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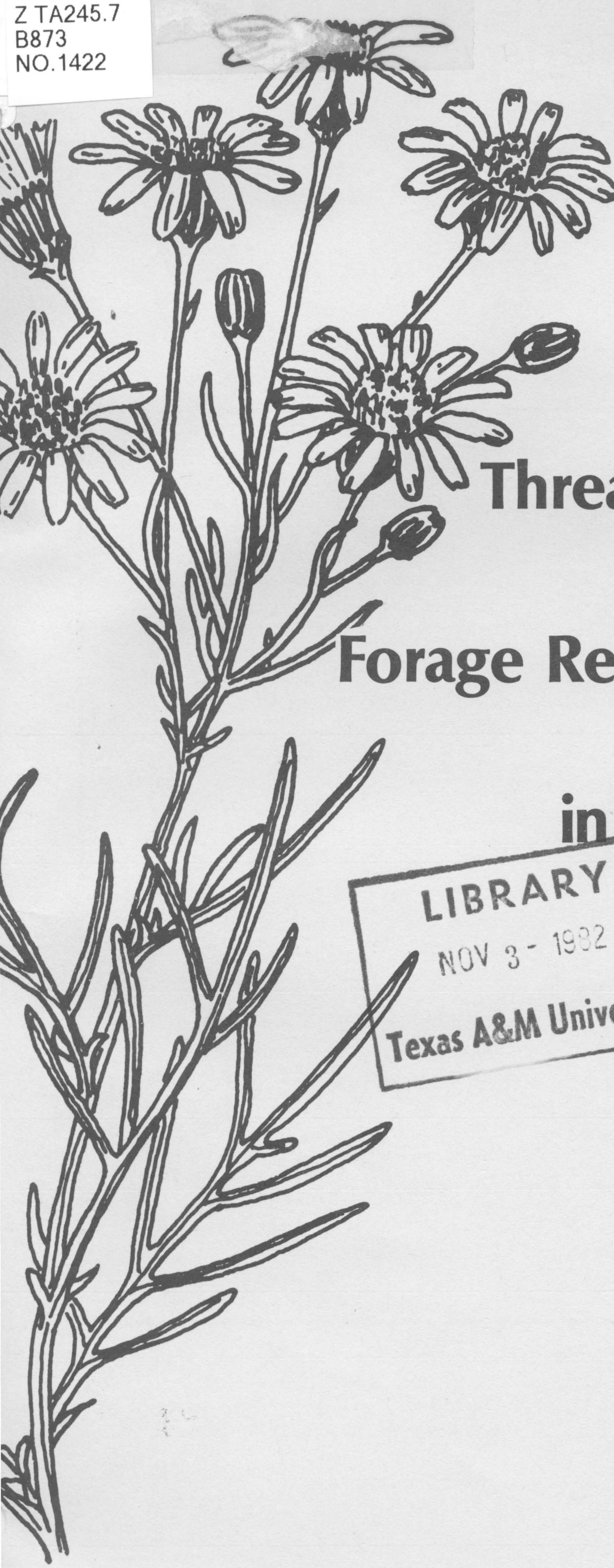

Threadleaf Groundsel and Forage Response to Herbicides in the Davis Mountains

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SUMMARY

Sprays of 2,4-D + picloram (4:1), 2,4,5-T + picloram (1:1), or picloram alone at 1.1 kilogram per hectare (kg/ha) in fall or winter effectively controlled threadleaf groundsel on Deep Upland and Igneous Hill and Mountain range sites in the Davis Mountains. Tebuthiuron applied as sprays of wettable powder in water or pellets at 1.1 kg/ha during summer reduced threadleaf groundsel densities by 99 to 100 percent for almost 20 months after treatment, but applications at other seasons were not effective. Sprays of 2,4-D, dicamba, or 2,4-D + dicamba (3:1) at 1.1 kg/ha and pelleted picloram at 1.1 kg/ha did not effectively control threadleaf groundsel. Fall or winter applications of the foliar-active herbicides were generally more effective for threadleaf groundsel control than were spring or summer applications, presumably because the plants were actively growing in the fall and winter. Blue grama and associated grasses were damaged by summer applications of most herbicides, but recovered during the subsequent growing season.

INTRODUCTION

Threadleaf groundsel (*Senecio douglasii* DC. var. *longilobus* [Benth.] L. Benson),[1] also referred to as "woolly groundsel" or "woolly senecio", causes serious livestock losses throughout the western range states, especially in the Trans Pecos resource area of Texas (Clawson, 1933; Mathews, 1933; Norris, 1951; and Vardiman, 1952). The perennial subshrub occurs throughout the western half of Texas and extends north to Nebraska and Wyoming, west to Arizona and south to the 20th parallel in Mexico (Ediger, 1970; Sperry *et al.*, 1964). The stems and leaves of threadleaf groundsel are covered with whitish, woolly hairs. The leaves may be pinnately lobed on the lower half of the plants but the lateral and terminal leaves are linear. The principal involucral bracts, which do not exceed 9 millimeters (mm) in length, usually number 21 (Correll and Johnston, 1970). The plant is herbaceous when young but becomes woody with maturity. Yellow flowers are produced from May through November (Patraw, 1953). Populations of threadleaf groundsel typically occur on rocky slopes and grass-dominated mesas at elevations from 762 to 2,134 meters (m) (Rickett, 1969). The species increases in abundance following overgrazing and soil disturbance (Sperry *et al.*, 1964).

Cattle are most susceptible to threadleaf groundsel toxicity, but horses, sheep, and goats may also be affected (Sperry *et al.*, 1964). Longilobine, a pyrrolizidine alkaloid, is the poisonous principle in threadleaf groundsel. Longilobine is more concentrated in young plants and leaves of older plants (Manske, 1931). Briske and Camp (1982) reported that total alkaloid concentration in threadleaf groundsel leaves, stems, and roots increased with increasing severity of water stress.

Threadleaf groundsel may be consumed by livestock at any season, but is usually eaten in greatest quantities when snow covers desirable forage or during extended dry periods. Toxicity symptoms or livestock losses are usually greatest during late spring and summer months since there may be a time lapse of several months between consumption and first visible signs of intoxication (Kingsbury, 1964; Sperry *et al.*, 1964). Consumption of 1 to 5 percent of an animal's body weight in a single feeding or over a period of several days will induce symptoms (Dollahite, 1972). Sperry *et al.* (1964) recommended supplemental feeding for reducing livestock losses to threadleaf groundsel poisoning. Dollahite (1972) reported that abundance of threadleaf groundsel may be reduced by grazing infested rangeland with goats or sheep.

The present recommendation for controlling threadleaf groundsel in West Texas is application of 2,4-D[2] sprays at 1.1 kg acid equivalent (ae)/ha during the spring (Sperry *et al.*, 1964). However, this practice has resulted in erratic control, and is usually applied too late to

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[1]eadleaf groundsel has long been referred to as *Senecio longilobus* Benth. until the taxonomic change by Barkley (1978).

[2]Chemical names of herbicides mentioned in text are given in Table 2.

prevent livestock toxicity problems. Norris (1951) reported 2,4-D to be more effective than 2,4,5-T for control of threadleaf groundsel. Application of low volatile esters of 2,4-D at 0.406 kg per liter (kg/l) of water during January or May completely controlled threadleaf groundsel, whereas applications in February when soils were dry did not effectively control the weed.

This study was initiated in 1978 to evaluate several herbicides applied at different seasons for consistent and extended control of threadleaf groundsel in western Texas; and to determine the response of associated forage species following control of threadleaf groundsel.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted on the Billy and Tommy Weston Ranch, 6.4 kilometers (km) southeast of Fort Davis, Texas in Jeff Davis County. Elevation of the study area is 1,524 m and average annual precipitation is 40.6 centimeters (cm). About two-thirds of the annual precipitation falls from June through September. The ranch was grazed with cattle, sheep, and goats prior to 1971 and has been grazed yearlong with cattle stocked at about 1 animal unit (AU) per 10 ha since 1971.

Experiments were installed on Deep Upland and Igneous Hill and Mountain range sites typified by soils within the Musquiz Association (Aridic Argiustolls) and very similar to the Brewster Association (Lithic Haplustolls). These soils were generally shallow and rocky throughout with about 80 percent of the surface covered with igneous gravel and 1 percent igneous cobbles. The A horizon is 8 to 10-cm deep, typically reddish brown in color, gravelly loam in texture, and moderate medium subangular blocky in structure. The B horizon averages 10 to 38 cm in depth and a B2 horizon may or may not be present. Igneous cobbles and gravel comprise about 50 percent (volume basis) of the A and B horizons, and these are coated with caliche in the B horizon, which rests above masive caliche or igneous rock.

Chemical and physical analyses of soils from the study area were conducted from six bulk samples taken from 0 to 15-cm and 15 to 30-cm deep. Soil analyses included texture by the hydrometer method (Day, 1965), organic matter by the Schollenberger method (Allison, 1965), and pH measured in 0.1 M $CaCl_2$ (Peech, 1965).

Soils of the study site were slightly acidic loams overlaying loam subsoil (Table 1). Clay contents averaged 23 and 24 percent in the 0 to 15-cm and 15 to 30-cm depth respectively. Soil organic matter content averaged 2.38 percent in the upper 15 cm and increased with depth to 2.73 percent (Table 1).

The major plants on the study area were blue grama,[3] black grama, hairy grama, hook threeawn, babywhite aster, and spiney goldenweed. The 4-ha study site was fenced to exclude livestock and pronghorn antelope throughout the study period.

Herbicide Applications

Herbicides were applied during summer (August 9) and fall (November 15) of 1978 and during the winter (March 15) and spring (May 15) of 1979 to 10-m by 20-m plots arranged in a completely randomized design with three replications (Table 2). Herbicide liquids were applied in 140 l/ha of a 1:14 (v:v) diesel fuel-water emulsion containing 0.1 percent (v/v) emulsifier (alkylaryl poly [ethyleneoxy] ethanol, ethylhexyl butanedioate, petroleum distillates) with a tractor-mounted, small-plot sprayer equipped with a 6-m boom. The wettable powder formulation of tebuthiuron was applied in 140 l/ha of water containing 0.1 percent (v/v) surfactant (alkylaryl-polyoxyethylene glycols, free fatty acids, isopropanol). Pelleted herbicides were applied with a hand spreader. Each herbicide treatment was applied at 1.1 kg/ha ai or ae in all experiments.

Soil temperature, relative humidity, air temperature, wind speed, and direction and cloud cover were recorded during treatment applications. Soil water contents in the surface 15 cm were determined by the gravimetric method (Gardner, 1965) at the time of treatment from 25 randomly selected samples from the experimental area. Precipitation was recorded after each occurrence during the study.

Response of Threadleaf Groundsel and Associated Vegetation to Herbicide Treatments

Densities of threadleaf groundsel plants were determined before and at selected intervals after treatment by counting live plants within a permanently marked, 18.3-m by 1.2-m belt transect on a diagonal across each plot. Post-treatment densities were determined at 98, 218, 271, 365, and 583 days after treatment in the August 9, 1978 experiment; at 120, 172, 212, 365, and 485 days

TABLE 1. GENERALIZED SOIL CHARACTERISTICS OF RANGE SITES UTILIZED FOR EVALUATION OF VARIOUS HERBICIDES FOR THREADLEAF GROUNDSEL CONTROL IN THE DAVIS MOUNTAINS, TEXAS[1]

Depth (cm)	Organic matter (%)	pH	Textural components (%)			Textural Class
			Sand	Silt	Clay	
0-15	2.38 ± 0.15	6.5 ± 0.2	48 ± 2	29 ± 4	23 ± 2	loam
15-30	2.73 ± 0.57	6.6 ± 0.03	45 ± 3	31 ± 3	25 ± 0.04	loam

[1]Values following means are the standard errors.

[3]Scientific names of plants mentioned in text are given in the Appendix.

after treatment in the November 15, 1978 experiment; at 60, 91, 213, and 365 days after treatment in the March , 1979 experiment; and at 101, 222, and 312 days after treatment in the May 15, 1979 experiment. Herbicide effectiveness was based on percentage reduction in numbers of live threadleaf groundsel plants in the belt transects. Standing crops of associated grasses were harvested in 10 randomly located, 30- by 30-cm quadrats in each plot at the end of the 1978 and 1979 growing seasons. Herbage was separated into grasses and forbs, ovendried for 48 hours (hr) and weighed.

Analysis of variance was applied to standing herbage data. Threadleaf groundsel density data were subjected to analyses of covariance, using pretreatment densities as the covariate (X). Duncan's Multiple Range Test was used to determine differences ($P \leq 0.05$) among treatment means where appropriate.

RESULTS AND DISCUSSION

Summer Treatments

Conditions were favorable for growth of threadleaf groundsel when herbicides were applied on August 9, 1978. About 2.5 cm of rain were received within 60 days prior to herbicide application and more than 20 cm fell within 60 days after treatments were applied (Table 3). Soil water content to 15 cm deep averaged 12.2 percent. The threadleaf groundsel population was composed almost entirely of mature plants. Relative humidity was 74 percent, air temperature was 20 degrees centigrade (°C), soil temperature at 2.5 cm deep was 17°C, and cloud cover was 95 percent at time of herbicide application.

Picloram applied at 1.1 kg/ha as sprays in August reduced threadleaf groundsel density by 96 percent after 98 days compared to adjacent untreated rangeland (Table 4), but did not control the weed by 271 days after treatment. Pelleted picloram reduced threadleaf groundsel densities 87 to 88 percent by 98 days after application in August and by 97 to 99 percent 218 days

TABLE 3. MONTHLY RAINFALL DURING THE PERIOD IN WHICH VARIOUS HERBICIDES WERE BEING EVALUATED FOR THREADLEAF GROUNDSEL CONTROL ON THE WESTON RANCH NEAR FORT DAVIS, TEXAS

Month	Rainfall by year (cm) 1978	1979	1980	55-year average
January	–	0.5	0.6	1.9
February	–	1.2	0.3	1.0
March	–	0.5	0.3	0.9
April	–	0.2	–	1.2
May	–	0.7	–	3.0
June	–	1.4	–	6.6
July	–	4.5	–	6.9
August	8.9	9.9	–	6.4
September	11.4	0.2	–	5.7
October	5.2	0.3	–	3.4
November	1.2	0.3	–	1.3
December	1.0	1.2	–	1.3
Annual Total	–	20.9	–	39.6

after application. Effectiveness of picloram pellets also decreased by 271 days after treatment (Table 4). At 98 days after application in August, pelleted tebuthiuron reduced the density of live threadleaf groundsel 85 to 90 percent compared to untreated rangeland. Tebuthiuron sprays reduced threadleaf groundsel by 39 percent after 98 days and by 93 percent at 218 days after treatment. Dicamba sprays reduced threadleaf groundsel densities by 72 percent after 98 days, but did not effectively control the weeds at 218 days after treatment. Sprays of 2,4-D reduced threadleaf groundsel densities by 43 percent after 98 days and by 60 percent at 218 days after treatment (Table 4).

Tebuthiuron sprays or pellets reduced threadleaf groundsel densities by 87 to 100 percent after 1 year, compared to untreated rangeland (Table 4). All other herbicides reduced threadleaf groundsel densities by 36

TABLE 2. HERBICIDAL TREATMENTS EVALUATED FOR THREADLEAF GROUNDSEL CONTROL

Common names(s)	Chemical name(s)	Formulation(s)[1]	Rates[2] (kg/ha ae or ai)
2,4-D	(2,4-dichlorophenoxy)acetic acid	2-ethylhexyl ester	1.1
2,4-D + dicamba (3:1)	(2,4-dichlorophenoxy)acetic acid + 3,6-dichloro-o-anisic acid	dimethylamine salts	1.1
2,4-D + picloram (4:1)	(2,4-dichlorophenoxy)acetic acid + 4-amino-3,5,6-trichloropicolinic acid	triisopropanolamine salts	1.1
dicamba	3,6-dichloro-o-anisic acid	dimethylamine salt	1.1
picloram	4-amino-3,5,6-trichloropicolinic acid	potassium salt	1.1
		10% ae pellet	1.1
		5% ae pellet	1.1
2,4,5-T + picloram (1:1)	(2,4,5-trichlorophenoxy)acetic acid + 4-amino-3,5,6-trichloropicolinic acid	triethylamine salt + diethylamine salt	1.1
tebuthiuron	N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea	80% ai wettable powder	1.1
		20% ai pellets (3.2-mm diameter)	1.1
		20% ai pellets (1.6-mm diameter)	1.1

[1]ae indicates acid equivalent; ai indicates active ingredient.

[2]Rates of treatment for acid-based herbicides are expressed on an acid equivalent (ae) basis; other herbicides are on an active ingredient (ai) basis.

percent or less. Threadleaf groundsel control was significantly better on plots treated with pelleted tebuthiuron than on plots treated with 2,4-D.

Tebuthiuron pellets and sprays reduced densities of live threadleaf groundsel by 99 to 100 percent at 583 days after the summer treatments were applied (Table 4). Threadleaf groundsel control was significantly better on plots treated with tebuthiuron, regardless of formulation, than on plots treated with 2,4-D. Other herbicides reduced threadleaf groundsel 48 percent or less (Table 4).

Fall Treatments

Soil water content was almost 13 percent, cloud cover was 100 percent, relative humidity was 94 percent, air temperature was 4°C, and soil temperature was 11°C at time of herbicide application on November 15, 1978. Precipitation during the 60-day period prior to treatment was 5.7 cm and only 1.7 cm of rainfall was received within 60 days after treatment (Table 3). Both mature threadleaf groundsel plants and seedlings were present and appeared to be vigorously growing.

Sprays of 2,4-D + picloram (4:1) had completely controlled threadleaf groundsel at 120 days after treatment whereas 2,4-D sprays had controlled less than half of the weeds (Table 5). Sprays of 2,4,5-T + picloram (1:1) or picloram had reduced the density of threadleaf groundsel by 73 and 70 percent, respectively. All other herbicides had reduced weed densities 58 percent or less (Table 5).

Sprays of 2,4-D + picloram (4:1) completely controlled threadleaf groundsel at 1 year following application in November 1978. Sprays of 2,4,5-T + picloram (1:1) and 5 percent (ae) picloram pellets reduced densities of threadleaf groundsel 95 percent (Table 5), and sprays of picloram, 2,4-D, and 2,4-D + dicamba (3:1) reduced densities 94, 83, and 81 percent respectively. Control was 68 percent or less on plots treated with the other herbicides. Control with 2,4-D + picloram (4:1) was not significantly better than that achieved with 2,4-D (Table 5).

The complete control obtained with sprays of 2,4-D + picloram (4:1) continued through 485 days after treatment (Table 5). Sprays of 2,4,5-T + picloram (1:1), picloram and 5 percent picloram pellets reduced weed densities by 86 to 92 percent compared to untreated rangeland. All other treatments reduced threadleaf groundsel densities by 78 percent or less. Control with 2,4-D + picloram (4:1) (100 percent) was not significantly better than that achieved with 2,4-D (Table 5). Poor coverage of the soil surface with the 10 percent picloram pellets compared to the 5 percent pellets probably accounted for the reduced effectiveness.

Winter Treatments

Precipitation during the 60-day period prior to herbicide applications on March 15, 1979 was 1.8 cm, and only 0.5 cm of rainfall was received within 60 days after treatment (Table 3). There was 100 percent cloud cover, air temperature was 12°C, humidity was 64 percent, soil water content was 10 percent, and soil temperature at 2.5 cm deep was 13°C on the morning herbicides were applied. Threadleaf groundsel foliage was severely reduced, apparently because of cold temperatures, but some new foliar growth was evident.

Sprays of 2,4-D + picloram (4:1) had reduced threadleaf groundsel density by 81 percent 60 days after winter application compared to untreated rangeland (Table 6). Other treatments reduced threadleaf groundsel densities by 67 percent or less.

All treatments significantly reduced threadleaf groundsel densities, compared to 2,4-D, at 213 and 365 days after treatment (Table 6). Sprays of picloram, 2,4,5-T + picloram (1:1) and dicamba reduced live threadleaf groundsel densities by 100, 91, and 81 percent, respectively, at 213 days after application, and by 100, 92, and 87 percent, respectively, after 1 year. Tebuthiuron sprays and the 1.6-mm diameter pellets reduced threadleaf groundsel densities by 91 percent at 1 year after application. The 3.2-mm diameter pellets reduced densities only by 57 percent, probably because of poorer coverage.

TABLE 4. PERCENTAGE REDUCTION IN THREADLEAF GROUNDSEL DENSITIES AT 98, 218, 271, 365, AND 583 DAYS FOLLOWING APPLICATION OF VARIOUS HERBICIDE TREATMENTS AT 1.1 KG/HA ON AUGUST 9, 1978 NEAR FORT DAVIS, TEXAS

		Days After Treatment				
Herbicides	Formulation	98	218	271	365	583
None	—	0 a[1]	0 a	0 bc	0 bcd	0 bc
2,4-D	Liquid	43 ab	60 a	−3 bc	−22 abc	−36 abc
2,4-D + dicamba (3:1)	Liquid	56 b	15 a	−63 ab	−117 a	−42 abc
Dicamba	Liquid	72 b	22 a	−83 a	−127 a	−87 ab
2,4-D + picloram (4:1)	Liquid	68 b	42 a	−8 bc	−111 a	−127 a
Picloram	Liquid	96 b	68 a	12 c	−25 ab	−28 bc
Picloram	5% pellets	87 b	99 a	46 cd	36 bcd	48 cd
Picloram	10% pellets	88 b	97 a	50 cd	33 bcd	29 cd
2,4,5-T + picloram (1:1)	Liquid	75 b	28 a	51 cd	1 bcd	27 cd
Tebuthiuron	Wettable powder	39 ab	93 a	92 d	87 cd	100 d
Tebuthiuron	20% pellets[2]	90 b	100 a	98 d	100 d	100 d
Tebuthiuron	20% pellets[3]	85 b	70 a	100 d	93 d	99 d

[1]Means within a column followed by similar lower case letters are not significantly different at P≤0.05.

[2]3.2-mm diameter.

[3]1.6-mm diameter.

Spring Treatments

There was no cloud cover, relative humidity was 67 percent, air temperature was 24°C, soil temperature was 26°C, and soil water content was less than 4 percent when herbicides were applied on May 15, 1979. Precipitation received during the 60-days prior to treatment was only 0.5 cm but 3.8 cm occurred during the 60-day period after treatment (Table 3). The threadleaf groundsel population consisted of juvenile and mature plants in the vegetative growth stage. The foliage was fairly well-developed, but the plants did not appear to be growing.

Sprays of 2,4,5-T + picloram (1:1) had reduced threadleaf groundsel density by 67 percent at 101 days after application compared to untreated rangeland (Table 7). Other treatments had reduced weed densities by 45 percent or less.

Pelleted picloram reduced threadleaf groundsel densities by 84 to 100 percent at 222 days after application (Table 7). Sprays of 2,4-D controlled only a third of the weeds. Other herbicides controlled 70 percent or less of the threadleaf groundsel.

Threadleaf groundsel was completely controlled at 312 days following spring application of 10 percent picloram pellets and densities were reduced by 75 to 82 percent on plots treated with 5 percent picloram pellets, sprays of picloram, or 2,4,5-T + picloram (1:1) (Table 7). The 3.2-mm diameter tebuthiuron pellets had reduced weed densities by 81 percent compared to untreated rangeland. All other treatments reduced weed densities by 61 percent or less.

Herbicide-Season Interaction

Significant herbicide-season interactions were identified in this experiment, based on percent reduction of threadleaf groundsel at approximately 3, 7, and 12 months subsequent to the four treatment dates. Essentially all herbicide sprays, except the wettable powder of tebuthiuron, more effectively controlled threadleaf groundsel 12 months after application in fall, winter, or spring than after summer application (Table 8).

TABLE 5. PERCENTAGE REDUCTION IN THREADLEAF GROUNDSEL DENSITIES AT 120, 172, 212, 365, AND 485 DAYS FOLLOWING APPLICATION OF VARIOUS HERBICIDE TREATMENTS AT 1.1 KG/HA ON NOVEMBER 15, 1978 NEAR FORT DAVIS, TEXAS

		Days After Treatment				
Herbicides	Formulation	120	172	212	365	485
None	—	0 bc[1]	0 a	0 ab	0 a	0 a
2,4-D	Liquid	43 bcd	68 bc	75 c	83 bc	78 b
2,4-D + dicamba (3:1)	Liquid	58 bcd	69 c	63 bc	81 bc	75 b
Dicamba	Liquid	27 bcd	48 abc	76 c	57 abc	72 b
2,4-D + picloram (4:1)	Liquid	100 d	100 c	100 c	100 c	100 b
Picloram	Liquid	70 cd	80 c	76 c	94 c	91 b
Picloram	5% pellets	−1 bc	64 bc	77 c	95 c	86 b
Picloram	10% pellets	23 bcd	6 a	10 ab	26 ab	40 ab
2,4,5-T + picloram (1:1)	Liquid	73 cd	82 c	78 c	95 c	92 b
Tebuthiuron	Wettable powder	29 bcd	47 abc	58 bc	56 abc	38 ab
Tebuthiuron	20% pellets[2]	−81 a	−6 a	−48 a	52 abc	60 b
Tebuthiuron	20% pellets[3]	−13 ab	12 ab	40 bc	68 bc	75 b

[1]Means within a column followed by similar lower case letters are not significantly different at P≤0.05.

[2]3.2-mm diameter.

[3]1.6-mm diameter.

TABLE 6. PERCENTAGE REDUCTION IN THREADLEAF GROUNDSEL DENSITIES AT 60, 91, 213, AND 365 DAYS FOLLOWING APPLICATION OF VARIOUS HERBICIDE TREATMENTS AT 1.1 KG/HA ON MARCH 15, 1979 NEAR FORT DAVIS, TEXAS

		Days After Treatment			
Herbicides	Formulation	60	91	213	365
None	—	0 a[1]	0 a	0 b	0 b
2,4-D	Liquid	−9 a	−33 a	−202 a	−146 a
2,4-D + dicamba (3:1)	Liquid	49 a	45 a	36 b	52 bc
Dicamba	Liquid	50 a	70 a	81 b	87 bc
2,4-D + picloram (4:1)	Liquid	81 a	89 a	63 b	96 c
Picloram	Liquid	54 a	82 a	100 b	100 c
Picloram	5% pellets	44 a	48 a	64 b	80 bc
Picloram	10% pellets	−88 a	−58 a	45 b	85 bc
2,4,5-T + picloram (1:1)	Liquid	67 a	85 a	91 b	92 bc
Tebuthiuron	Wettable powder	55 a	63 a	68 b	91 bc
Tebuthiuron	20% pellets[2]	−10 a	−29 a	12 b	57 bc
Tebuthiuron	20% pellets[3]	−1 a	1 a	78 b	91 bc

[1]Means within a column followed by similar lower case letters are not significantly different at P≤0.05.

[2]3.2-mm diameter.

[3]1.6-mm diameter.

Tebuthiuron sprays applied in summer or winter tended to result in better control than fall or spring applications. However, sprays of 2,4-D applied in fall or spring were significantly more effective than those applied in summer or winter, and there was a strong trend toward increased effectiveness of fall treatments compared to spring treatments. There were no significant herbicide-season interactions with pelleted herbicides, and trends varied among formulations with both picloram and tebuthiuron (Table 8).

Forage Response

Blue grama and associated grasses, which were rapidly growing, were damaged by most herbicides applied in early August 1978 (Table 9). Sprays and pellets of tebuthiuron and picloram reduced standing crop of grasses by 30 to 42 percent at 3 months after application. Damage to grasses was intermediate on plots sprayed with 2,4,5-T + picloram (1:1) and least on plots sprayed with dicamba or 2,4-D. Associated grasses were not affected on plots sprayed with 2,4-D + dicamba (3:1) (Table 9).

Herbicides applied during fall, winter, or spring did not affect standing biomass of grasses compared to untreated rangeland, as determined by clipping within the fenced study area at the end of the 1979 growing season (Table 10). Also, grasses on the plots treated in August 1978 had recovered by the end of the 1979 growing season. Damage incurred on plots treated during summer 1978 was apparently short-term since most of the plants had recovered by the second autumn after herbicide applications.

CONCLUSIONS

Sprays of 2,4-D, dicamba, or 2,4-D + dicamba (3:1) at 1.1 kg/ha did not effectively control threadleaf groundsel on Deep Upland and Igneous Hill and Mountain range sites in the Davis Mountains. Fall applications of 2,4-D tended to be more effective than applications at other seasons. However, almost 7 months lapsed before three-fourths of the threadleaf groundsel plants died following fall treatments. The relatively high toxicity of threadleaf

TABLE 7. PERCENTAGE REDUCTION IN THREADLEAF GROUNDSEL DENSITIES AT 101, 222, AND 312 DAYS FOLLOWING APPLICATION OF VARIOUS HERBICIDE TREATMENTS AT 1.1 KG/HA ON MAY 15, 1979 NEAR FORT DAVIS, TEXAS

		Days After Treatment		
Herbicides	Formulation	101	222	312
None	—	0 a[1]	0 ab	0 a
2,4-D	Liquid	31 a	33 a-d	49 abc
2,4-D + dicamba (3:1)	Liquid	−6 a	−31 a	−2 a
Dicamba	Liquid	21 a	29 a-d	30 ab
2,4-D + picloram (4:1)	Liquid	32 a	39 a-d	45 abc
Picloram	Liquid	25 a	65 bcd	82 bc
Picloram	5% pellets	16 a	84 cd	79 bc
Picloram	10% pellets	16 a	100 d	100 c
2,4,5-T + picloram (1:1)	Liquid	67 a	57 bcd	75 bc
Tebuthiuron	Wettable powder	45 a	67 bcd	61 abc
Tebuthiuron	20% pellets[2]	19 a	70 bcd	81 bc
Tebuthiuron	20% pellets[3]	27 a	22 abc	34 abc

[1]Means within a column followed by similar lower case letters are not significantly different at $P \leq 0.05$.
[2]3.2-mm diameter.
[3]1.6-mm diameter.

TABLE 8. MEAN PERCENT REDUCTION IN LIVE THREADLEAF GROUNDSEL NUMBERS AT APPROXIMATELY 12 MONTHS FOLLOWING SUMMER, FALL, WINTER, OR SPRING APPLICATIONS OF VARIOUS HERBICIDE TREATMENTS AT 1.1 KG/HA IN 1978-1979 NEAR FORT DAVIS, TEXAS

		12 Months			
Herbicide	Formulation	Summer	Fall	Winter	Spring
2,4-D	Liquid	−22 a[1]	83 b	−146 a	49 b
2,4-D + dicamba (3:1)	Liquid	−117 a	81 b	52 b	−2 b
Dicamba	Liquid	−127 a	57 b	87 b	30 b
2,4-D + picloram (4:1)	Liquid	−111 a	100 b	96 b	45 b
Picloram	Liquid	−25 a	94 b	100 b	82 b
Picloram	5% pellets	36 a	95 a	80 a	79 a
Picloram	10% pellets	33 a	26 a	85 a	100 a
2,4,5-T + picloram (1:1)	Liquid	1 a	95 b	92 b	75 b
Tebuthiuron	Wettable powder	87 a	56 a	91 a	61 a
Tebuthiuron	20% pellets[2]	100 a	52 a	57 a	81 a
Tebuthiuron	20% pellets[3]	93 a	68 a	91 a	34 [illegible]

[1]Means within a row followed by similar lower case letters are not significantly different at $P \leq 0.05$.
[2]3.2-mm diameter.
[3]1.6-mm diameter.

groundsel to livestock dictates that control be manifested quickly and that a high proportion of the weeds be killed to effectively reduce livestock poisoning.

Sprays of 2,4-D + picloram (4:1) at 1.1 kg/ha during the fall completely controlled threadleaf groundsel for almost 16 months and winter applications effectively controlled the weeds for 1 year. However, applications in spring or summer were no more effective than 2,4-D alone at the same rate. Picloram at 1.1 kg/ha applied as sprays in the fall maintained a 91 percent reduction in threadleaf groundsel densities for almost 16 months and winter applications completely controlled the weeds for 1 year. Spring or summer applications of picloram sprays did not effectively control the weeds. Foliar sprays of 2,4,5-T + picloram (1:1) at 1.1 kg/ha applied in fall or winter reduced threadleaf groundsel densities 92 percent for more than a year, whereas spring or summer applications did not provide satisfactory control.

Tebuthiuron applied as sprays or pellets at 1.1 kg/ha during late summer reduced threadleaf groundsel densities 99 to 100 percent for 19 months, whereas applications in fall, winter, or spring resulted in erratic control. Five percent picloram pellets were generally more effective for threadleaf groundsel control than were 10 percent picloram pellets. However, summer applications of picloram pellets effectively controlled the weeds for only about 7 months, whereas more than 7 months lapsed following fall and spring applications, and 1 year lapsed following winter applications, before three-fourths of the weeds were killed.

Fall or winter applications of foliar active herbicides were generally more effective for threadleaf groundsel control than spring or summer applications, presumably because seedlings were emerging and actively growing in the fall and winter. Low soil water contents usually severely limit plant growth during late winter, spring, and early summer in the Davis Mountain area and threadleaf groundsel populations during late summer consisted mostly of mature, flowering plants. The susceptibility of most plants to foliar-active herbicides decreases as the plants mature and flower and as growing conditions become less favorable.

Blue grama and other grasses associated with threadleaf groundsel incurred moderate-to-severe short-term damage following application of most herbicides during late summer, presumably because the plants were succulent and rapidly growing following summer rains. However, no damage was caused by herbicide applications during fall, winter, or spring when growing conditions were less favorable and the associated species were mature or dormant.

TABLE 9. MEAN GRASS STANDING CROPS ON NOVEMBER 15, 1978 FOLLOWING APPLICATION OF VARIOUS HERBICIDE TREATMENTS AT 1.1 KG/HA ON AUGUST 9, 1978 NEAR FORT DAVIS, TEXAS

Herbicide	Formulation	Standing crop (kg/ha)
None	—	963 a[1]
2,4-D + dicamba (3:1)	Liquid	887 ab
Dicamba	Liquid	806 b
2,4-D	Liquid	776 b
2,4,5-T + picloram (1:1)	Liquid	709 bcd
Picloram	10% pellets	670 d-g
Tebuthiuron	20% pellets[2]	608 fg
Tebuthiuron	20% pellets[3]	604 fg
Picloram	5% pellets	587 g
Picloram	Liquid	573 g
Tebuthiuron	Wettable powder	563 g

[1]Means within a column followed by the same letter are not significantly different at $P \leq 0.05$.

[2]3.2-mm diameter.

[3]1.6-mm diameter.

TABLE 10. MEAN GRASS STANDING CROPS (KG/HA) ON NOVEMBER 3, 1979 FOLLOWING GROUND APPLICATION OF VARIOUS HERBICIDE TREATMENTS AT 1.1 KG/HA ON FOUR DIFFERENT DATES IN 1978 NEAR FORT DAVIS, TEXAS

		Standing crop (kg/ha)			
		Date Treated			
Herbicide	Formulation	August 1978	Nov. 1978	March 1979	May 1979
None	—	925 a[1]	807 a	685 a	710 a
2,4-D	Liquid	553 a	929 a	815 a	578 a
Dicamba	Liquid	452 a	528 a	678 a	535 a
Picloram	Liquid	574 a	642 a	850 a	477 a
Tebuthiuron	Wettable powder	431 a	603 a	578 a	664 a
2,4-D + dicamba (3:1)	Liquid	718 a	628 a	693 a	703 a
2,4,5-T + picloram (1:1)	Liquid	782 a	746 a	1166 a	513 a
2,4-D + picloram (4:1)	Liquid	675 a	761 a	850 a	685 a
Picloram	10% pellets	553 a	531 a	667 a	736 a
Picloram	5% pellets	675 a	649 a	743 a	1051 a
Tebuthiuron	20% pellets[2]	617 a	1073 a	348 a	1051 a
Tebuthiuron	20% pellets[3]	682 a	589 a	502 a	556 a

[1]Means within a column followed by similar lower case letters are not significantly different at $P \leq 0.05$.

[2]3.2-mm diameter.

[3]1.6-mm diameter.

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APPENDIX
Scientific Names of Plants and Animals Mentioned in Text

Common Name	Scientific Name
Animals	
Pronghorn antelope	*Antilocapra americana*
Plants	
Babywhite aster	*Leucelene ericoides*
Black grama	*Bouteloua eriopoda*
Blue grama	*Bouteloua gracilis*
Hairy grama	*Bouteloua hirsuta*
Hook threeawn	*Aristida hamulosa*
Spiney goldenweed	*Machaeranthera pinnatifida*

Metric Units — English Equivalents

Metric Unit	English Equivalent
Centimeter (cm)	0.394 inches
Hectare (ha)	2.47 acres
Kilogram (kg)	2.205 pounds
Kilograms per hectare (kg/ha)	0.983 pound per acre
Kilometer (km)	0.62 statute mile
Liter (l)	0.264 gallon
Meter (m)	3.28 feet
Millimeter (mm)	0.0394 inches
Square meter (m^2)	10.758 square feet
(Degrees centigrade $\times$ 1.8 + 32)	Degrees Fahrenheit

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