for added head ($)	Variable cost savings from present herd ($)	Total increase in variable costs ($)
8	45	9	86.0	774	108	666
9	44	8	86.6	693	86	606
10	45	9	86.6	779	86	693
11	45	9	86.6	779	86	693
12	43	7	87.2	610	65	546
13	42	6	87.2	523	65	458
14	43	7	87.2	610	65	546

Net-Present Value Report

Year	Animal units (no.)	Total increase in sales ($)	Total added investment ($)	Increased variable costs ($)	Added revenue ($)	Cash flow ($)	Annual N.P.V. ($)	Accum. N.P.V. ($)
0	36.0	0	14,007	0	0	-14,007	-14,007	-14,007
1	42.9	1899	2400	458	0	-959	-888	-14,895
2	46.2	3128	1600	752	0	776	665	-14,230
3	46.2	3379	0	752	0	2627	2085	-12,144
4	46.2	3379	0	752	0	2627	1931	-10,213
5	45.5	3087	2563	666	-760	-901	-613	-10,827
6	46.2	3379	400	752	0	2227	1403	-9423
7	46.2	3379	0	752	0	2627	1533	-7890
8	45.4	3087	-400	666	0	2821	1524	-6366
9	44.3	2526	1756	606	-1774	-1610	-806	-7172
10	45.5	2841	400	693	0	1748	810	-6362
11	45.5	2841	0	693	0	2148	921	-5440
12	43.9	2183	-800	546	0	2438	968	-4472
13	42.9	1899	1756	458	-1715	-2030	-746	-5219
14	43.7	2183	400	546	0	1238	421	-4797
			Salvage value			3743	1274	-3523

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