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Whitebrush Response to Tebuthiuron and Picloram Pellets

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

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Whitebrush Response to Tebuthiuron and Picloram Pellets

C. J. Scifres, D. L. Embry, and J. L. Mutz*

SUMMARY

Ground or aerial applications of 20 percent active ingredient tebuthiuron pellets at 1.1 or 2.2 kilograms per hectare (kg/ha) during the winter controlled whitebrush on the South Texas Plains more effectively than either the 5 or 10 percent formulations of picloram pellets. Whitebrush control varied little whether the tebuthiuron pellets were applied in the fall, winter or spring. Tebuthiuron applied at 0.3 or 0.6 kg/ha did satisfactorily control whitebrush. Applications of picloram pellets (5 or 10 percent active ingredient) at 1 to 1.3 kg/ha in the summer did not control whitebrush. Shredding whitebrush immediately prior to application of tebuthiuron or picloram pellets usually did not improve whitebrush control, but shredding did improve accessibility to the rangeland by eliminating standing woody debris which typically persists for several years following herbicide application.

INTRODUCTION

Whitebrush (*Aloysia lycioides* Cham.), also called "beebrush" and "vara dulce," is a serious range management problem on the South Texas Plains and Edwards Plateau vegetation regions of Texas. It also occurs in New Mexico, Arizona, Mexico, and South America. This difficult-to-control member of the *Verbenaceae* family occurs on approximately 2.4 million hectares of South Texas rangeland of which almost 250 thousand hectares support infestations of 20 percent or greater canopy cover (Smith and Rechenthin 1964). Whitebrush may occur in mixed stands with more than 15 other species of woody plants or in almost pure, dense thickets of individuals 2 meters (m) tall. Moderate to dense infestations of whitebrush seriously decrease range forage production and efficiency of utilization, and infestation occurs in greatest densities on sites having relatively high production potential (Scifres 1980). Although its flowers are sought out by bees and other insects, whitebrush is of little value as browse for cattle or whitetailed deer (*Odocoileus virginianus*).

Whitebrush will defoliate almost completely when soil water is inadequate, but rapid refoliation accompanied by profuse flowering may readily occur after significant rainfall any time during the growing season (March-November) (Meyer and Bovey 1980). Whitebrush inflorescences are dense, many-flowered spikes or racemes having white or violet-tinged corollas (Correll and Johnston 1970). The fruit is a small, dry schizocarp composed of two small berries, and the seeds are without endosperm. The leaves are entire and generally narrow but width is somewhat variable. Stems and branches are greyish-white, brittle; and the underlying wood is yellowish.

Herbicides commonly used for range improvement, such as 2,4-D ([2,4-dichlorophenoxy]acetic acid), 2,4,5-T ([2,4,5-trichlorophenoxy]acetic acid), and dicamba (3,5-dichloro-*o*-anisic acid) at application rates of 1.1 kilograms per hectare (kg/ha) generally do not effectively control whitebrush (McCully 1955; Bovey et al. 1965; Meyer et al. 1969). For several years, a suggested treatment for whitebrush control was 1.4 kg of MCPA ([(4-chloro-*o*-tolyl)-oxy] acetic acid) amine salt in 9.4 liters of diesel oil and enough water to make 75 liters per hectare (L/ha) of spray solution. This treatment is most effective when whitebrush is in full bloom (Hoffman and Ragsdale 1967). Although MCPA effectively

*Respectively, professor and research assistant, Texas Agricultural Experiment Station (Department of Range Science); and assistant research scientist, Texas Agricultural Experiment Station, Corpus Christi.

kills whitebrush topgrowth, it kills the roots of very few plants. Root kill from MCPA at rates between 1.1 and 9.0 kg/ha generally averaged less than 25% (Meyer 1966). If the whitebrush roots are not killed, the canopy is rapidly replaced by resprouting from basal stem buds.

Picloram (4-amino-3,5,6-trichloropicolinic acid) is one of the few herbicides evaluated for rangeland use which has effectively controlled whitebrush. Picloram sprays applied at 1.1 kg/ha in the spring killed 80 percent of the whitebrush plants (Meyer et al. 1969). Higher picloram rates killed more whitebrush plants but also injured some of the desirable grasses. Aerial sprays of picloram applied in the fall at 3.4 or 4.5 kg/ha killed more than 90 percent of the whitebrush (Gibson and Grumbles 1970). Picloram applications in the spring were usually less effective than those in the fall.

Herbicide pellets or graunules have also shown promise for whitebrush control (Meyer and Riley 1969; Scifres et al. 1979). Applications of dry formulations have several advantages compared to herbicide sprays. Drift potential is greatly reduced if dust associated with dry formulations is minimized. In addition, sprays must normally be applied during short periods in the spring or fall when the brush foliage is fully developed and the woody plants are actively growing. In contrast, pellets or granules may be applied over a much broader time span (Scifres 1980).

Generally, 3.4 or 4.5 kg/ha of pelleted picloram have been necessary to control whitebrush effectively. Meyer (1966) found that pelleted picloram was almost as effective as equal rates of sprays when applied during October, February or April. Picloram granules applied at 4.5 kg/ha killed 80 percent or more of the whitebrush plants in another study. Applications of picloram granules were most effective when applied during cooler months and followed shortly thereafter by enough rainfall to move the herbicide into the soil (Meyer and Riley 1969).

Tebuthiuron (*N*-[5-(1,1-dimethylethyl)-1,3,5-thiadiazol-2-yl]-*N*,*N*′-dimethylurea) is a promising new herbicide for range improvement (Bovey et al. 1975; Scifres 1979). Application rates of 1.1 to 6.7 kg/ha have selectively controlled a variety of woody plant species on rangeland. Applications of tebuthiuron pellets in the spring at 1.1 kg/ha effectively controlled whitebrush, spiny hackberry,[1] and Berlandier wolfberry (McNeill et al. 1977; Scifres et al. 1979; Meyer and Bovey 1980). At 2.2 kg/ha, tebuthiuron pellets applied in the spring effectively controlled post oak, blackjack oak, winged elm, yaupon, water oak, woollybucket bumelia, guajillo, downy hawthorn, Texas colubrina, blackbrush acacia, and willow baccharis (Bovey et al. 1975; Meyer et al. 1978; Mutz et al. 1979; Scifres et al. 1979, 1981). Lotebrush, guayacan, cenizo, twisted acacia and javelinabush are controlled by 2.2 to 3.4 kg/ha of the herbicide. The highest rate evaluated by Scifres et al. (1979), 4.5 kg/ha, controlled huisache, but was only partially effective against honey mesquite. Lime pricklyash, Texas persimmon, pricklypear, eastern redcedar, saw greenbrier, American beautyberry, peppervine, and tasajillo tolerated 4.5 kg/ha of tebuthiuron (Scifres et al. 1979, 1981). Macartney rose is apparently fairly tolerant of tebuthiuron since 2.2 to 4.5 kg/ha killed only 10 to 30 percent of the plants (Meyer and Bovey 1979).

Shredding reduces the overall stature and stem density of some woody plant species but generally results in a net increase in stem density of plants that resprout from basal buds (Dodd and Holtz 1972; Scifres 1980). However, shredding followed by herbicide applications has shown promise for control of some problem range species. For example, 1.1 kg/ha of picloram pellets applied immediately after shredding effectively controlled spiny aster (Mutz et al. 1979). Neither shredding [illegible] pellet applications effectively controlled undisturbed stands. Shredding mixed brush communities prior to pelleted picloram applications did not improve control compared to use of picloram pellets only (Kitchen et al. 1980).

The objectives of this study were to (1) determine the influence of date of application of tebuthiuron application on whitebrush control and (2) evaluate the interrelationship of top removal [illegible] shredding with control from tebuthiuron and picloram pellets.

[1]Scientific names of plants mentioned in text are given in the appendix.

MATERIALS AND METHODS

Description of the Study Area and Sites

This research was conducted on the 74 Ranch located 80 kilometers (km) south of San Antonio on the South Texas Plains. Annual precipitation ranges from 52 to 115 centimeters (cm) with wettest periods generally occurring in May, June, and September. Extremely high summer temperatures and mild winters are common (Gould 1975).

Chemical and physical analyses of soils from the immediate study areas were conducted on quadruplicate samples recovered at 15-cm increments to 60-cm deep and from 60 to 90-cm deep. Soil analyses included texture by the hydrometer method (Milford 1975), organic matter by acid digestion and titration (Mortensen 1965), and pH of a 1:1 soil-water slurry (Peech 1965).

The 1975 experiment was established on a Claypan Prairie range site typified by Laparita loam. Laparita soils occur on nearly level to gently sloping uplands usually in close proximity to small drainageways. Slopes are oft[illegible] less than 1 percent but may range to 3 percent. The solum thickn[illegible] ranges from 100 to 159 cm.

On the immediate study area, soils of the Claypan Prairie range site were sandy clay loams overlaying a clay loam subsoil which gradually increased in clay content with increasing depth (Table 1). A claypan was prominent at the 15 or 30 cm depth, where the clay content increased from 36 to 54 percent. Surface organic matter content was approximately 2.6 percent and gradually decreased with depth. Claypan Prairie soils were acidic or slightly acidic.

Experiments established in 1976 or later were located on a gently sloping, upland, Tight Sandy Loam range site characterized by fine-loams of the Imogene series (Typic Natrustalfs). These deep, moderately well drained, slowly permeable soils have a solum thickness of 55 to 90 cm. Soils of the immediate study area contained considerably more sand than those of the Claypan Prairie site (Table 1). Organic matter content varied from 2.1 percent to 1.4 percent, decreasing with depth, and pH was neutral or near neutral.

Moderate to dense stands of whitebrush dominated the sites, with scattered honey mesquite, Texas colubrina, Texas persimmon, spiny hackberry, agarito, guayacan, guajillo, blackbrush acacia, and twisted acacia comprising the remainder of the woody vegetation. Major grasses were buffalograss, common curly mesquite, plains bristlegrass, hooded windmillgrass, Texas wintergrass, and several threeawns. Forbs include frostweed, western and common ragweeds, yellow thistle, and common lantana as well as members of the Acanthaceae, Euphorbiaceae, Malvaceae, and Solanaceae families. The study area was fenced to prevent livestock grazing, and rain gauges were installed prior to herbicide application.

Herbicide Applications

Picloram (5 to 10 percent active ingredient [a.i.]) or tebuthiuron (20 percent a.i.) pellets, depending on the specific experiment, were applied by hand, with a tractor-mounted spreader or with fixed-wing aircraft. Herbicide was hand-applied with a crank-type spreader normally used for dispensing fertilizer or seeds. Herbicide was applied to some experiments, usually in 6.2-m-wide swaths, with a fertilizer spreader on a small tractor. Where liquid formulations were included for comparison to pellets, sprays were applied in 82 L/ha of water with a tractor-mounted sprayer equipped with a 6.2-m-wide boom. Tebuthiuron was aerially applied with a fertilizer spreader-seeder attachment in swaths 11 m wide in one experiment.

On July 14, 1975, picloram pellets (5 percent a.i.) were applied at 0.7, 1, or 2 kg/ha with the tractor-mounted spreader to plots 15 × 45 m in size, arranged in a randomized complete block design with six replications. The whitebrush stand had been shredded 18 months previously, and the regrowth was about 1 m tall on the uplands and 1.5 to 2 m tall on the lowlands. At the time of herbicide application, about 75 percent of the whitebrush foliage was fully developed, and floral structures were 25 percent formed. Light rains for two days previously had wet the surface cm of soil. On July 15, 1975, the tractor-mounted spreader was used to apply the picloram pellets to stands shredded 30 days previously on which the regrowth averaged 15 cm. Picloram pellets were applied at 0.5, 1 or 2 kg/ha to each of six, 15 × 45 m plots arranged as randomized complete blocks.

On June 9, 1976, the tractor applicator was used in an experiment to evaluate herbicides for control of mature and recently shredded whitebrush. Treatments included picloram pellets, 5 or 10 percent a.i., applied at 1 or 1.3 kg/ha, respectively, to undisturbed whitebrush, and at 1.1 kg/ha to shredded whitebrush. Sprays of the potassium salt of picloram were applied at 1.1 kg/ha. Tebuthiuron pellets (20 percent a.i.) were applied at 0.7 and 1.7 kg/ha to undisturbed whitebrush, and at 0.9 and 1.7 kg/ha to shredded whitebrush. Each treatment was replicated three times using plots 24 × 46 m in size, in a whitebrush stand of plants 1-2 m tall which represented mature growth (last shredded in October 1973), and in a stand shredded 30 days prior to the herbicide application with regrowth 2-15 cm tall. The experiment was designed as a randomized complete block design arranged in split plots with shredding treatment as the main plot effect and herbicide rate as the subplot effect.

On May 25, 1977, tebuthiuron pellets (20 percent a.i.) were aerially applied at 1.5 or 2 kg/ha in swaths 11 m wide to plots 100 m wide and 275 m long. Treatments were duplicated in a randomized complete block design.

Tebuthiuron and picloram pellets were applied to undisturbed whitebrush stands and to areas which were shredded immediately prior to herbicide application at various dates in 1976 and 1977. Pelleted tebuthiuron (20 percent

TABLE 1. GENERALIZED SOIL CHARACTERISTICS OF RANGE SITES UTILIZED FOR EVALUATION OF PICLORAM AND TEBUTHIURON PELLETS FOR WHITEBRUSH CONTROL ON THE SOUTH TEXAS PLAINS NEAR CAMPBELLTON

Depth (cm)	Organic matter (%)	pH (1:1)	Textural components (%)		
			Sand	Silt	Clay
		Claypan Prairie			
0-15	2.6	5.5	41	23	36
15-30	2.2	6.0	25	21	54
30-45	2.1	6.5	20	20	55
		Tight Sandy Loam			
0-15	2.1	7.0	71	15	14
15-30	1.6	6.9	63	15	22
30-45	1.4	7.1	51	13	36

a.i.) was applied broadcast with a hand-operated spreader to shredded and undisturbed whitebrush stands in the fall (October 12, 1976), winter (February 25, 1977), or spring (June 1, 1977). Experimental design was a randomized complete block with three replications and arranged as a split-split plot. Date of treatment constituted main plot effects, and shredding treatment contributed subplot variation. Sub-subplots, 15 × 23 m, were treated with 0, 0.3, 0.6, 1.1, or 2.2 kg/ha of tebuthiuron. Picloram pellets, 5 and 10 percent a.i., were applied at 1.1 and 2.2 kg/ha during the winter of 1977 to shredded and to unshredded whitebrush immediately adjacent to the experiment with tebuthiuron. Main plots were shredded on February 25, 1977, and herbicide was applied the same day to 15 × 30-m subplots using the hand-operated broadcast spreader. Because picloram was applied only during the winter, data were analyzed as a separate experiment designed as a randomized complete block having three replications and arranged in a split plot. Shredding constituted main plot effects while subplot variation was contributed by picloram rate or formulation.

Whitebrush Response to Herbicide Treatments

Whitebrush response was evaluated periodically following treatment, generally at 6- to 12-month intervals, in all experiments treated with ground equipment except those installed at the various seasons from the fall 1976 to spring 1977. Ocular estimates of canopy reduction, usually by three workers, were averaged for presentation. At the same times, live whitebrush stems were counted in six to ten 1 m^2 plots, located on a line diagonally across each plot. In some cases, height of whitebrush regrowth stems was measured in each quadrat.

Line transects were established diagonally across each experimental unit (subplot of picloram-treated areas or sub-subplot on tebuthiuron-treated areas) in the experiment evaluating date of herbicide application. Percentage whitebrush foliar cover and average height of canopy were recorded prior to the installation of each treatment and again in October 1977 and May 1978. During these evaluations, six 1 m^2 quadrats were also sampled at regular intervals to determine densities of live whitebrush stems. Numbers of new growth and original live stems were recorded separately. Foliar cover and live stem density are reported as percentages of pretreatment values. On September 5, 1980, canopy cover in each plot was estimated by three workers.

Canopy reduction of whitebrush in plots aerially treated with tebuthiuron was visually estimated at 6, 16 and 38 months after herbicide application. Percentage of whitebrush plants apparently killed (plants completely defoliated, branches dead, no growth) were recorded in belt transects, 2-m wide, down the center of each plot.

RESULTS AND DISCUSSION

Picloram pellets applied in July 1975 did not control undisturbed whitebrush (Table 2, see footnote). Although only about 9 cm of rainfall occurred on the study site in June, more than 23 cm were received in May (Table 3). That rainfall combined with about 1 cm of total precipitation the week before herbicide application had wet the surface thoroughly, and the whitebrush was fully foliated. At 11 months after application, the pelleted picloram applied at 0.5 or 1 kg/ha was only slightly more effective when applied to stands

TABLE 2. PERCENTAGE CANOPY REDUCTION AND APPARENT STEM KILL AT VARIOUS TIMES AFTER APPLICATION OF PICLORAM PELLETS WITH GROUND EQUIPMENT IN JULY 1975 TO WHITEBRUSH SHREDDED 30 DAYS PREVIOUSLY ON THE SOUTH TEXAS PLAINS NEAR CAMPBELLTON[1]

	Months after treatment					
	11		29		44	
Picloram rate (kg/ha)	Canopy reduction	Dead stems	Canopy reduction	Dead stems	Canopy reduction	Dead stems
0	0 a	0 a	0 a	0 a	0 a	0 a
0.5	20 c	5 ab	0 a	0 a	0 a	0 a
1.0	20 c	5 ab	0 a	0 a	0 a	0 a
2.0	80 e	31 d	15 bc	6 ab	10 b	5 ab

[1]Means followed by the same letter are not significantly different at the 95% level according to Duncan's multiple range test. Mean canopy reduction of undisturbed whitebrush treated at the same time with 0, 0.7, 1 or 2 kg/ha of picloram pellets was 0 a, regardless of time after treatment.

TABLE 3. MONTHLY RAINFALL ON THE STUDY AREA DURING THE PERIOD IN WHICH PELLETED HERBICIDES WERE BEING EVALUATED FOR WHITEBRUSH CONTROL ON THE SOUTH TEXAS PLAINS NEAR CAMPBELLTON

	Rainfall (cm) by year					
Month	1975	1976	1977	1978	1979	1980
January	0.1	1.5	6.0	1.8	5.5	1.1
February	4.1	0	2.0	0.8	3.0	2.0
March	0.9	0.9	2.3	8	3.0	0.7
April	8.2	8.5	15.5	1.8	4.4	0.1
May	23.1	15.3	5.7	7.5	4.9	
June	8.8	9.1	1.4	9.1	10.2	
July	5.6	11.1	5.5	8.2	4.9	
August	10.1	6.3	0	5.5	1.9	
September	5.4	7.7	0	4.7	3.3	
October	10.2	20.6	10.0	1.8	0.2	
November	T[1]	7.9	4.5	2.2	T	
December	2.7	9.9	1.0	2.3	2.5	
Annual total	79.2	98.9	53.9	45.7	43.8	

[1]T = trace, less than 0.05 cm.

shredded 30 days earlier than when applied to undisturbed stands (Table 2). From the time of herbicide application until the first evaluation almost a year later, about 69 cm of rainfall occurred, most during late summer to early fall after treatment and the following April and May (Table 3). This amount of rainfall was considered adequate to leach the herbicide into the root zone of the whitebrush. However, canopy reduction on shredded areas was only 20 percent where 0.5 or 1 kg/ha of picloram had been applied (Table 2). Canopy reduction was 80 percent 11 months after shredded whitebrush stands were treated with 2 kg/ha of the picloram, and 31 percent of the stems appeared dead. By 29 months after application of the picloram pellets at 0.5 or 1 kg/ha, the whitebrush had completely recovered on the shredded areas, and the canopies were reduced by only 15 percent where 2 kg/ha were applied. Whitebrush control at 44 months after application of the pellets was no different from that after 29 months.

Applications of picloram pellets in the winter were generally more effective than those applied in the summer. At 8 months after application of the 5 or 10 percent picloram pellets at 1.1 kg/ha (a.i.) to undisturbed stands in February 1977, whitebrush canopies were reduced by 85 to 87 percent (Table 4). Shredding did not significantly increase the defoliation of whitebrush by the picloram pellets, and defoliation from 2.2 kg/ha of the herbicide was only slightly greater where the lower rate was applied, regardless of shredding treatment. Canopy reduction percentages at 14 months after application of the picloram pellets differed little from those at 8 months after treatment of the whitebrush. Moreover, there was little difference attributable to the percentage active ingredient of pellets applied or to shredding treatment. By 42 months after application of the picloram pellets in winter of 1977, effects of the shredding treatment were not discernible. There was a tendency for the herbicide applications to be less effective on the plots which had been shredded prior to picloram application. Although the 5 percent formulation more effectively reduced whitebrush canopy where 1.1 kg/ha of the herbicide was applied, there was no difference in response to 2.2 kg/ha.

By 14 months after application of the picloram pellets in the winter of 1977, there tended to be fewer stems killed by the herbicide in shredded than in unshredded areas (Table 4). A greater percentage of stems were killed by the higher rate than by 1.1 kg/ha but there was little difference in stem kill between formulations within an application rate applied to undisturbed stands.

Foliar cover of the untreated whitebrush stand did not change appreciably from the time of tebuthiuron application to evaluations of plots in May 1978 (Table 5). Applications of 0.3 kg/ha of tebuthiuron in the fall or winter did not significantly decrease the whitebrush foliar cover, but application in the spring reduced the canopies by 40 percent. New sprouts on undisturbed plants increased, on the average, by 18 percent from initiation of the study to evaluations almost 19 months later (Table 6). However, the number of live whitebrush stems was significantly reduced by the lower rate of tebuthiuron only after application in the winter 1977. Based on these data, 0.3 kg/ha of tebuthiuron was considered ineffective for whitebrush control.

TABLE 4. PERCENTAGE REDUCTION IN FOLIAR COVER AND LIVE STEM DENSITIES OF WHITEBRUSH 8, 14 AND 42 MONTHS AFTER APPLICATION OF PELLETED PICLORAM TO UNDISTURBED STANDS AND IMMEDIATELY FOLLOWING SHREDDING IN THE WINTER 1977 ON THE SOUTH TEXAS PLAINS NEAR CAMPBELLTON

Rate (kg/ha)	Formulation (%)	Months after treatment[1]					
		8		14		42	
		Undisturbed	Shredded	Undisturbed	Shredded	Undisturbed	Shredded
		Foliar cover reduction					
0	—	16 a	61 b	4 a	35 b	0 a	0 a
1.1	5	85 c	90 c	91 d	85 cd	57 bc	41 b
1.1	10	87 c	90 c	76 c	87 cd	14 a	19 a
2.2	5	96 c	94 c	95 c	89 d	89 e	65 cd
2.2	10	94 c	94 c	90 d	85 cd	85 de	67 cd
		Reduction in live stem densities					
0	0	0 a	0 a	0 a	0 a	—[2]	—
1.1	5	87 cd	65 b	67 e	20 b	—	—
1.1	10	88 cd	61 b	61 e	30 bc	—	—
2.2	5	99 d	78 bc	83 f	55 de	—	—
2.2	10	98 d	89 cd	86 f	39 cd	—	—

[1]Means within an attribute and time of evaluation are not significantly different at the 95% level according to Duncan's multiple range test. Values in parentheses represent actual increases relative to original densities.

[2]Densities not recorded.

Tebuthiuron applied at 0.6 kg/ha had significantly reduced the foliar cover of the unshredded whitebrush by May 1978, but there was no difference in defolition attributable to season of application (Table 5). The 0.6 kg/ha rate reduced the live stem density by 29 to 54 percent, and fall applications tended to be more effective than treatments in the spring or summer (Table 6). Scifres et al. (1979) indicated the possibility of 0.6 kg/ha being an effective rate of tebuthiuron for whitebrush control. However, in this study, at least 1.1 kg/ha of the herbicide was required to reduce the canopies of undisturbed whitebrush by 78 percent or more on these range sites, regardless of application date, by May 1978.

Whitebrush control on unshredded areas was no different within a season of application whether 1.1 or 2.2 kg/ha of tebuthiuron were applied (Tables 5 and 6). However, there was a trend for applications in the fall or winter to reduce live stem density and foliar canopy of whitebrush more effectively than when tebuthiuron was applied in the spring.

From 34 to 52 percent of the whitebrush foliar cover on areas which were shredded but not treated with herbicides had been replaced by May 1978 (Table 5). In general, shredding followed immediately by application of 0.3 kg/ha of tebuthiuron tended to be only slightly more effective for reducing the foliar cover of whitebrush than was shredding alone. Based on canopy reduction from the same rate of herbicide applied to undisturbed whitebrush, the combined effects of tebuthiuron at 0.3 kg/ha with shredding were simply additive.

There was a general tendency for 0.6 kg/ha of tebuthiuron and shredding to reduce the whitebrush canopies more effectively than herbicide application alone (Table 5). However, there was no difference in stem kill whether 0.6 kg/ha of the herbicide was applied to undisturbed stands or to shredded areas, except when the herbicide was applied in the fall (Table 6).

There was no difference in foliar cover reduction of whitebrush from 1.1 or 2.2 kg/ha of tebuthiuron whether the herbicide was applied to shredded or undisturbed stands, regardless of application date (Table 5). Based on evaluations in May 1978, percentage of stem kill was increased when shredding was used as pretreatment in the spring but not in the fall or winter (Table 6).

Regrowth of unshredded whitebrush stands treated with 0.6, 1.1 or 2.2 kg/ha of tebuthiuron h[illegible] not attained the height of untreated stands by May 1978, regardless of season of herbicide application (Table 7). There was no significant difference in the height of untreated whitebrush and stands treated with 0.3 kg/ha of tebuthiuron. Stands of whitebrush which were shredded only were significantly shorter than undisturbed stands, having replaced

TABLE 5. PERCENTAGE REDUCTION IN FOLIAR COVER OF WHITEBRUSH IN MAY 1978 ON SHREDDED AND UNSHREDDED RANGELAND FOLLOWING FALL 1976, WINTER 1977 OR SPRING 1977 APPLICATIONS OF PELLETED TEBUTHIURON NEAR CAMPBELLTON, TEXAS

Rate (kg/ha)	Season of treatment[1]		
	Fall 1976	Winter 1977	Spring 1977
		Unshredded	
0	9 ab	0 a	(+13) a
0.3	18 b	11 ab	41 c
0.6	59 c-f	53 cde	50 cd
1.1	95 i	81 f-i	78 e-i
2.2	92 hi	90 ghi	78 e-i
		Shredded[2]	
0	68 d-h	48 cd	66 c-g
0.3	58 c-f	69 d-h	83 ghi
0.6	79 e-i	84 ghi	89 ghi
1.1	96 i	89 ghi	89 ghi
2.2	98 i	96 i	96 i

[1]Means followed by the same letter are not significantly different at the 95% level according to Duncan's multiple range test.

[2]Shredded immediately prior to herbicide application.

TABLE 6. PERCENTAGE REDUCTION OF WHITEBRUSH STEM DENSITY IN MAY 1978 ON SHREDDED AND UNSHREDDED AREAS FOLLOWING FALL 1976, WINTER 1977 OR SPRING 1977 APPLICATIONS OF PELLETED TEBUTHIURON NEAR CAMPBELLTON, TEXAS

Rate (kg/ha)	Season of treatment[1]		
	Fall 1976	Winter 1977	Spring 1977
		Unshredded	
0	0 a	0 a	0 a
0.3	0 a	12 abc	4 a
0.6	54 fgh	29 bcd	42 def
1.1	96 k	71 hij	35 cde
2.2	83 ijk	80 ijk	55 fgh
		Shredded[2]	
0	0 a	0 a	34 cde
0.3	3 a	5 ab	3 a
0.6	30 cd	14 abc	42 def
1.1	71 hij	61 ghi	71 hij
2.2	97 k	82 ijk	92 jk

[1]Means followed by the same letter are not significantly different at the 95% level according to Duncan's multiple range test.

[2]Shredded immediately prior to herbicide application.

from 27 to 53 percent of the average height of untreated plants by May 1978. Within shredded stands, there was no difference in the height of whitebrush regrowth on areas treated with 0.3 or 0.6 kg/ha of tebuthiuron and those shredded only, regardless of date of herbicide application. Although regrowth height was variable, regrowth on shredded areas treated with 1.1 or 2.2 kg/ha of tebuthiuron generally was shorter than where stands were shredded only, and shorter than regrowth where the herbicide was applied to undisturbed stands.

In September 1980, approximately 4 years after application of the tebuthiuron pellets in 1976, whitebrush canopies on plots receiving 0.6 kg/ha or more of the herbicide were reduced by more than 90 percent (Table 8). Canopy reduction of whitebrush treated in the spring of 1977 was the same as where the herbicide was applied in the fall of 1976 at 0.6, 1.1 or 2.2 kg/ha. Control from winter 1977 applications tended to be less than from fall or spring applications, except where 0.3 kg/ha of tebuthiuron was applied. The percentage of canopy reductions of whitebrush was similar within an application rate and date whether originally applied to shredded or unshredded plots.

Picloram sprays applied at 1.1 kg/ha on June 9, 1976 more effectively reduced the canopy of undisturbed whitebrush than did picloram pellets applied at 1 or 1.3 kg/ha (Table 9). Based on canopy reduction at 18 months after application, picloram sprays were more effective than dry herbicide formulations for controlling undisturbed whitebrush. However, 28 months after treatment, tebuthiuron at 1.7 kg/ha had completely defoliated the whitebrush and had apparently killed more than 90 percent of the stems. In comparison, the whitebrush had recovered completely where the picloram pellets were applied, and canopy reduction was only 15 percent where the lower rate of tebuthiuron was applied. As in the previous experiment, whitebrush control with less than 1 kg/ha of tebuthiuron was not considered satisfactory. Also, as reported by Mutz et al. (1979), tebuthiuron tends to act somewhat more slowly than picloram pellets or sprays and does not usually manifest potential brush control levels until the second or subsequent growing seasons following application.

Whitebrush which had been shredded 30 days prior to chemical treatment was neither controlled by picloram sprays nor either formulation of the picloram pellets (Table 9). However, in contrast to results from previous experiments, whitebrush control from both rates of tebuthiuron were improved when applied to the shredded stands, compared to the undisturbed brush. The degree of improvement in control was most pronounced where 0.9 kg/ha of tebuthiuron was applied.

Whitebrush control from aerially applied tebuthiuron was similar to results from ground applica-

TABLE 7. AVERAGE HEIGHT (CM) OF LIVE WHITEBRUSH IN MAY 1978 FOLLOWING APPLICATION OF TEBUTHIURON IN THE FALL 1976, WINTER 1977 OR SPRING 1977 TO SHREDDED AND UNSHREDDED STANDS NEAR CAMPBELLTON

Rate (kg/ha)	Season of treatment[1]		
	Fall 1976	Winter 1977	Spring 1977
		Unshredded	
0	91 l	106 l	113 l
0.3	94 l	86 kl	97 l
0.6	56 f-i	60 g-j	73 jk
1.1	63 hij	52 e-i	46 d-h
2.2	64 ij	58 g-j	38 cde
		Shredded[2]	
0	40 def	56 f-i	31 a-d
0.3	48 d-i	49 d-i	24 a-c
0.6	44 d-g	33 b-e	24 a-c
1.1	21 abc	24 abc	17 ab
2.2	18 ab	15 a	14 a

[1]Means followed by the same letter are not significantly different at the 95% level according to Duncan's multiple range test.

[2]Shredded immediately prior to herbicide application.

TABLE 8. PERCENTAGE CANOPY REDUCTION OF WHITEBRUSH IN SEPTEMBER 1980 FOLLOWING APPLICATION OF TEBUTHIURON IN THE FALL 1976, WINTER 1977 OR SPRING 1977 TO SHREDDED AND UNSHREDDED STANDS NEAR CAMPBELLTON

Rate (kg/ha)	Season of treatment[1]		
	Fall 1976	Winter 1977	Spring 1977
		Unshredded	
0	0 a	0 a	0 a
0.3	16 ab	33 bc	39 c
0.6	92 de	39 c	91 de
1.1	96 de	84 d	92 de
2.2	96 de	73 d	98 e
		Shredded[2]	
0	0 a	0 a	0 a
0.3	17 ab	36 bc	37 c
0.6	84 d	36 bc	91 de
1.1	96 de	94 de	89 de
2.2	99 e	98 e	95 de

[1]Means followed by the same letter are not significantly different at the 95% level according to Duncan's multiple range test.

[2]Shredded immediately prior to herbicide application.

tions of the herbicide. At 6 months after aerial application of 1.5 or 2 kg/ha, canopy reduction averaged about 80 percent, but adequate time had not lapsed to allow stem mortality (Table 10). By 18 months after treatment, the whitebrush canopies were eliminated, and 80 to 92 percent of the original stems were showing no signs of life. At 40 months after aerial application of tebuthiuron, canopy reduction was greater than 95 percent, and the stems killed by the herbicide had deteriorated.

CONCLUSIONS

Tebuthiuron 20 percent (a.i.) pellets at 1 kg/ha control whitebrush more effectively than picloram or than other concentrations of tebuthiuron. Season of tebuthiuron application was not as important as rate of application. Shredding immediately prior to tebuthiuron application does not affect the level of whitebrush control substantially. Tebuthiuron acts more slowly than picloram and usually requires at least one full growing season before maximum defoliation of the brush occurs.

Although shredding as a pretreatment does not significantly increase whitebrush control with herbicide pellets, it immediately reduces the physical obstructions caused by the brush. Since whitebrush regrows rapidly following shredding, application of tebuthiuron pellets prevents redevelopment of the brush stands. Thus, the combination of treatments has merit for immediately improving ease of management of whitebrush-infested rangeland followed by long-term range improvement from the herbicide application.

Application of picloram pellets containing 5 or 10 percent a.i. in the summer (June-July) at 1 to 1.3 kg/ha does not effectively control whitebrush on the South Texas Plains. Although rainfall following treatment in the summer may be adequate to dissolve the herbicide and move it into the root zone of the whitebrush, effects of 1.3 kg/ha of the herbicide are usually not evident by the second growing season after application. July applications of 2 kg/ha of the 10 percent picloram pellets to shredded whitebrush initially suppresses the brush stands, but the whitebrush can recover by the third growing season after treatment. Applications of picloram pellets in the winter are more effective for whitebrush control than are summer applications. There is no advantage to shredding the whitebrush prior to application of picloram pellets and no difference in whitebrush control between the 5 and 10 percent formulations, regardless of season of application.

TABLE 9. PERCENTAGE CANOPY REDUCTION AND MORTALITY OF SHREDDED OR UNSHREDDED WHITEBRUSH PLANTS TREATED WITH PICLORAM OR TEBUTHIURON ON JUNE 9, 1976 ON THE SOUTH TEXAS PLAINS NEAR CAMPBELLTON[1]

			Months after treatment			
			18		28	
Herbicide	Formulation	Rate (kg/ha)	Canopy reduction	Dead plants	Canopy reduction	Dead plants
		Unshredded				
None	—	0	0 a	0 a	0 a	0 a
Picloram	Liquid	1.1	95 fg	50 d	30 bc	6 abc
Picloram	5% pellets	1.0	34 c	15 c	0 a	0 a
Picloram	10% pellets	1.3	29 bc	7 abc	0 a	0 a
Tebuthiuron	20% pellets	0.7	40 c	13 bc	15 ab	0 a
Tebuthiuron	20% pellets	1.7	73 de	65 e	100 g	90 f
		Shredded[2]				
None	—	0	33 bc	0 a	0 a	0 a
Picloram	Liquid	1.1	0 a	0 a	0 a	0 a
Picloram	5% pellets	1.1	0 a	0 a	0 a	0 a
Picloram	10% pellets	1.1	4 a	3 ab	5 a	0 a
Tebuthiuron	20% pellets	0.9	58 d	53 de	80 ef	50 d
Tebuthiuron	20% pellets	1.7	93 f	86 f	95 fg	95 f

[1]Means followed by the same letter within an evaluation criterion are not significantly different at the 95% level according to Duncan's multiple range test.

[2]Shredded approximately 30 days prior to herbicide application.

TABLE 10. PERCENTAGE CANOPY REDUCTION AND DEAD WHITEBRUSH PLANTS AT 6, 16, AND 40 MONTHS AFTER AERIAL APPLICATION OF TEBUTHIURON ON MAY 25, 1977 NEAR CAMPBELLTON

	Months after herbicide application[1]				
	6		18		40
Rate (kg/ha)	Canopy reduction	Dead plants	Canopy reduction	Dead plants	Canopy reduction
0	0 a	0 a	0 a	0 a	0 a
1.5	83 b	0 a	100 b	92 b	95 b
2.0	78 b	0 a	100 b	80 b	99 b

[1]Means within a column followed by the same letter are not significantly different at the 95% level according to Duncan's multiple range test.

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Metric Units — English Equivalents

Metric Unit	English Equivalent
Centimeter	0.394 inch
Hectare	2.47 acres
Kilogram	2.205 pounds
Kilogram per hectare	0.983 pound per acre
Kilometer	0.62 statute mile
Kilometer per hour	0.62 mile per hour
Liter	0.264 gallon
Meter	3.28 feet
Square meter	10.758 square feet
(Degrees centigrade × 1.8 + 32)	Degrees fahrenheit

APPENDIX
Scientific Names of Plants Mentioned in Text

Common name	Scientific name
American beautyberry	*Callicarpa americana*
Agarito	*Berberis trifoliolata*
Berlandier wolfberry	*Lycium berlandieri*
Blackbrush acacia	*Acacia ridigula*
Blackjack oak	*Quercus marilandica*
Buffalograss	*Buchloe dactyloides*
Cenizo	*Leuchophyllum frutescens*
Common ragweed	*Ambrosia artemisiifolia*
Common curlymesquite	*Hilaria berlangeri*
Common lantana	*Lantana horrida*
Downy hawthorn	*Crataegus mollis*
Eastern redcedar	*Juniperus virginiana*
Frostweed	*Verbesina microptera*
Guajillo	*Acacia berlandieri*
Guayacan	*Porlieria angustifolia*
Honey mesquite	*Prosopis glandulosa* var. *glandulosa*
Hooded windmillgrass	*Chloris cucullata*
Huisache	*Acacia farnesiana*
Javelinabrush	*Microrhamnus ericoides*
Lotebush	*Ziziphus obtusifolia*
Lime pricklyash	*Zanthoxylum fagara*
Macartney rose	*Rosa bracteata*
Peppervine	*Ampelopsis arborea*
Post oak	*Quercus stellata*
Pricklypear	*Opuntia* sp.
Plains bristlegrass	*Setaria macrostachya*
Saw greenbrier	*Smilax bona-nox*
Spiny aster	*Aster spinosus*
Spiny hackberry	*Celtis pallida*
Tasajillo	*Opuntia leptocaulis*
Texas colubrina	*Colubrina texensis*
Texas persimmon	*Diospyros texana*
Texas wintergrass	*Stipa leucotricha*
Threeawns	*Aristida* sp.
Twisted acacia	*Acacia tortuosa*
Water oak	*Quercus nigra*
Western ragweed	*Ambrosia psilostachya*
Willow baccharis	*Baccharis salicina*
Winged elm	*Ulmus alata*
Woollybucket bumelia	*Bumelia lanuginosa*
Yaupon	*Ilex vomitoria*
Yellow thistle	*Cirsium horridulum*

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