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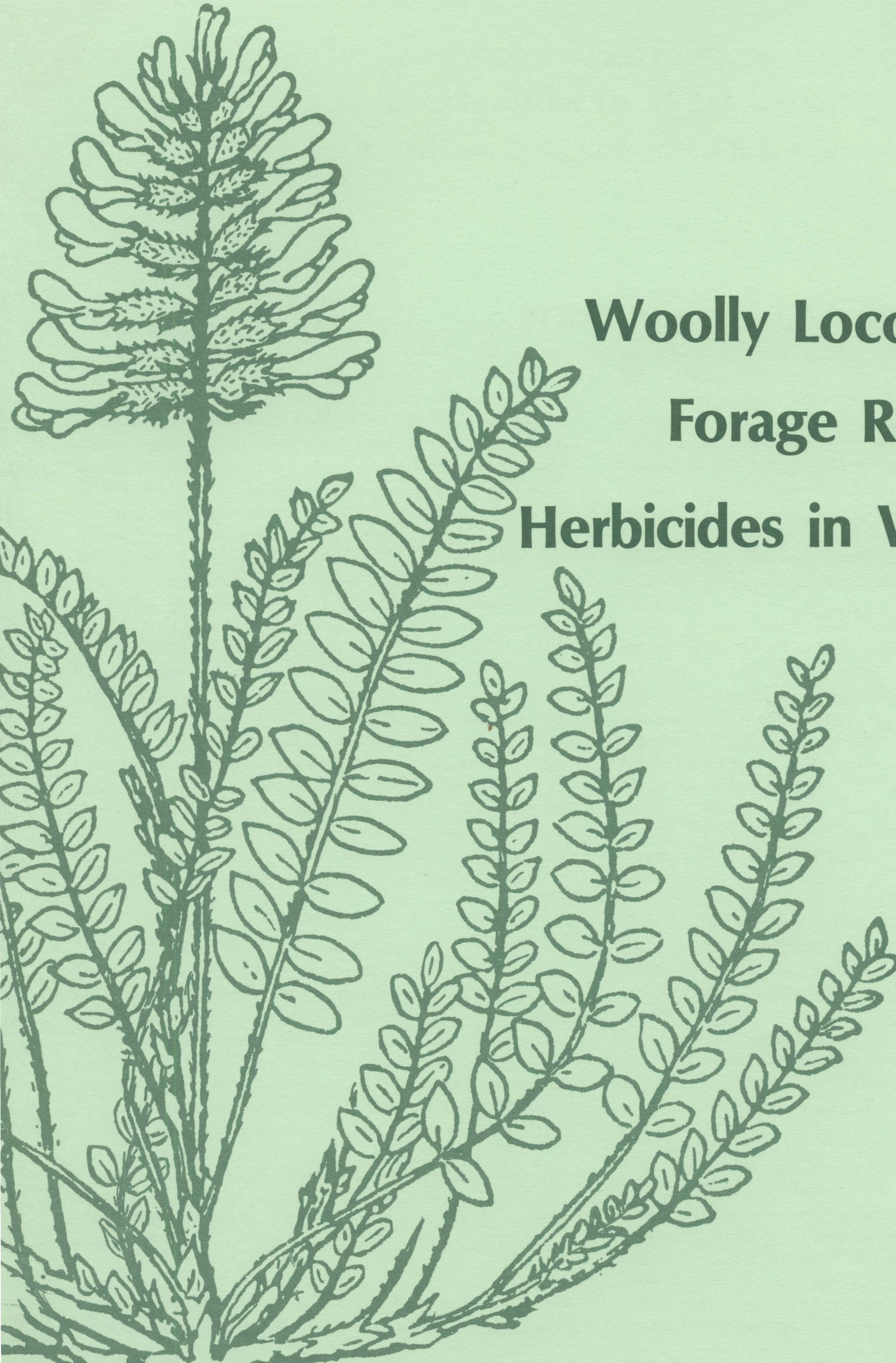

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CONTENTS

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Woolly Locoweed and Forage Response to Herbicides in West Texas

M. R. Freeman, D. N. Ueckert, and J. T. Nelson*

Summary

Applications of 2,4-D[1] in fall, winter or spring did not satisfactorily control woolly locoweed[2] in the Davis Mountain area of the Trans Pecos of west Texas. Picloram at 0.2 to 1.1 kilograms per hectare (kg/ha) alone or in mixtures with other herbicides, applied in fall or winter, usually controlled woolly locoweed for a year or longer. Woolly locoweed was usually killed within 120 days following application of foliar sprays containing picloram, whereas control usually was not manifested for almost a year following application of picloram pellets. Woolly locoweed was effectively controlled in the fall with foliar sprays of picloram + triclopyr ester (1:1) at 0.6 kg/ha; picloram at 1.1 kg/ha; 3,6-dichloropicolinic acid + triclopyr (1:1) at 0.6 kg/ha; 2,4,5-T + picloram (1:1) at 0.6 to 1.1 kg/ha; picloram + dicamba (1:1) at 0.6 kg/ha; dicamba at 1.1 kg/ha; 3,6-dichloropicolinic acid + dicamba (1:1) at 0.6 kg/ha; and 2,4-D + dicamba (3:1) at 1.1 kg/ha. Control of woolly locoweed during fall was generally superior to that in winter or spring, for most herbicides evaluated, presumably because of more favorable temperatures for herbicide absorption and translocation, and because of the earlier phenological stages of the weeds. Control of woolly locoweed where densities averaged 1.4 to 1.9 weeds per square meter (m^2) did not increase production of desirable forages.

Introduction

Ranch firms in the Big Bend region of the Texas Trans Pecos have suffered serious livestock losses for decades as the result of poisoning by poisonous plants including woolly locoweed (*Astragalus mollissimus* Torr. var. *earlei* [Rydb.] Tidestr.), also referred to as Earle loco, purple loco, and Texas loco. Woolly locoweed, a robust perennial of only a few years duration, occurs in the Trans Pecos resource area of Texas and in Chihuahua and Coahuila, Mexico (Norris, 1951; Sperry *et al*., 1964; Correll and Johnston, 1970).

Cattle, horses, and sheep are the primary livestock affected by woolly locoweed (Norris, 1951; Dollahite, 1965; Nielsen, 1978). The toxic principles in woolly locoweed have not been determined, but it has been suggested that there are several toxins (James, 1972). Livestock consume woolly locoweed primarily during fall, winter, and spring. Animals usually will not consume lethal quantities of woolly locoweed or other toxic species of *Astragalus* if high quality forage is available (James and Johnson, 1976; Krueger and Sharp, 1978; Sperry *et al*., 1964). Sperry *et al*. (1964) indicated that proper supplemental feeding reduced the amount of woolly locoweed consumed by livestock. However, James *et al*. (1968) reported from Utah that sheep addicted to Green River milkvetch consumed the weeds in preference to cottonseed meal, mineral supplement, or alfalfa hay.

The present recommendation for controlling woolly locoweed in west Texas is application of foliar sprays of esters of 2,4-D at 1.1 kg/ha during October through April (Sperry *et al*., 1964). However, this treatment is not commonly used, because it has resulted in erratic control (Norris 1951). Research on herbicidal control of various species of *Astragalus* as well as *Oxytropis* has been reported by Alley (1973), Cronin and Williams (1964), Norris (1951), Sperry (1951), and Williams (1970). Foliar sprays of dicamba, 2,4-D, or 2,4-D + dicamba (3:1) at 2.2 kg/ha or picloram at 0.3 kg/ha have killed 90 percent or more of the Lambert crazyweed treated in Wyoming studies (Alley, 1976). James *et al*. (1980) reported that locoweeds can be controlled by spraying actively growing or budding plants with 2,4-D ester at 2.2 to 3.4 kg/ha; dicamba at 1.1 kg/ha; or picloram at 1.1 kg/ha. This study was initiated in 1978 to evaluate several herbicides applied at different seasons for consistent and extended control of woolly locoweed in west Texas and to determine the response of associated forage species to control of woolly locoweed.

Materials and Methods

Description of the Study Areas

The major portion of this study was conducted on the Morrow-McIntyre Ranch, 19 kilometers (km) west of Alpine, Texas. Two experiments were conducted on the Billy and Tommy Weston Ranch, 6 km southeast of Ft. Davis, Texas. Elevations of both study areas are about 1586 meters (m) and average annual precipitation is 40 centimeters (cm). About two-thirds of the annual precipitation occurs from June through September. Both

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

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

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ranches are cow-calf operations normally stocked yearlong at 1 animal unit per 10 hectares (1 A.U./10 ha).

Experiments at the Alpine study site were installed on an Igneous Hill and Mountain range site typified by Brewster clay loam soils (loamy-skeletal, mixed, thermic family of Lithic Haplustolls) on 1 to 1.5 percent slopes. Soils of the Brewster series are shallow to very shallow, well-drained, noncalcareous stony soils underlain by igneous bedrock. Permeability is moderate in these soils, and runoff is rapid.

Experiments at the Fort Davis study site were installed on a Draw range site on Gageby loam soils (fine-loamy, mixed, thermic family of Cumulic Haplustolls). The Gageby series consists of deep, well-drained, noncalcareous loamy soils formed in stratified alluvium. Permeability is moderate in these soils, runoff is slow, and these soils are occasionally flooded in summer.

Chemical and physical analyses of soils from the study areas were conducted from six bulk samples taken from 0- to 8-cm, 9- to 41-cm, and 42- to 76-cm depths (Alpine study site) or 0- to 30-cm and 31- to 61-cm depths (Fort Davis study site). 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 Igneous Hill and Mountain range site were clay loams or sandy clay loams overlaying clay, clay loam or loam subsoil (Table 1). Clay content of the surface 8 cm of soil averaged 24 percent (range 16.2 to 31.3 percent) and increased with depth to 35 percent (range 29 to 41.9 percent). Soil organic matter content averaged 3.2 percent in the upper 8 cm and decreased to 1.3 percent at the 42- to 76-cm depth. The soils were slightly acidic (Table 1).

Soils of the Draw range site were clay loams to a depth of 61 cm (Table 1). Clay content of the surface 30 cm of soil averaged 28 percent and increased with depth to 31 percent. Soil organic matter content averaged 3.5 percent in the upper 30 cm and decreased to 2.2 percent at the 31- to 61-cm depth. The soils were slightly acidic (Table 1).

TABLE 1. GENERALIZED SOIL CHARACTERISTICS OF RANGE SITES UTILIZED FOR EVALUATION OF VARIOUS HERBICIDES FOR WOOLLY LOCOWEED CONTROL IN THE DAVIS MOUNTAINS, TEXAS

Depth (cm)	Organic matter (%)	pH	Textural components (%) Sand	Silt	Clay	Texture
Morrow-McIntyre Ranch Winter & Spring 1979 Experiments						
0-8	4.1	6.5	24.9	43.8	31.3	clay loam
9-41	2.3	6.6	23.7	37.9	38.4	clay loam
42-76	1.4	6.8	25.1	32.9	41.9	clay
Morrow-Mcintyre Ranch Fall 1979 Experiment						
0-8	2.2	6.6	55.1	28.7	16.2	sandy loam
9-41	1.6	6.9	43.3	31.7	24.9	loam
42-76	1.1	7.2	36.8	34.2	29.0	clay loam
Weston Ranch Winter 1978-79 Experiments						
0-30	3.5	6.6	29.0	42.6	28.4	clay loam
31-61	2.2	6.9	27.2	42.1	30.7	clay loam

Major plants on the Alpine study site were blue grama, threeawns, woolly locoweed, garbancillo, cane bluestem, Halls panicum, and wolftail. Major plants on the Fort Davis study area were blue grama, sideoats grama, cane bluestem, woolly locoweed, hook threeawn, and inland saltgrass.

Herbicide Applications

Herbicide treatments were applied at the Alpine site during winter, spring, and fall 1979 (Table 2) to 10-m by 20-m plots arranged in a completely randomized design with three replications. Plots treated in winter and spring 1979 were fenced to exclude livestock. Herbicides were applied on January 23, May 15, and November 14, 1979. Herbicides including 5 and 10 percent active ingredient (a.i.) picloram pellets, 20 percent a.i. tebuthiuron pellets (0.16- and 0.32-cm diameter) and 5 percent a.i. dicamba granules were applied at 1.1 kg/ha (a.i.) to 10-m by 20-m plots arranged in a completely randomized design with three replications on December 5, 1978 or February 9, 1979 at the Fort Davis site.

Liquid herbicide formulations were applied in 140 liters per hectare (L/ha) of a 1:14 (v:v) diesel fuel-water emulsion with 0.1 percent emulsifier from a tractor-mounted, small-plot sprayer equipped with a 6-m boom, except for the wettable powder formulation of tebuthiuron, which was applied in water with 0.1 percent surfactant. Pelleted herbicides were applied with a hand spreader. Each herbicide treatment was applied at 1.1 kg/ha (a.i.) in all experiments, except that in the fall 1979 experiment at the Alpine study site herbicides were also applied at selected lower rates (Table 2).

Soil temperature, relative humidity, air temperature, wind speed, and cloud cover were recorded during and subsequent to treatment applications. Soil water content was determined by the gravimetric method (Gardner, 1965) by taking 25 randomly-selected soil samples from 0- to 8-cm, 8- to 15-cm and 15- to 30-cm depths. Precipitation data were recorded after each significant occurrence during the study on the Alpine study site.

Densities of live woolly locoweed were determined before and at selected intervals after treatment by counting live plants within a permanently marked, 18-m by 1.2-m, belt transect on a diagonal across each plot. Herbicide effectiveness was based on percentage reduction in numbers of live woolly locoweed plants in the belt transects. Phenology of woolly locoweed was recorded throughout the study. The number of seeds produced by individual woolly locoweed plants was determined from 15 plants in the spring of 1980. Response of herbaceous vegetation was determined on plots treated in winter or spring 1979 on the Alpine study site. Standing crop of herbaceous vegetation was harvested in ten, 30- by 30-cm quadrats in each plot during September 1979. Herbage was separated into grasses and forbs, ovendried for 48 hours and weighed.

Analysis of variance was applied to standing herbage data. Weed control data were analyzed by analysis of covariance, using pretreatment densities as the covariate (X). Where appropriate, Duncan's Multiple Range Test was used to determine differences among adjusted means at P≤0.05.

Results and Discussion

Woolly Locoweed Phenology

Woolly locoweed seedlings emerged from October through December in both 1978 and 1979. Densities of woolly locoweed plants on untreated rangeland at the Alpine study site averaged 1.9 plants/m^2 in the winter of 1978-79, and 1.4 plants/m^2 in the winter of 1979-80. The plants developed vegetatively through March, and flowering began in April and continued into July. Seeds were present on woolly locoweed plants from May to early July. Mature woolly locoweed plants produced an average of 1,673 seeds each. Barneby (1964) reported that locoweed seeds may remain viable in the soil for several years until germination requirements are met. About 75 percent of the woolly locoweed population died during July through September in 1979 and 1980.

Woolly locoweed is well adapted to the desert grasslands of the Davis Mountain area. The species produces large numbers of seed that remain viable in the soil for several years. Its seeds germinate and seedlings emerge in fall when soil water content is high. The seedlings grow deep taproots, develop vegetatively, and produce flowers and seeds when the dominant grasses are dormant due to low temperatures and/or low soil water content.

Winter Treatments

Conditions were favorable for growth of woolly locoweed when herbicide treatments were applied on January 23, 1979 near Alpine. Over 5 cm of precipitation had fallen within 60 days prior to treatment, and 3.3 cm were received within 60 days after treatment (Table 3). Soil water content to 30 cm deep averaged 14 percent. About 90 percent of the woolly locoweed plants were seedlings less than 5 cm tall. Relative humidity was 93 percent, air temperature was 0 degrees centigrade (° C), and soil temperature at 2.5 cm deep was 2° C at time of herbicide application.

At 60 days after treatment, foliar sprays of dicamba at 1.1 kg/ha (a.i.) had killed 99 percent of the woolly locoweed. Foliar sprays of 2,4-D + dicamba (3:1); 2,4-D + picloram (4:1); and 2,4,5-T + picloram (1:1) at the same rates had killed 80, 76, and 70 percent of the weeds, respectively (Table 4). All other herbicide treatments controlled less than 70 percent of the woolly locoweed. Foliar sprays of 2,4-D ester at 1.1 kg/ha reduced densities of the species by 53 percent, not significantly different from control achieved with foliar sprays of dicamba.

TABLE 2. HERBICIDAL TREATMENTS EVALUATED FOR WOOLLY LOCOWEED CONTROL

Common name(s)	Chemical name(s)	Formulation(s)	Rates (kg/ha a.i.)
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	0.7, 1.1
dicamba	3,6-dichloro-o-anisic acid	dimethylamine salt 5% a.i. pellets	1.1 1.1
3,6-dichloropicolinic acid	3,6-dichloropicolonic acid	monoethanolamine salt	0.3, 0.6
3,6-dichloropicolonic acid + dicamba (1:1)	3,6-dichloropicolinic acid + 3,6-dichloro-o-anisic acid	monoethanolamine salt + dimethylamine salt	0.6
3,6-dichloropicolinic acid + triclopyr (1:1)	3,6-dichloropicolinic acid + [(3,5,6-trichloro-2-2pyridinyl)oxy] acetic acid	monoethanolamine salt + ethylene glycol buytl ether ester	0.6
picloram	4-amino-3,5,6-trichloropicolinic acid	potassium salt 10% a.i. pellet 5% a.i. pellet	0.3, 0.6, 1.1 1.1 1.1
picloram + dicamba (1:1)	4-amino-3,5,6-trichloropicolinic acid + 3,6-dichloro-o-anisic acid	potassium salt + dimethylamine salt	0.6
picloram + triclopyr (1:1)	4-amino-3,5,6-trichloropicolinic acid + [(3,5,6-trichloro-2-pyridinyl) oxy]acetic acid	potassium salt + ethylene glycol butyl ether ester	0.6
2,4,5-T + picloram (1:1)	(2,4,5-trichlorophenoxy)acetic acid + 4-amino-3,5,6-trichloropicolinic acid	triethylamine salt + diethylamine salt	0.3, 0.6, 1.1
tebuthiuron	N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N′-dimethylurea	80% a.i. wettable powder 20% a.i. pellets (0.32-cm diameter) 20% a.i.pellets (0.16-cm diameter	1.1 1.1 1.1

At 120 days after treatment, woolly locoweed was completely controlled on plots treated with foliar sprays of dicamba (Table 4). More than 85 percent of the weeds were controlled on plots treated with sprays of 2,4-D + picloram (4:1) or 2,4,5-T + picloram (1:1). However, reduction in woolly locoweed densities from dicamba sprays was not significantly greater than that attained with 2,4-D (52 percent). Neither 2,4-D, the 10 percent (a.i.) formulation of pelleted picloram, nor any of the formulations of tebuthiuron significantly reduced woolly locoweed densities compared to untreated rangeland (Table 4).

By 1 year after treatment all picloram treatments and herbicide mixtures containing picloram had reduced woolly locoweed densities by at least 84 percent (Table 4). Reduction in live woolly locoweed density averaged 83 percent where dicamba had been applied. All herbicide treatments reduced densities of the species compared to untreated rangeland, but none of the treatments provided significantly better control than 2,4-D (69 percent).

At 420 days after herbicide application, all picloram treatments or herbicide mixtures containing picloram, except the 10 percent (a.i.) pellet formulation, controlled 85 percent or more of the woolly locoweed (Table 2). All treatments except 0.16-cm tebuthiuron pellets, significantly reduced woolly locoweed densities compared to untreated rangeland. Control achieved with 5 percent (a.i.) picloram pellets (96 percent) was not significantly better than that achieved with 2,4-D ester (65 percent) (Table 4).

At 126 days after application on December 5, 1978 near Fort Davis, tebuthiuron pellets at 1.1 kg/ha had controlled 81 to 96 percent of the woolly locoweed population (Table 5). Population densities were not affected by dicamba granules or 10 percent a.i. picloram pellets. By 190 days after treatment, emergence of new populations of woolly locoweed seedlings had nullified the early control achieved by tebuthiuron pellets. At 1 year after treatment, all of the original woolly locoweed plants on these unfenced plots had been consumed by cattle and only a few seedlings about 5 cm in height were present. Analysis of variance on seedling density data indicated no significant differences in seedling density among the treatments or untreated rangeland ($p<0.05$) (data not shown). Cattle losses were heavy in this pasture in the winter of 1979. Thirty-five calves died in the winter of 1979 due to woolly locoweed toxicity (Billy Weston, *personal communication*).

At 103 days after application on February 9, 1979 near Fort Davis, none of the pelleted herbicides had effectively controlled woolly locoweed (Table 5). At 1 year after treatment all of the mature woolly locoweed had been consumed by cattle. Analysis of variance of new seedling density data indicated no significant differences among the herbicide treatments or untreated rangeland ($P<0.05$) (data not shown).

TABLE 3. MONTHLY RAINFALL DURING THE PERIOD IN WHICH VARIOUS HERBICIDES WERE BEING EVALUATED FOR WOOLLY LOCOWEED CONTROL ON THE MORROW-MCINTYRE RANCH NEAR ALPINE, TEXAS

Month	Rainfall by year (cm) 1979	1980	55-year average
January	1.0	1.5	1.9
February	2.3	0.5	1.0
March	t[1]	2.0	0.9
April	1.5	1.1	1.2
May	2.0	2.6	3.0
June	4.4	2.4	6.6
July	10.1	0.1	6.9
August	10.2	6.7	6.4
September	3.0	17.5	5.7
October	0	4.2	3.4
November	0	2.6	1.3
December	0	1.9	1.3
Annual Total	34.5	43.1	39.6

[1]t = trace

TABLE 4. PERCENTAGE REDUCTION IN WOOLLY LOCOWEED DENSITIES AT 60, 120, 365 AND 420 DAYS FOLLOWING APPLICATION OF 11 HERBICIDE TREATMENTS AT 1.1 kg/ha ON JANUARY 23, 1979 NEAR ALPINE, TEXAS

Herbicide	Formulation	Days after treatment[1] 60	120	365	420
None	—	0 a	0 ab	0 a	0 a
2,4-D	Liquid	53 b-e	52 b-e	69 bc	65 b
2,4-D + dicamba (3:1)	Liquid	80 de	58 c-e	56 bc	50 b
Dicamba	Liquid	99 e	100 e	83 bc	76 b
2,4-D + picloram (4:1)	Liquid	76 de	85 de	94 c	94 b
Picloram	Liquid	69 c-e	74 c-e	87 bc	85 b
Picloram	5% pellets	64 c-e	58 c-e	95 c	96 b
Picloram	10% pellets	33 a-d	23 a-c	85 bc	75 b
2,4,5-T + picloram (1:1)	Liquid	70 c-e	86 de	84 bc	90 b
Tebuthiuron	Wettable powder	55 b-e	39 a-d	66 bc	71 b
Tebuthiuron	20% pellets[2]	17 ab	-15 a	48 bc	56 b
Tebuthiuron	20% pellets[3]	29 a-c	26 a-c	43 b	45 ab

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

[2]0.32-cm diameter.

[3]0.16-cm diameter.

TABLE 5. PERCENTAGE REDUCTION IN WOOLLY LOCOWEED DENSITIES AFTER APPLICATION OF FIVE PELLETED HERBICIDES AT 1.1 kg/ha ON DECEMBER 5,1978 AND FEBRUARY 9, 1979 NEAR FORT DAVIS, TEXAS

		Treatment dates		
		December 5, 1978		February 9, 1979
		Days after treatment		
Herbicide	Formulation	126	190	103
None	—	0 a[1]	0 a	0 b
Dicamba	5% granules	58 ab	51 a	13 b
Picloram	5% pellets	68 b	58 a	−55 ab
Picloram	10% pellets	41 ab	40 a	−121 a
Tebuthiuron	20% pellets[2]	96 b	68 a	5 b
Tebuthiuron	20% pellets[3]	81 b	32 a	8 b

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

[2]0.32-cm diameter.

[3]0.16-cm diameter.

Spring Treatments

Growing conditions and plant phenology were less than optimal for herbicidal control of woolly locoweed when treatments were applied on May 15,1979. Only 1.7 cm of precipitation had fallen within 60 days prior to herbicide application (Table 3). Soil water content averaged 4.8 percent, air temperature was 25° C, soil temperature 2.5 cm deep was 29° C, and relative humidity was 17 percent at time of herbicide application. Most of the woolly locoweed plants were mature and flowering. More than 14 cm of precipitation were received within 60 days after treatments were applied.

Foliar sprays of 2,4,5-T + picloram (1:1) at 1.1 kg/ha controlled 81 percent of the woolly locoweed at 30 days after treatment (Table 6). Control with 2,4,5-T + picloram (1:1) was significantly greater than that achieved with foliar sprays of 2,4-D (14 percent) at the same rate. Control on plots treated with all other herbicides was 61 percent or lower.

At 240 days after treatment, foliar sprays of 2,4,5-T + picloram (1:1) and picloram at 1.1 kg/ha rates reduced woolly locoweed density by 83 percent compared to adjacent untreated rangeland (Table 6). Foliar sprays of 2,4-D + picloram (4:1) and 5 percent picloram pellets at 1.1 kg/ha had controlled 75 percent and 78 percent of the weed population, respectively. The other treatments had not effectively controlled woolly locoweed. However, control attained with 2,4-D foliar spray (37 percent) was not significantly different than that attained with foliar sprays of picloram or 2,4,5-T + picloram (1:1) (83 percent).

At 1 year following herbicide applications in May 1979, woolly locoweed densities were reduced by 82, 84 and 89 percent on plots treated with 5 percent picloram pellets, foliar sprays of 2,4,5-T + picloram (1:1) and foliar sprays of picloram at 1.1 kg/ha respectively, compared to untreated rangeland (Table 6). Foliar sprays of 2,4-D + picloram (4:1) controlled 79 percent of the woolly locoweed plants whereas all other herbicide treatments killed 37 percent or less. Control with 2,4-D foliar sprays (34 percent) was not significantly different from control attained with picloram foliar spray (89 percent).

Fall Treatments

Treatments were applied on November 14, 1979. The woolly locoweed population consisted of assorted age classes, but all plants were vigorous and in vegetative growth stages. Soil water content averaged 4.9 percent, air temperature was 16° C, soil temperature at 2.5 cm was 20° C, and relative humidity was 23 percent at time of treatment. Precipitation in the 60-day period prior to treatment totalled 3 cm and only 1.5 cm were received for 60 days after treatment (Table 3).

At 60 days following November 1979 treatments, only foliar sprays of picloram or 2,4,5-T + picloram at 1.1 kg/ha had controlled more than 72 percent of the woolly locoweed (Table 7). None of the other herbicides had effectively controlled woolly locoweed.

At 120 days after treatment, foliar sprays of picloram + triclopyr ester (1:1) at 0.6 kg/ha had completely controlled woolly locoweed (Table 7). Picloram sprays at 1.1 kg/ha had killed 96 percent of the weeds. Herbicide treatments controlling 85 to 93 percent of the woolly

TABLE 6. PERCENTAGE REDUCTION IN WOOLLY LOCOWEED DENSITIES AT 30, 240 AND 365 DAYS FOLLOWING APPLICATION OF 11 HERBICIDE TREATMENTS AT 1.1 kg/ha ON MAY 15, 1979 NEAR ALPINE, TEXAS[1]

Herbicide	Formulation	30	240	365
None	—	0 a-c	0 a-c	0 a-d
2,4-D	Liquid	14 bc	37 a-c	34 a-d
2,4-D + dicamba (3:1)	Liquid	5 a-c	−41 a	−47 a
Dicamba	Liquid	26 b-d	39 a-c	37 a-d
2,4-D + picloram (4:1)	Liquid	50 b-d	75 bc	79 cd
Picloram	Liquid	61 cd	83 c	89 d
Picloram	5% pellets	45 b-d	78 c	82 cd
Picloram	10% pellets	−15 ab	64 bc	68 b-d
2,4,5-T + picloram (1:1)	Liquid	81 d	83 c	84 cd
Tebuthiuron	Wettable powder	1 a-c	−14 ab	−18 ab
Tebuthiuron	20% pellets[2]	−53 a	−13 ab	−6 a-c
Tebuthiuron	20% pellets[3]	26 b-d	19 a-c	16 a-d

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

[2]0.32-cm diameter.

[3]0.16-cm diameter.

TABLE 7. PERCENTAGE REDUCTION IN WOOLLY LOCOWEED DENSITIES AT 60, 120 AND 180 DAYS FOLLOWING APPLICATION OF 18 LIQUID HERBICIDE TREATMENTS ON NOVEMBER 14, 1979 NEAR ALPINE, TEXAS

Herbicides	Rate (kg/ha)	Days after treatment[1] 60	120	180
None	—	0 ab	0 a	0 a
2,4-D	1.1	35 b-e	60 c-e	62 cd
2,4-D + dicamba (3:1)	1.1	56 c-f	85 d-g	86 de
2,4-D + picloram (4:1)	1.1	57 c-f	76 d-g	75 c-e
2,4-D + picloram (4:1)	0.7	41 c-f	57 b-d	53 bc
Dicamba	1.1	64 d-f	88 e-g	87 de
3,6-dichloropicolinic acid	0.6	24 a-c	76 d-g	78 c-e
3,6-dichloropicolonic acid	0.3	26 a-d	67 d-f	65 cd
3,6-dichloropicolonic acid + triclopyr (1:1)	0.6	52 c-f	90 e-g	92 de
3,6-dichloropicolinic acid + dicamba (1:1)	0.6	34 b-d	86 d-g	83 c-e
Picloram	1.1	72 ef	96 fg	93 de
Picloram	0.6	32 b-d	68 d-f	71 c-e
Picloram	0.3	−6 a	29 b	31 b
Picloram + triclopyr (1:1)	0.6	55 c-f	100 g	100 e
Picloram + dicamba (1:1)	0.6	39 c-e	89 e-g	89 de
2,4,5-T + picloram (1:1)	1.1	78 f	93 fg	89 de
2,4,5-T + picloram (1:1)	0.6	64 d-f	87 d-g	87 de
2,4,5-T + picloram (1:1)	0.3	41 c-f	78 d-g	79 c-e
Tebuthiuron (w.p.)[2]	1.1	36 b-e	34 bc	32 b

[1]Means within a column followed by similar lower case letters are not significantly different at $P<0.05$.
[2]Wettable powder formulation.

locoweeds included 3,6-dichloropicolinic acid + dicamba (1:1); 2,4,5-T + picloram (1:1); picloram + dicamba (1:1); and 3,6-dichloropicolinic acid + triclopyr (1:1) at 0.6 kg/ha rates, as well as 2,4-D + dicamba (3:1); dicamba; and 2,4,5-T + picloram (1;1) at 1.1 kg/ha. At 120 days following November 1979 treatments, sprays of picloram + triclopyr (1:1) at 0.6 kg/ha; picloram; and 2,4,5-T + picloram (1:1) at 1.1 kg/ha controlled significantly more woolly locoweed than foliar sprays of 2,4-D at 1.1 kg/ha (Table 7).

At 180 days following fall 1979 treatments, foliar sprays of picloram + triclopyr ester (1:1) at 0.6 kg/ha completely controlled woolly locoweed (Table 7). Foliar sprays of dicamba; 2,4,5-T + picloram (1:1); and picloram at 1.1 kg/ha rates, as well as sprays of 2,4,5-T + picloram (1:1); picloram + dicamba (1:1); and 3,6-dichloropicolinic acid + triclopyr (1:1) at 0.6 kg/ha rates controlled 87 to 93 percent of the woolly locoweed. Herbicide treatments that reduced densities of the species by 75 to 86 percent at 180 days post-treatment included 2,4-D + picloram (4:1) and 2,4-D + dicamba (3:1) at 1.1 kg/ha; 3,6-dichloropicolinic acid and 3,6-dichloropicolinic acid + dicamba (1:1) at 0.6 kg/ha; and 2,4,5-T + picloram (1:1) at 0.3 kg/ha. Only picloram + triclopyr (1:1) at 0.6 kg/ha reduced woolly locoweed densities significantly more than foliar sprays of 2,4-D at 1.1 kg/ha (100 vs 62 percent reduction) at 180 days after treatment.

Season x Treatment Interaction

Among the seven herbicide treatments that were applied in all three seasons, significant season x treatment interactions were identified for foliar sprays of 2,4-D + dicamba (3:1); dicamba; and tebuthiuron at 1.1 kg/ha rates (Table 8) ($P<0.05$). Fall and winter applications of 2,4-D + dicamba controlled significantly more woolly locoweed than spring applications, and fall applications controlled significantly more woolly locoweed than winter applications at 1-year post-treatment. A similar pattern was observed for dicamba foliar sprays (Table 8).

TABLE 8. MEAN PERCENT REDUCTION OF WOOLLY LOCOWEED AT 60 DAYS AND 365 DAYS FOLLOWING WINTER, SPRING OR FALL APPLICATIONS OF 7 LIQUID HERBICIDE TREATMENTS NEAR ALPINE, TEXAS

Herbicides	Rate (kg/ha)	60 days			365 days		
		Winter	Spring	Fall	Winter	Spring	Fall
2,4-D	1.1	53 a[1]	14 a	35 a	69 a	34 a	62 a
2,4-D + dicamba (3:1)	1.1	80 b	5 a	56 b	56 b	−47 a	86 c
Dicamba	1.1	99 b	26 a	64 b	83 ab	37 a	87 b
2,4-D + picloram (4:1)	1.1	76 a	50 a	57 a	94 a	79 a	75 a
Picloram	1.1	69 a	61 a	72 a	87 a	89 a	93 a
Tebuthiuron (w.p.)[2]	1.1	55 b	1 a	36 ab	66 b	−18 a	32 b
2,4,5-T + picloram (1:1)	1.1	70 a	81 a	78 a	84 a	84 a	89 a

[1]Means within a row, for each evaluation date, followed by similar lower case letters are not significantly different at $P<0.05$.
[2]Wettable powder formulation.

Winter application of foliar sprays of tebuthiuron at 1.1 kg/ha controlled significantly more woolly locoweed than spring applications, and there was a trend of better control in winter compared to fall.

Fall applications of foliar sprays of picloram and 2,4,5-T + picloram (1:1) at 1.1 kg/ha rates tended to control more woolly locoweed than either winter or spring applications, although differences were not significant (Table 8). Fall and winter applications of 2,4-D at 1.1 kg/ha tended to be more effective than spring applications, but the differences were not statistically significant.

Forage Response

None of the herbicide treatments applied in January or May 1979 affected production of desirable grasses or forbs compared to untreated rangeland (data not shown). Standing herbage crop averaged 1,565 kg/ha in the ungrazed exclosure in the fall of 1979. Woolly locoweed apparently does not compete with desirable forage species at the low weed densities encountered in this study.

Conclusions

Control of woolly locoweed was better following fall treatments with most herbicides, compared to winter or spring treatments, presumably because seedlings were emerging and actively growing in the fall. In the Davis Mountain area conditions for rapid vegetative growth of woolly locoweed are normally more favorable during fall than during winter or spring, because of the summer-fall rainfall pattern. Herbicidal control improved in the fall of 1979, when soil water content averaged less than 5 percent and air temperature was 16° C at time of herbicide application, compared to that achieved in the winter of 1979 when soil water content averaged 14 percent and air temperature was 0° C. This suggests that the susceptibility of woolly locoweed to several herbicides may be reduced at low temperatures, even when soil water contents are optimal for plant growth. Ueckert *et al*. (1980) reported similar responses for bitterweed. Rates of absorption and translocation of foliar-applied herbicides increase with increased air temperatures, so less herbicide may be required at moderate temperatures (i.e. 16 to 20° C) than at lower temperatures (i.e. 0° C) for absorption and translocation of lethal amounts of herbicide (Klingman and Ashton, 1975; Leopold and Kriedemann, 1975; Ashton and Crafts, 1973).

Winter applications of most herbicides tended to control more woolly locoweed than spring applications, probably because growing conditions were more favorable and plants were younger when treated. The susceptibility of most herbaceous plants to herbicides usually decreases with advancing maturity and as growing conditions become less favorable.

Foliar sprays of esters of 2,4-D at 1.1 kg/ha did not satisfactorily control woolly locoweed. Foliar sprays of picloram or herbicide combinations containing picloram at 0.2 to 1.1 kg/ha effectively controlled woolly locoweed for a year or longer following winter or fall applications. However, picloram pellets did not consistently control woolly locoweed, and 10 percent a.i. picloram pellets were less effective than 5 percent a.i. pellets, presumably due to uneven distribution. Herbicidal control of woolly locoweed with foliar sprays of picloram was usually manifested within 120 days or less, compared to 1 year for pelleted formulations of picloram. Foliar sprays of dicamba at 1.1 kg/ha completely controlled woolly locoweed by 60 to 120 days after application during a cold winter. However, short-term control following spring or fall applications of dicamba was poor to fair. Long-term (365 days ±) control of woolly locoweed was generally best on rangeland treated with either picloram at 1.1. kg/ha or herbicide mixtures containing picloram at 0.2 to 0.6 kg/ha, apparently because of the persistence of picloram in the soil (Crafts, 1975; Bovey and Scifres, 1971; Scifres *et al*., 1971).

Tebuthiuron, applied as foliar sprays or as 20 percent a.i. pellets, did not effectively control woolly locoweed. Herbicide mixtures of 2,4-D + dicamba (3:1) at 1.1 kg/ha, applied in the fall, killed 85 percent of the weeds by 120 days after treatment. However, winter and spring treatments did not effectively control the weed.

Foliar sprays of 3,6-dichloropicolinic acid applied in fall at 0.3 to 0.6 kg/ha did not effectively control woolly locoweed. However, fall application of foliar sprays of 3,6-dichloropicolinic acid + triclopyr (1:1) or 3,6-dichloropicolinic acid + dicamba (1:1) at 0.6 kg/ha killed over 86 percent of the weed population by 120 days after treatment. Foliar sprays of picloram + triclopyr (1:1) and picloram + dicamba (1:1), applied in the fall at 0.6 kg/ha controlled 100 and 89 percent of the weed within 120 days after treatment, respectively. Fall application of foliar sprays of 2,4,5-T + picloram (1:1) at 0.6 kg/ha were as effective for woolly locoweed control as the 1.1 kg/ha rate.

Production of desirable forage was not affected by the herbicide treatments evaluated, presumably because the low densities of woolly locoweed (1.4 to 1.9/m^2) did not compete with desirable forage plants.

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Metric Units — English Equivalents

Metric Unit	English Equivalents
Centimeter (cm)	0.394 inches
Hectare (ha)	2.47 acres
Kilogram (kg)	2.205 pounds
Kilogram 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
Square meter (m^2)	10.758 square feet
(Degrees centigrade $\times$ 1.8 + 32)	Degrees fahrenheit

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APPENDIX

Scientific Names of Plants Mentioned in Text

Common Name	Scientific Name
Bitterweed	*Hymenoxys odorata*
Blue grama	*Bouteloua gracilis*
Cane bluestem	*Bothriochloa barbinodis*
Garbancillo	*Astragalus wootonii*
Green River milkvetch	*Astragalus pubentissimus*
Halls panicum	*Panicum hallii*
Hook threeawn	*Aristida hamulosa*
Inland saltgrass	*Distichlis spicata* var. *stricta*
Lambert crazyweed	*Oxytropis lambertii*
Locoweed	*Astragalus* spp.
Sideoats grama	*Bouteloua curtipendula*
Threeawns	*Aristida* spp.
Wolftail	*Lycurus phleoides*
Woolly locoweed	*Astragalus mollissimus* var. *earlei*

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