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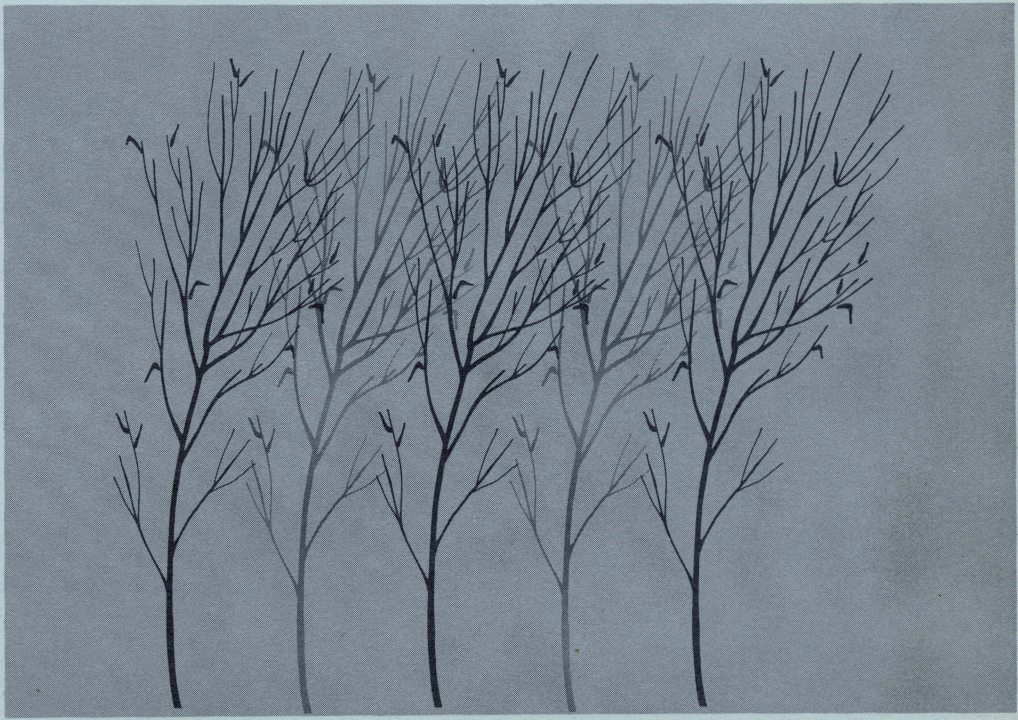
Control of Willow Baccharis and Spiny Aster with Pelleted Herbicides



The Texas A&M University System • The Texas Agricultural Experiment Station • Neville P. Clarke, Director, College Station, Texas

Metric Units - English Equivalents

Metric Unit	*English Equivalent*
Centimeter	0.394 inch
Hectare	2.47 acres
Kilogram	2.205 pounds
Kilogram per hectare	0.893 pounds per acre
Kilometer	0.62 statute mile
Kilometer per hour	0.62 miles per hour
Liter	0.264 gallons
Meter	3.28 feet
Square meter	10.758 square feet
(Degrees centigrade × 1.8 + 32)	Degrees fahrenheit

Welder Wildlife Foundation Contribution No. 229.

Contents

Authors

Mutz, J. L., assistant range scientist, The Texas Agricultural Experiment Station, Corpus Christi

Scifres, C. J., professor, The Texas Agricultural Experiment Station (Department of Range Science)

Mohr, W. C., range research technician, The Texas Agricultural Experiment Station (Department of Range Science)

Drawe, D. L., assistant director, The Rob and Bessie Welder Wildlife Foundation, Sinton, Texas

Summary

Willow baccharis is an invader of grasslands throughout Texas, and spiny aster is an increasing problem on lowlands of the Coastal Prairie. Conventional herbicide sprays cannot be used on many areas infested with willow baccharis because of the proximity of susceptible crops, and conventional sprays are not effective for control of spiny aster. Pelleted picloram or tebuthiuron, applied at 1 to 2 kilograms per hectare in the spring, effectively controlled willow baccharis. Both herbicides controlled willow baccharis, but the effects of tebuthiuron were not completely manifested until the second growing season after application.

Picloram pellets at 1 to 2 kilograms per hectare applied immediately after shredding spiny aster resulted in effective control. Neither component of the proposed spiny aster control system, shredding or herbicide application, was effective when used alone. Integration of the control methods resulted in increased production of native range forages on an Odem sandy clay loam soil in South Texas which supported residual forage plants at the time of treatment. However, artificial revegetation may be necessary when the system is used to renovate rangeland supporting dense stands of spiny aster with no seed source of native forage species. There were no differences between 5 or 10 percent picloram pellets for control of willow baccharis or spiny aster. The pelleted herbicides greatly reduce the drift potential associated with sprays, essentially eliminate the volatility hazards, and can be applied with ground or aerial equipment.

Control of

Willow Baccharis and Spiny Aster With Pelleted Herbicides

During the last decade, willow baccharis (*Baccharis salicina*), a woody member of the Compositae, has progressively become a management problem on native rangeland and tame pastures. Formerly restricted primarily to low, mesic areas, it aggressively invades the more productive grassland soils following disturbance, and is a persistent invader of abandoned fields (Hoffman, undated). Willow baccharis generally attains heights of 1 to 4 meters.[1] It resembles the true willows[2] in growth form, and is often referred to locally as "dryland willows," "seep willow," and "Roosevelt willow" (Figure 1). Willow baccharis is a management problem on grasslands in the southern half of Texas but also occurs in New Mexico, Colorado, and north to Kansas (Vines, 1960). It spreads by wind-blown achenes, and vegetative regeneration is apparently limited to stem buds.

Since willow baccharis seedlings and young plants are browsed by cattle, established plants are relatively rare in pastures with a history of grazing. Dense infestations invariably occur on grasslands which have been disturbed, mechanically or from a history of overgrazing, then completely protected from grazing by domestic livestock. Once established, the plants grow rapidly and may, within a few years, reduce desirable forage production and retard improvement in range condition. Mature willow baccharis is only lightly browsed by cattle; thus some control measure is generally needed to improve infested rangeland (Mutz et al., 1978b).

Since willow baccharis resprouts from surviving stem segments at or below ground line, top removal methods such as shredding and controlled burning result in only temporary control (Scifres and Haas, 1974). However, no research on the use of grazing following shredding or burning treatments for sprout control has been conducted. Since the species is shallow rooted, grubbing is effective for control where plant densities are low (<250 per hectare). Broadcast sprays of 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] at 1 kilogram of active ingredient per hectare or less result in only partial control. However, the low volatile esters of 2,4-D [(2,4-dichlorophenoxy) acetic acid] at 1.68 to 2.24 kilograms of active ingredient per hectare effectively control willow baccharis. Broadcast applications of 1:1 combination of 2,4,5-T + picloram (4-amino-3,5,6-trichloropicolinic acid) at 1.12 kilograms of active ingredients per hectare total herbicide have shown promise for willow baccharis control (Scifres and Haas, 1974).

Another troublesome composite on range sites with high production potential in South Texas is spiny aster (*Aster spinosus*). Also known as "Mexican devilweed" or "wolfweed," spiny aster is a warm-season perennial which may exceed 1 meter in height. It commonly occurs in ditches, swales, stream bottoms, and other low mesic areas (Jones, 1975) and will invade upland sites where soils have a high clay content and a high water-holding capacity (Mayeux, 1977). Infestations of spiny aster often essentially exclude desirable vegetation (Figure 2).

Spiny aster occurs in the southern and western half of Texas with the northeast range extending to Brazos County (Correll and Johnston, 1970) and in New Mexico, Arizona, and Utah. The Coastal Prairie supports the most extensive infestations of spiny aster in Texas. Most sites supporting only spiny aster have high potential for range forage production (Mutz, 1976; Mutz et al., 1978a).

Spiny aster initiates vegetative growth from a well-developed rhizome system during early spring. Small leaves are present for a brief period during the spring while the young stems are succulent. The leaves drop off after 2 or 3 weeks, and the stem becomes photosynthetically active (Mayeux, 1977). Since only a portion of the mature spiny aster

[1]To convert metric to English unit, see table inside front cover.
[2]Scientific names of all plants and animals mentioned in text are given in Appendix.

stems overwinter to continue growth and development the following season, mature stands are often characterized by an abundance of dead stems. A mature spiny aster community may support more than 100 stems per square meter.

White-tailed deer and feral hogs apparently utilize spiny aster communities for cover. Although white-tailed deer will occasionally eat succulent stems and leaves during the early spring (Chamrad and Box, 1968), the overall extent of utilization is apparently low. Therefore, range improvement following spiny aster control is generally considered to be more practical than leaving the stands for wildlife cover.

Effective control of undisturbed spiny aster has not been achieved with foliar herbicides. Dicamba (3,6-dichloro-o-anisic acid) and 2,4-D at 1.12 or 2.24 kilograms active ingredients per hectare alone or the same rates in combinations applied as a foliar spray in the fall failed to control mature spiny aster (Mayeux and Scifres, 1975). However, shredding as a pretreatment to stimulate new growth, followed by a foliar spray of the potassium salt of picloram at 1.12 kilograms of active ingredients per hectare completely controlled spiny aster.

Although willow baccharis and spiny aster may be controlled with foliar sprays of some herbicides under certain conditions, potential drift hazards have restricted treatment of many infested areas. The potential of spray drift damage to susceptible crops and stringent timing requirements relative to plant phenology for effective application of herbicide sprays have provided the impetus for evaluating dry herbicide formulations for range improvement (Scifres et al., 1978). Pelleted herbicides greatly reduce drift potential, essentially eliminate the hazard of volatility and extend the period for effective herbicide application.

Pelleted picloram effectively controls troublesome range species such as redberry juniper (Scifres, 1972), lotebush (Scifres and Kothmann, 1976), Macartney rose (Scifres, 1975a), and Texas persimmon (Scifres, 1975b). These species are difficult or impossible to control with conventional broadcast sprays. A relatively new herbicide, tebuthiuron (*N*- [5-(1,-dimethylethyl)-1,3,4-thiadiazol-2yl] -*N*,*N*' - dimethylurea) appears promising for control of whitebrush, spiny hackberry, Berlandier wolfberry, and other woody plants not effectively controlled by other herbicides and formulations (Scifres et al., 1978). The objective of this research was to evaluate the effectiveness of pelleted picloram and tebuthiuron for control of willow baccharis and spiny aster.

Figure 1. Willow baccharis, a management problem following disturbance of rangeland and on abandoned fields, resembles the true willows in growth form.

MATERIALS AND METHODS

Willow Baccharis

The first experiment was installed near College Station on March 24, 1976. A typical East Texas mixed-brush infestation had been removed from the area by tree-dozing in 1964. The area supported a dense stand (>1,200 plants per hectare) of willow baccharis, 2.5 to 3 meters tall, when the experiment was initiated. Primary grasses were

Figure 2. Spiny aster infestations usually are so dense that most desirable range forages are excluded.

brownseed paspalum, broomsedge bluestem, silver bluestem, and scattered clones of little bluestem. The soil was a Tabor fine sandy loam, a member of the fine, montmorillonitic, thermic family of Udertic Paleristalfs. Pelleted picloram was applied broadcast to 12.5 by 40.5- meter plots separated by 2-meter-wide buffer strips. Herbicide was applied in swaths 6.25 meters wide with a tractor-mounted broadcast spreader (Figure 3). The spreader was calibrated with pellets not containing active herbicide prior to actual plot application, but final application rates were based on the "weight difference" method relative to exact area treated. Therefore, rates applied varied somewhat among formulations. Treatments, duplicated in randomized complete block design, included picloram pellets containing 5 percent active ingredient (approximately 2.4 millimeters in diameter) applied to 0.5 and 1.5 kilograms of active ingredients per hectare, and pellets containing 10 percent active ingredients (approximately 3.2 millimeters in diameter) applied at 0.8 and 1.5 kilograms per hectare. At 7 and 14 months after application, percentage canopy reduction of each plant was recorded within a 2-meter-wide transect down the center of each plot. The number of willow baccharis completely defoliated and showing no signs of life was also recorded. At 17 months after application, the number of live seedlings was recorded in ten 0.25-square-meter quadrats equidistantly spaced along a diagonal across each plot.

Three composite soil samples were recovered from 0 to 8, 8 to 15, 15 to 30, and 30 to 60 centimeters deep. Organic matter content by acid digestion and titration, pH on a 1:4 soil:water slurry, and textural components by the hydrometer method were determined on triplicate subsamples from each depth.

A second experiment, located within 100 meters of the first, was installed on May 25, 1976, in a field abandoned from crop production in 1972. The area supported a dense, uniform stand of willow baccharis about 2.5 meters tall. Herbicides applied at 1.12 and 2.24 kilograms of active ingredient per hectare with a hand spreader to 23.4- by 23.4-meter plots included picloram as the 5- or 10-percent formulations, and tebuthiuron as a 20-percent formulation. Tebuthiuron pellets were extruded and about 3.2 millimeters in diameter. Each treatment was triplicated in a randomized complete block design. Plots were separated by 2-meter-wide buffer strips. At 2, 7, and 11 months after herbicide application, percentage canopy reduction of willow baccharis and number of plants completely defoliated were recorded on each plot. The study areas near College Station were not grazed.

On March 29, 1977, an experiment was installed near Agua Dulce, Texas on the Coastal Prairie. The soil was a Clareville clay loam, a member of the fine, montmorillonitic, hyperthermic family of the Pachic Arguistalls. The study area had been abandoned from row-crop production in 1972 and sprigged with coastal Bermudagrass in 1973. The study area supported a well-established stand of coastal Bermudagrass limited only by the dense (>3,000 plants per hectare) infestation of willow baccharis which averaged 2.5 meters tall. Picloram pellets as the 5-percent formulation were applied with a tractor-mounted broadcast seeder/spreader at 1.34 and 2.89 kilograms of active ingredients per hectare, and at 1.17 and 2.37 kilograms of active ingredients per hectare as the 10-percent formulation (Figure 4). Tebuthiuron pellets were applied at 1 and 4.2 kilograms active ingredient per hectare. Plot size was 32.7 by 65.5 meters, and each treatment was duplicated in a randomized complete block design. The study area was not grazed for 5 months after herbicide application. Soils were characterized as described for the study near College Station.

Figure 3. A tractor mounted broadcast seeder/spreader was used to apply pelleted herbicides to willow baccharis and spiny aster infested areas.

Figure 4. Excellent control of willow baccharis was achieved within 1 year following application of 1.12 kilograms per hectare of 5 or 10 percent active ingredient picloram pellets near Agua Dulce, Texas.

At 4 and 14 months after treatment, percentage canopy reduction of each willow baccharis plant, and the number of plants completely defoliated were recorded within a 2-meter-wide belt down the center of each plot.

Spiny Aster

On June 1, 1976, an experiment was installed on the Rob and Bessie Welder Wildlife Foundation approximately 15 kilometers northeast of Sinton, in the Gulf Prairie and Marshes (Gould, 1975). Average annual precipitation is approximately 92 centimeters. Soil within the study area is an Odem fine sandy loam, a member of the fine-loamy, mixed, hyperthermic family of the Cumulic Haplustolls. The study area was located in a spiny aster-longtom plant community (Drawe et al., 1978) within 100 meters of the Aransas River which periodically inundates the area. Picloram pellets (5 or 10 percent active ingredient) at 0.56 and 1.12 kilograms of active ingredients per hectare, and tebuthiuron pellets (20 percent active ingredient) at 1.12 kilograms of active ingredient per hectare, were applied to plots which had been shredded to a 10-centimeter height on May 15, 1976, and to undisturbed spiny aster. The pelleted herbicides were applied with the tractor-mounted broadcast seeder/spreader to plots 12.2 by 45.7 meters. The experiment was designed as a randomized complete block arranged as a split-plot with two replications of each treatment. Pretreatment (shredding) constituted the main block effect and herbicide treatments were applied to subplots, 12.2 by 22.8 meters. At 3 and 12 months after herbicide application, number of live spiny aster stems and average stem height were recorded within ten 0.25-square-meter sample areas equally spaced down the center of each plot.

A second study was installed in 1977 within 20 meters of the 1976 experiment. The spiny aster was shredded on March 28, 1977. Five and 10 percent active ingredient picloram pellets were applied to 24- by 45.7-meter plots on March 29. Experimental design, method of herbicide application, and soil series were identical to the first experiment. On July 25, 1977, and June 23, 1978, number of live spiny aster stems was recorded, and forage standing crop was determined within ten 0.25-square-meter quadrats equidistantly spaced along a diagonal line across each plot. Cattle had been grazing within the study area for approximately 6 weeks prior to the evaluation on June 23, 1978 (Figure 5). Percent overall utilization by cattle within each treated plot was estimated by two workers.

Two additional experiments were installed on March 22, 1978, near Refugio, Texas. One experimental area was located on an upland site supporting a sparse stand of spiny aster (<2,000 live stems per hectare) 10 to 20 centimeters tall. Other vegetation present within the study area included Hall's panicum, little bluestem, Texas wintergrass, pink eveningprimrose, and narrowleaf sumpweed. The spiny aster was not tall enough to justify shredding. Therefore, picloram pellets were applied without pretreatment to the spiny aster at 1.2 kilograms of active ingredient per hectare as the 5-percent or 10-percent formulation to 30.5 by 61-meter plots. Pellets were applied with a tractor-mounted broadcast seeder/spreader to triplicate plots arranged in a randomized complete block design.

The other experimental site near Refugio supported a dense stand of spiny aster, 2 meters tall (>20,000 live stems per hectare) and was located on bottomland virtually devoid of other vegetation. Picloram as the 5- or 10-percent pellets was applied at 1.2 kilograms of active ingredient per hectare to triplicate, 30.5 by 61-meter plots. Half of each plot was shredded to a 10-centimeter stubble

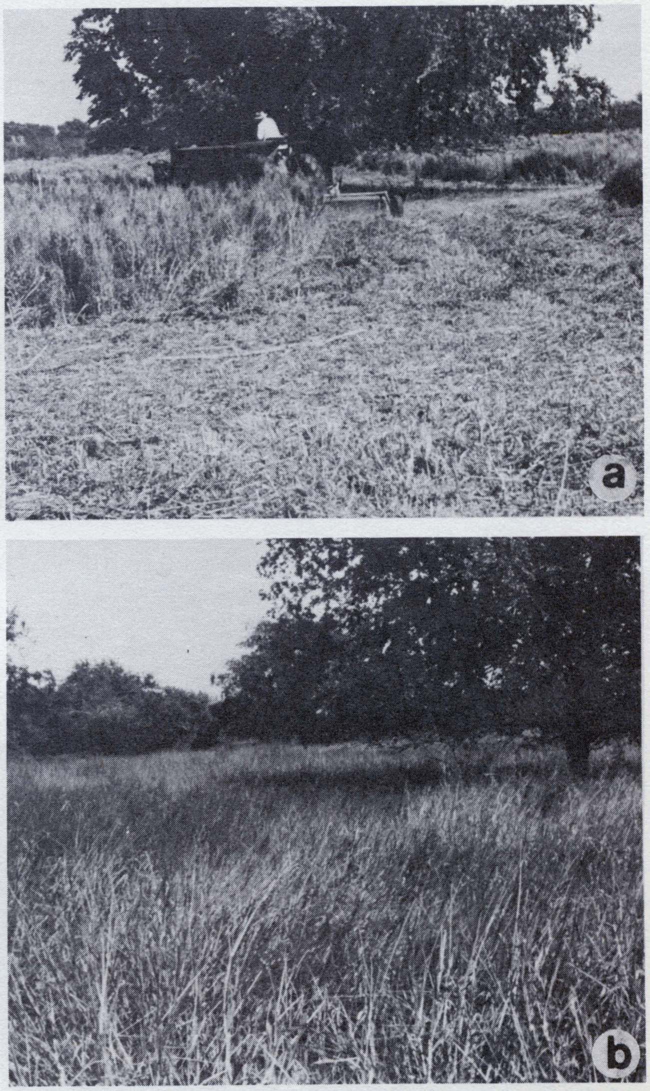


Figure 5. Shredding spiny aster on the Welder Wildlife Refuge near Sinton and immediately applying 1.12 kilogram per hectare of picloram (5- or 10-percent formulation) on March 29, 1977 (a) resulted in tenfold increase in forage standing crop after 85 days (b).

height immediately prior to herbicide application. Treatment effects were evaluated, as previously described, at 4 months after herbicide application. The soil of both sites was a Victoria clay, a member of the fine, montmorillonitic, hyperthermic family of the Udic Pellusterts.

Data from each experiment were subjected to analysis of variance, and Duncan's New Multiple Range Test was used to separate means at the 95-percent confidence level.

RESULTS AND DISCUSSION

Willow Baccharis

The time required for manifestation of phytotoxicity of soil-applied herbicides is a function of root-uptake and amount of rainfall, soil characteristics, and the target species involved. Willow baccharis on Tabor sandy loam (Table 1) exhibited symptoms of picloram phytotoxicity, epinasty of young stem tips and leaf chlorosis, within 2 weeks after the first significant rainfall (1 centimeter or more). Average defoliation of willow baccharis was 26 percent, and 5 percent of the plants were completely defoliated and showing no signs of life at 7 months after application of the 5-percent formulation of picloram pellets at 0.5 kilogram per hectare (Table 2). The 10-percent formulation applied at 0.8 kilograms per hectare reduced average live canopy by 91 percent, and 69 percent of the plants were completely defoliated.

The influence of formulation was confounded by rate in this study, particularly since the threshold rate for maximum response of willow baccharis is relatively low, apparently between 0.5 and 0.8 kilogram of picloram per hectare (Table 2). Canopy reduction was 99 to 100 percent, and 96 to 100 percent of the plants were completely defoliated, regardless of picloram formulation, at 7 months after application of 1.5 kilogram of active ingredients per hectare. The 1.5 kilogram of active ingredient per hectare rate of either formulation completely controlled the willow baccharis by 14 months after picloram pellet application (Table 2). Control at the 0.5- and 0.8-kilogram-of-active-ingredient-per-hectare rate was not satisfactory.

Willow baccharis seedlings had established in treated plots by 17 months after herbicide application. Plots treated with 1.5 kilograms per hectare of picloram supported significantly fewer willow baccharis seedlings than did untreated plots (Table 3). The lower number of seedlings in treated plots was attributed to residual activity of picloram. At rates of 1.12 kilograms per hectare or higher, picloram residues following application of pellets can be expected to persist in the soil into the next growing season (Bovey and Scifres, 1971). This persistence is a positive attribute when deep-rooted perennial plants and invading seedlings are the target of control efforts.

In August, 4 months after evaluation of reinvasion of the experimental plots with willow baccharis seedlings, the study site near College Station was grazed with heifers at four animals per hectare for 14 days. Willow baccharis seedlings, 15

Table 1. Organic matter content, pH, and textural components of two soils treated with pelleted picloram and tebuthiuron for willow baccharis control.

Depth (cm)	Organic matter (%)	Textural components			
		pH	Sand	Silt	Clay
	Tabor sandy loam (College Station)				
0-8	1.55	5.6	50	39	11
8-15	1.07	5.5	48	37	15
15-30	0.87	5.1	36	37	27
30-60	0.92	6.1	28	37	35
	Clareville clay loam (Agua Dulce)				
0-8	2.12	6.7	57	17	26
8-15	1.66	6.8	56	17	26
15-30	1.75	7.0	54	16	30
30-60	1.22	7.0	51	16	33

Table 2. Average canopy reduction (%) of willow baccharis and percentage of the population completely defoliated and not resprouting after application of picloram pellets on March 24 and 25, 1976, near College Station, Texas.

Treatment		Months after treatment[a]			
		7		14	
Active ingredient (%)	Rate (kg/ha)	Canopy reduction (%)	Plant kill (%)	Canopy reduction (%)	Plant kill (%)
Untreated	0	0 a	0 a	0 a	0 a
5	0.5	26 b	5 a	46 b	17 b
10	0.8	91 c	69 b	75 c	73 c
10	1.5	100 c	100 c	100 d	100 d

[a]Means within a column followed by the same letter are not significantly different at the 0.5-level according to the Student-Newman-Keul's Test.

Table 3. Average density of willow baccharis seedlings on August 29, 1977 after treatment of mature stands with pelleted picloram on March 24 and 25, 1976, near College Station, Texas.

Picloram treatment		
Active ingredient (%)	Rate (kg/ha)	Seedlings/m^2 [a]
	0	7.2 c
5	0.5	4.1 b
5	1.5	0.7 a
10	0.8	7.8 c
10	1.5	0.2 a

[a]Means within a column followed by the same letter are not significantly different at the 95% level according to Duncan's New Multiple Range Test.

to 20 centimeters tall, were counted immediately before and again after the grazing period. Cattle removed essentially all willow baccharis seedlings, regardless of original picloram treatment (data not shown). Integration of grazing management with picloram pellet treatment, then, holds promise for permanent control of willow baccharis.

The 5-percent picloram formulation tended to be more effective than the 10-percent formulation for controlling willow baccharis at 2 months after installation of the second experiment near College Station (Table 4). There was no difference in willow baccharis control between the picloram formulations within a rate or between rates at 7 and 11 months after application. At 7 months after application, tebuthiuron at 1.12 kilograms per hectare reduced the willow baccharis canopy by 83 percent, which was significantly less than the amount of canopy reduction by 5 or 10 percent formulation of picloram at 1.12 kilograms per hectare and tebuthiuron at 2.24 kilograms per hectare (Table 4). At 11 months after treatment, the 1.12 kilogram per hectare rate reduced the canopies by 96 to 98 percent, and complete control was achieved by the high application rate, regardless of formulation. Willow baccharis tended to respond to tebuthiuron somewhat more slowly than to picloram pellets, but there was no difference in level of control between herbicides, regardless of application rate, at 11 months after application (Table 4). Tebuthiuron has shown promise for controlling several other woody species on rangeland (Scifres et al., 1978).

There was no difference in canopy reduction of willow baccharis at 4 or 14 months after application of 5- or 10-percent formulations of picloram at rates ranging from 1.1 to 2.9 kilograms per hectare near Agua Dulce (Table 5). The canopy was reduced from 97 to 99 percent at 4 months after application, and was essentially eliminated by 14 months after application of picloram pellets. After 4 months approximately one-half of the willow baccharis population was killed by the lower rates of 5- or 10-percent formulation of picloram pellets. The 5-percent formulation at 2.9 kilograms of active ingredient per hectare killed approximately 91 percent of the willow baccharis after 4 months. Fourteen months following application there was no difference in the percentage of the willow baccharis population killed by the various rates of the two formulations of picloram. Tebuthiuron at 1 and 4.2 kilograms per hectare reduced willow baccharis canopies by 17 and 57 percent, respectively, at 4 months following application. However, the tebuthiuron treatments eliminated willow baccharis canopies by 14 months after herbicide application. Tebuthiuron applied at 1 kilogram per hectare had not killed any willow baccharis plants after 4 months. However, approximately 24 percent of the plants were killed by 4.2 kilograms of herbicide per hectare (Table 5). After 14 months, 1 kilogram of active ingredient per hectare of tebuthiuron killed 43 percent of the willow baccharis plants while 4.2 kilograms of active ingredients per hectare killed 92 percent of the plants.

Results of these experiments indicate that willow baccharis can be effectively controlled by applications of picloram pellets at rates of at least 1 kilogram per hectare. Tebuthiuron appeared to control willow baccharis at 1.12 kilograms of active

Table 4. Average canopy reduction (%) of willow baccharis after application of various rates of picloram and tebuthiuron pellets on May 25, 1976, near College Station, Texas.

Herbicide	Active ingredient (%)	Rate (kg/ha)	Months after treatment[a] 2	7	11
None		0	7 a	7 a	7 a
Picloram	5	1.12	96 d	96 c	98 b
Picloram	5	2.24	98 d	100 c	100 b
Picloram	10	1.12	85 bc	95 c	96 b
Picloram	10	2.24	89 c	95 c	100 b
Tebuthiuron	20	1.12	78 b	83 b	99 b
Tebuthiuron	20	2.24	83 bc	94 c	98 b

[a]Means within a column followed by the same letter are not significantly different at the 0.5-level according to Student-Newman-Keul's Test.

Table 5. Average canopy reduction (%) and percentage of population of willow baccharis completely defoliated and showing no signs of life at 4 and 14 months after application of various rates of pelleted picloram and tebuthiuron on March 29, 1977, near Agua Dulce, Texas.

Herbicide	Active ingredient (%)	Rate (kg/ha)	4 months: Canopy reduction[a] (%)	4 months: Dead plants[a] (%)	14 months: Canopy reduction (%)	14 months: Dead plants (%)
None		0	7 a	0 a	0 a	0 a
Picloram	5	1.3	99 d	55 c	98 b	87 c
Picloram	5	2.9	99 d	91 d	100 b	99 d
Picloram	10	1.1	97 d	47 c	100 b	97 d
Picloram	10	2.4	99 d	70 c	100 b	99 d
Tebuthiuron	20	1.0	17 b	0 a	100 b	43 b
Tebuthiuron	20	4.2	57 c	24 b	100 b	92 cd

[a]Means within a column followed by the same letter are not significantly different at the 95% level according to Duncan's New Multiple Range Test.

ingredients per hectare on a sandy loam soil, but higher rates were necessary on a clay loam soil. Higher rates of either herbicide might be advantageous on seriously deteriorated rangeland to retard reinvasion of seedlings until a grass cover is established. Thereafter, establishment of willow baccharis seedlings may be prevented by grazing management. These pelleted herbicide formulations offer the resource manager considerable flexibility in that both aerial and ground applications are feasible, depending on extent of willow baccharis infestation.

Spiny Aster

Undisturbed spiny aster exhibited slight symptoms of picloram phytotoxicity at 3 to 4 weeks after the first significant rainfall following herbicide application to an Odem fine sandy loam on the Welder Wildlife Refuge. By 95 days after herbicide treatment, undisturbed spiny aster was not affected by 0.56 or 1.12 kilograms per hectare of picloram, regardless of formulation, or by 1.12 kilograms per hectare of tebuthiuron (Table 6). Shredding reduced the original standing crop to a 10-centimeter stubble, but by 95 days after top removal, spiny aster had replaced approximately 30 percent of its original top growth when no herbicide was applied. Shredding followed by applications of 0.56 or 1.12 kilograms of active ingredients per hectare of picloram (5- or 10-percent formulation) reduced the original stem density from 69 to 94 percent after 95 days (Table 6). Picloram at 0.56 kilogram of active ingredients per hectare was generally less effective in reducing live stem densities of spiny aster than was 1.12 kilograms of active ingredients per hectare. However, surviving stems did not make significant additional growth until 1 year after herbicide application. One year following application of picloram pellets, the lower rate was less effective than the higher rate in reducing the height of surviving spiny aster stems (data not shown). At 95 days after application, tebuthiuron at 1.12 kilograms per hectare reduced original live stem densities of spiny aster by 49 percent (Table 6). This reduction was not considered adequate for improving spiny aster-infested communities based on forage response. Therefore, only picloram at 1.12 kilograms per hectare was evaluated in subsequent studies.

Spiny aster growth was significantly reduced by 85 days after application of the 5- or 10-percent picloram pellets at 1.12 kilograms per hectare in the second experiment on the Welder Wildlife Refuge (Table 7). Only trace amounts (<0.1 stem per 0.25 square meter yielding less than 5 kilograms per hectare) of spiny aster occurred on shredded plots which were treated with picloram. At the same time, plots that had been shredded and then treated with 5- or 10-percent picloram pellets supported 4,410 and 4,580 kilograms per hectare, respectively, of oven-dry standing crop. Untreated plots supported only 450 kilograms per hectare of grasses. Spiny aster standing crop was 8,210 kilograms per hectare at 85 days after initiation of the second experiment on the Welder Wildlife Refuge (Table 7). Shredded plots treated with 1.12 kilograms per hectare of picloram supported only trace amounts of spiny aster, reflecting the value of shredding as a pre-treatment to herbicide application. Shredding without picloram allowed foliar cover of grasses to increase from 6 to 45 percent during the year of treatment. However, unless shredded areas were treated with herbicide, spiny aster regrowth markedly reduced grass standing crop by the following growing season.

Based on a 25-percent utilization of forage by cattle and a daily requirement of 12 kilograms dry matter per day to support an animal unit (450 kilogram cow with calf), plots shredded and treated with 1.12 kilograms per hectare of picloram pellets on the Welder Refuge offered about 93 animal-unit days grazing per hectare (about 3.1 animal-unit months). A projected stocking rate for this site was about 4 hectares (10 acres) per animal unit yearlong, based on forage recovery within 90 days after treatment. In comparison, the untreated site would

Table 6. Live stem reduction (%) and mean height (m) of spiny aster stems at 95 days after herbicide application to plots shredded on May 15, 1976, and to undisturbed plots treated on June 1, 1976, with several rates of picloram and tebuthiuron pellets on Welder Wildlife Refuge near Sinton, Texas.

Herbicide	Formulation (% a.i.)	Rate (kg/ha)	Undisturbed[a] Live stem reduction (%)	Shredded Live stem reduction[b] (%)	Shredded Ht (m)
None	0	0	0	0 a	0.3
Picloram	5	0.56	0	83 d	0.1
Picloram	5	1.12	0	94 d	0.1
Picloram	10	0.56	0	69 c	0.1
Picloram	10	1.12	0	85 d	0.1
Tebuthiuron	20	1.12	0	49 b	0.2

[a]Undisturbed spiny aster stems average 1 meter tall.

[b]Means followed by the same letter are not significantly different at the 95% level according to Duncan's New Multiple Range Test.

support 1 animal unit per 39 hectares. Spiny aster control combined with good grazing management and average rainfall should easily provide grazing for 1 animal unit per 6 hectares yearlong on sites similar to those on the Welder Wildlife Refuge study area.

At 15 months after application, standing crop of grasses on shredded plots treated with 5- or 10-percent formulation of picloram pellets was 2410 and 2290 kilograms per hectare, respectively, of which 55 and 60 percent, respectively, was utilized by cattle during the 90-day grazing period preceding evaluation (Table 8). Unshredded plots treated with 1.12 kilograms per hectare of pelleted picloram supported 370 to 490 kilograms per hectare of grass standing crop of which only 10 percent was utilized by livestock. Shredded plots which were not treated with pelleted picloram supported 531 kilograms per hectare of standing crop of which 20 percent was utilized. Untreated plots supported only 130 kilograms per hectare of standing crop of which 12 percent was utilized by cattle (Table 8).

Spiny aster responses to applications of picloram pellets at 1.12 kilograms per hectare on the Victoria clay sites near Refugio were similar to those on the Odem fine sandy loam site near Sinton, regardless of shredding treatment. Four months following application of the pellets during which time 15 centimeters of precipitation were received, the untreated upland site supported 27 live spiny aster stems per square meter while plots treated with 5- or 10-percent picloram pellets contained three and one live spiny aster stems per square meter, respectively (Table 9). On the low-

Table 9. Spiny aster densities (plants per square meter) at 4 months after application of 5- or 10-percent picloram pellets at 1.2 kilograms of active ingredients per hectare on March 27, 1978, to undisturbed spiny aster on an upland site, and to shredded and undisturbed spiny aster on a lowland site near Refugio, Texas.[a]

Picloram formulation (%)	Spiny aster density (plants/m²): Upland site, Not shredded	Lowland site, Shredded	Lowland site, Not shredded
None	27 b	76 c	75 c
5	3 a	5 a	41 b
10	1 a	4 a	34 b

[a]Means within a column followed by the same letter are not significantly different at the 95% level according to Duncan's New Multiple Range Test.

Table 7. Standing crop of grasses and spiny aster (kilograms per hectare), foliar cover of grasses, and spiny aster densities at 85 days after application of 1.12 kilograms per hectare of 5- or 10-percent picloram pellets on March 29, 1977, to shredded and undisturbed spiny aster on the Welder Wildlife Refuge near Sinton, Texas.[a]

Treatment: Herbicide	Formulation (%)	Standing crop (kg/ha): Grasses	Spiny Aster	Grass foliar cover (%)	Spiny aster density (plants/m²)
		Not shredded			
None		450 a	8,210 e	6 a	44 d
Picloram	5	1,070 b	3,470 c	30 b	28 c
Picloram	10	1,280 b	4,915 d	45 b	11 b
		Shredded			
None		1,750 c	1,420 b	45 b	56 d
Picloram	5	4,410 d	T[b] a	68 c	T a
Picloram	10	4,580 d	T a	69 c	T a

[a]Means within a column followed by the same letter are not significantly different at the 95% level according to Duncan's New Multiple Range Test.

[b]Trace — a few scattered spiny aster plants (fewer than 0.04 per square meter) yielding less than 5 kilograms per hectare.

Table 8. Standing crop of grasses (kilograms per hectare) and percentage utilization (%) at 15 months after application of 1.12 kilograms per hectare of the 5- or 10-percent formulation of pelleted picloram to shredded and undisturbed spiny aster on the Welder Wildlife Refuge near Sinton, Texas, on March 29, 1977.[a]

Treatment: Herbicide	Formulation (%)	Standing crop (kg/ha): Shredded	Not shredded	Utilization (%): Shredded	Not shredded
Control	-	531 c	130 a	20 a	12 a
Picloram	5	2,410 d	370 b	55 b	10 a
Picloram	10	2,290 d	490 c	60 b	10 a

[a]Means within a column followed by the same letter are not significantly different at the 95% level according to Duncan's New Multiple Range Test.

land site, shredded plots supported 4 or 5 live spiny aster stems per square meter, while untreated plots supported 76 live spiny aster stems per square meter. Plots treated only with herbicide supported 34 and 41 live spiny aster stems per square meter.

Since the lowland site had been heavily infested with spiny aster for several years, other vegetation did not become established following spiny aster control. Revegetation with adapted grass species will be necessary to expedite the cost return of shredding and herbicide treatment on such sites.

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Appendix

Scientific Names of Plants and Animals Mentioned in Text

Plants

Common Name	Latin Name
Redberry juniper	*Juniperus pinchoti*
Lotebush	*Ziziphus obtusifolia*
Macartney rose	*Rosa bracteata*
Texas persimmon	*Diospyros texana*
Whitebrush	*Aloysia lycioides*
Spiny hackberry	*Celtis pallida*
Berlandier wolfberry	*Lycium berlandieri* var. *berlandieri*
Brownseed paspalum	*Paspalum plicatulum*
Broomsedge bluestem	*Andropogon virginicus*
Silver bluestem	*Bothriochloa saccharoides*
Little bluestem	*Schizachyrium scoparium* var. *frequens*
Coastal Bermudagrass	*Cynodon dactylon*
Hall's panicum	*Panicum hallii*
Texas wintergrass	*Stipa leucotricha*
Pink eveningprimrose	*Oenothera speciosa* var. *speciosa*
Narrowleaf sumpweed	*Iva angustifolia*

Animals

Feral hogs	*Sus scrofa*
White-tailed deer	*Odocoileus virginianus*

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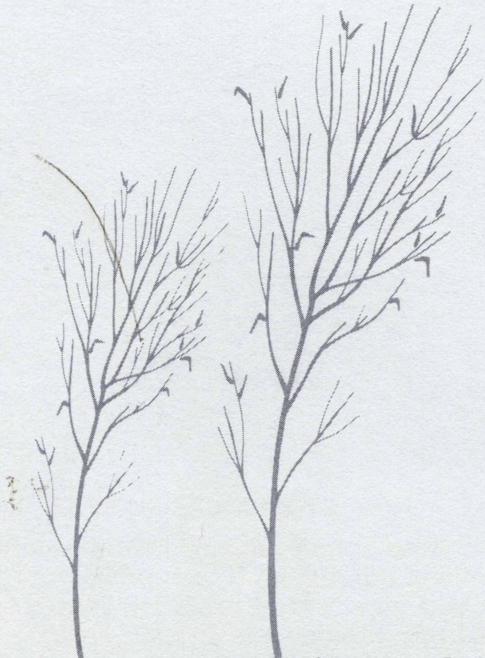

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