Creosotebush control and forage production in the Chihuahuan and Sonoran Deserts

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Abstract

Creosotebush (*Larrea tridentata* [Sesse & Moc. ex DC.] Cov) and other shrubs have spread into semidesert grasslands of the southwestern United States and northern Mexico; and as creosotebush increases, perennial grasses decrease. This study evaluated 3 rates of tebuthiuron and 4 mechanical treatments in 1981 and 1982 for creosotebush control at 4 locations, 3 in Chihuahua, Mexico, and 1 in Arizona, U.S.A., and compared forage production after treatment with untreated checks. Creosotebush mortalities averaged across locations and years were 75, 87, 93, 3, 33, 68, and 68% for the 0.5, 1.0, and 1.5 kg ai/ha tebuthiuron (*N*-(5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N,N'*-dimethylurea), land imprinting, 2-way railing, disk plowing, and disk plowing with contour furrowing treatments, respectively. Forage production averaged across locations and years was 529, 524, 606, 303, 344, 290, 330, and 302 kg/ha for the 0.5, 1.0, and 1.5 kg ai/ha tebuthiuron, land imprinting, 2-way railing, disk plowing, disk plowing with furrowing, and untreated check treatments, respectively. Precipitation was below long-term means at all Chihuahuan locations in 1983, and forage production was significantly greater on most treated plots where brush was controlled than on untreated checks. At the Arizona location precipitation was above the long-term mean in 1983 and all plots treated in 1981, except the disk plowing and disk plowing with furrowing which destroyed perennial grasses, produced significantly more grass forage than the untreated checks. Precipitation was above the long-term means at all locations in 1984 and about half of the plots treated with tebuthiuron produced significantly more forage than the untreated checks but not any mechanically treated plots. When treatments reduced shrub density and remnants of native forage grasses were present, forage production increased in both wet and dry years.

Key Words: tebuthiuron, railing, disking, land imprinting, tarbush, whitethorn acacia, mesquite, *Larrea tridentata*

Creosotebush (*Larrea tridentata* [Sesse & Moc. ex DC.] Cov) and associated desert shrub species dominate approximately 19 million ha in the United States (Platt 1959) and approximately 45 million ha in northern Mexico (Leopold 1950). Studies by Buffington and Herbel (1965) indicate that creosotebush continues to spread onto desert grasslands. It is important to control creosotebush and other shrubs because as they increase in density, perennial grass production decreases (Anderson et al. 1957).

Proper grazing management has no effect on creosotebush density and no biological control methods are available. Tebuthiuron has been the most effective selective broadcast treatment for creosotebush control on rangelands in the Southwestern United States (Bovey and Meyer 1978, Scifres et al. 1979, Herbel et al. 1985). Jacoby et al. (1982) reported that 0.5 and 1.0 kg/ha of tebuthiuron reduced the density of creosotebush near Ft. Stockton, Texas, by 86 and 99%, respectively, and grass production 32 months after treatment was 257 kg/ha on an untreated area and 702 and 1,039 kg/ha on plots treated at 0.5, and 1.0 kg/ha, respectively.

Root plowing and disking are among the oldest methods for controlling woody vegetation. However, these operations destroy existing herbaceous vegetation and should be limited to areas where plant removal will be followed by reseeding. Effective mechanical treatments cut off the shrub below the crown. Chaining, railing, roller chopping, land imprinting, and rotary mower reduce cover but do not kill shrubs which sprout from roots and crowns. Thus, native grass growth is enhanced for only 2 to 5 years (Scifres 1980). Previous studies have evaluated either chemical or mechanical methods for their effectiveness in controlling creosotebush and effects on forage production but have not directly compared both chemical and mechanical methods. This study was conducted to evaluate 3 chemical and 4 mechanical treatments for control of creosotebush and other woody species, and compare native grass production on treated and untreated areas at 4 sites in southwestern United States and northern Mexico.

Materials and Methods

The study was conducted at Rancho La Reforma, 60 km east of Hidalgo del Parral, Chihuahua; Rancho Los Pozos, 30 km northeast of Villa de Aldama, Chihuahua; and Rancho El Toro, 100 km east of Villa Ahumada, Chihuahua, all within the Chihuahuan Desert; and the Santa Rita Experimental Range (SRER), 40 km south of Tucson, Arizona, in the Sonoran Desert. Elevation was 1,500 m at La Reforma; about 1,400 m at Los Pozos and El Toro; and 970 m at SRER. Long-term mean annual precipitation at La Reforma, Los Pozos, El Toro, and SRER is 430, 224, 227, and 320 mm, respectively, and occurs primarily from June through September at the Chihuahuan locations, but is bimodal at SRER, with about 60% occurring June through October (Fig. 1) (COTECOCA 1978, Green and Martin 1967). Slope inclination varies from 2 to 16% at La Reforma, and from 0 to 5% at the other 3 sites. Surface soil textures at the 4 sites are sandy loams underlain by a caliche hardpan that ranges from 5 to 100 cm below the soil surface. Physical and chemical properties of the soils are shown in Table 1.

Creosotebush was the dominant shrub species at all locations except La Reforma, where it shared codominance with whitethorn acacia (*Acacia constricta* Benth.), tarbush (*Flourencia cernua* DC.), and shrubby senna (*Cassia wislenizeni* Gray). Mariola (*Parthenium incanum* H.B.K.) and whitethorn acacia were abundant at Los Pozos; javelina brush (*Condalia ericoides* [A. Gray] M.C. Johnston) and honey mesquite (*Prosopis glandulosa* Torr.) at El Toro; and velvet mesquite (*Prosopis velutina* Woot.) and desert zinnia (*Zinnia pumila* Gray) at SRER. The most prevalent

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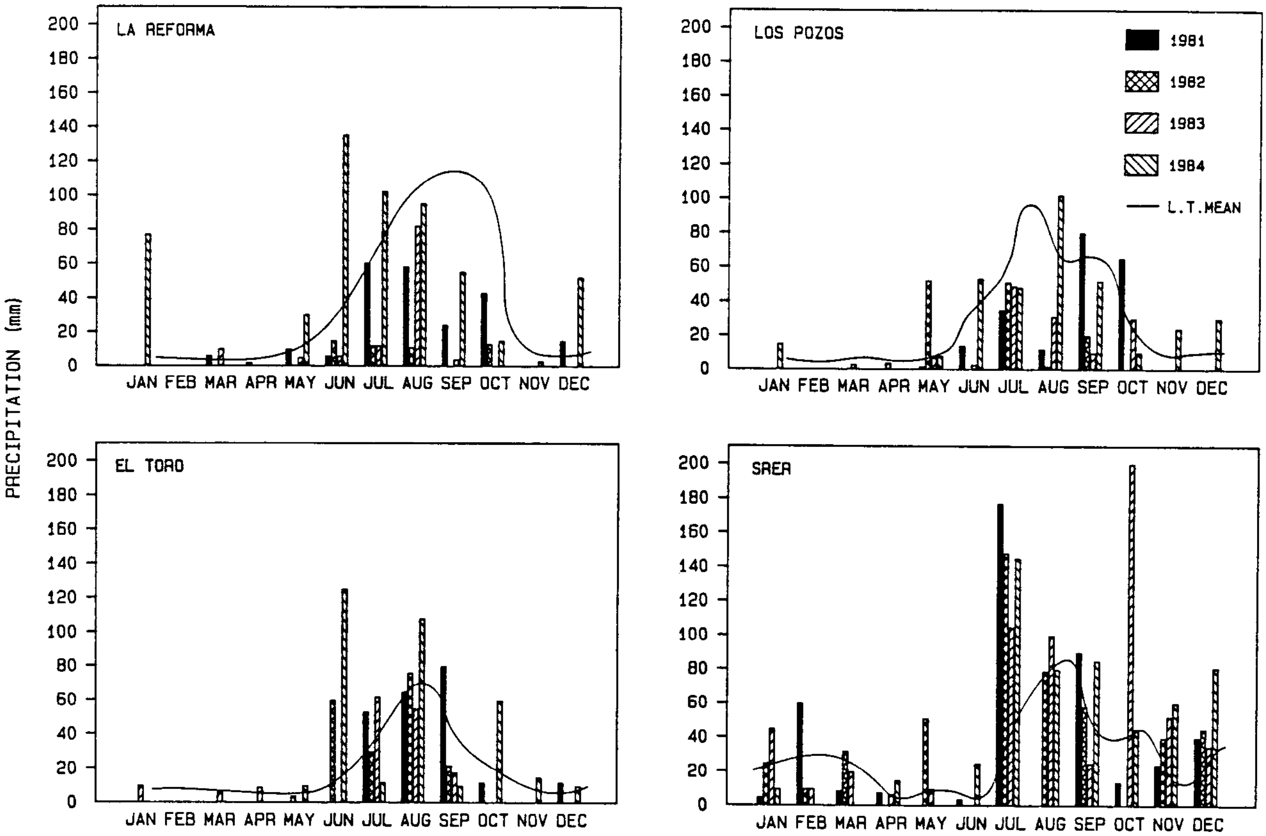

Fig. 1. Monthly precipitation (mm) from 1981 to 1984 and long-term mean (L.T. mean) at Ranchos La Reforma, Los Pozos, and El Toro, Chihuahua, Mexico; and Santa Rita Experimental Range (SRER), Arizona, U.S.A.

native grasses at the 4 locations were fluffgrass (*Erioneuron pulchellum* [H.B.K.] Tateoka) at all locations; black grama (*Bouteloua eriopoda* Torr.) at La Reforma and El Toro; spike pappusgrass (*Enneapogon desvauxii* Beauv.) at La Reforma and Los Pozos; threeawns (*Aristida* spp.) at Los Pozos and SRER; and bushmuhly (*Muhlenbergia poterii* Scribn.) at Los Pozos, El Toro, and SRER.

Study sites (about 30 ha) were fenced to exclude livestock in summer 1981 and divided in half with treatments placed on one side in 1981 and on the other in 1982. Each part was further divided into 24 plots, each 50 by 100m. The experimental design was a randomized block with 3 replications. The following 8 treatments were applied: broadcast applications of 20% pellets of tebuthiuron at (1) 0.5, (2) 1.0, and (3) 1.5 kg ai/ha, (4) land imprinting, (5) 2-way railing, (6) disk plowing, (7) disk plowing with contour furrowing, and (8) untreated check. Tebuthiuron pellets were distributed by hand and the plot was covered 4 times: twice lengthwise on 10 swaths spaced 5 m apart and twice crosswise on 20 swaths, spaced 5 m apart. The clay pellets were 3.2 mm in diameter and approximately 4.8 mm in length.

Mechanical treatments were applied between 15 June and 17 July 1981, and between 26 May and 27 June 1982. Land imprinter

Table 1. Physical and chemical properties of the upper 20 cm of soils at Ranchos La Reforma, Los Pozos, and El Toro in Chihuahua, Mexico and at Santa Rita Experimental Range (SRER) in Arizona, U.S.A.

Location	Percent soil particles >2 mm	<2 mm	Sand	Silt	Clay	Organic Matter	ph	Electrical Conductivity	Series	Classification[1]
	(%)							(ds/m)		
La Reforma	45	55	59	26	15	3.6	6.9	2.9	Kimbrough	loamy, mixed, thermic shallow, Petrocalcic, Calciustoll
Los Pozos	29	71	60	29	11	1.5	7.2	1.3	Jerag	loamy, mixed, thermic shallow, Petrocalcic Ustollic Paleargid
El Toro	23	77	66	24	10	1.1	7.9	1.1	Algerita	loamy, mixed, thermic, coarse, Ustollic Typic Calciorthid
SRER	17	83	58	28	11	0.7	7.9	1.1	Anthony	loamy, thermic, Typic Torrifluvent

[1]Soil classification is from Soil Survey Staff (1975).

Table 2. Percent mortality with 95% confidence intervals (CI) for creosotebush and major associated woody species after 3 tebuthiuron and 4 mechanical treatments applied in 1981 and 1982 at 4 locations in the Chihuahuan and Sonoran Deserts.[1]

Brush species	Treatment year	Tebuthiuron kg ai/ha 0.5	1.0	1.5	Land imprinting	Two-way railing	Disk plowing	Disk plowing with furrowing	Untreated check
		(% mortality ± 95% CI)[2]							
		(Rancho La Reforma)							
Creosotebush	1981	73±8	59±7	82±6	—[3]	55±5	81±6	76±10	4±2
	1982	60±5	89±5	97±3	0±2	42±3	44±5	55±6	1±1
Whitethorn	1981	33±6	53±6	89±5	—	11±4	14±4	36±6	0±1
acacia	1982	82±4	88±4	98±2	48±5	18±5	32±5	69±4	0±0
Tarbush	1981	98±3	96±4	99±1	—	38±10	68±9	97±2	4±5
	1982	100±5	100±4	98±6	0±2	88±13	74±10	97±5	4±4
Shrubby	1981	90±6	93±6	98±5	—	64±10	47±10	73±14	0±2
senna	1982	100±10	80±8	81±18	0±3	97±5	76±14	62±11	7±10
		(Rancho Los Pozos)							
Creosotebush	1981	83±4	84±4	90±3	—	34±3	79±4	68±3	0±0
	1982	66±6	90±4	98±2	0±2	62±3	48±3	43±4	6±2
Whitethorn	1981	95±15	89±18	100±9	—	27±14	58±11	20±14	19±14
acacia	1982	95±6	91±6	97±5	42±6	38±10	51±10	50±8	0±1
Mariola	1981	94±6	88±7	100±2	—	66±8	74±9	41±10	9±4
	1982	95±4	92±3	100±0	48±6	81±5	95±3	96±2	0±0
		(Rancho El Toro)							
Creosotebush	1981	78±6	94±4	96±2	—	27±6	82±5	89±4	0±0
	1982	91±4	100±2	98±2	13±4	12±4	87±4	83±5	0±0
Honey	1981	39±10	53±10	77±12	—	21±7	51±10	67±10	0±1
mesquite	1982	74±6	90±10	93±6	0±1	15±6	55±9	68±9	0±2
Javelina	1981	98±7	100±4	95±10	—	0±3	94±16	94±8	9±8
brush	1982	98±4	100±4	100±4	12±7	30±10	71±9	84±8	0±2
		(SRER))							
Creosotebush	1981	58±5	92±5	98±4	0±1	7±2	38±6	47±6	0±1
	1982	70±6	87±6	88±5	0±1	26±6	88±4	87±4	0±1
Velvet	1981	100±4	86±4	85±11	42±11	50±15	78±22	100±6	0±6
mesquite	1982	91±10	94±16	92±11	35±15	85±11	64±13	92±17	0±7
Desert	1981	91±3	100±1	100±1	2±1	33±3	69±3	54±4	0±0
zinnia	1982	100±2	100±1	100±4	80±4	5±2	93±2	87±2	0±2

[1]Treatments evaluated between 26 September and 31 October, 1984.
[2]Mortality calculated from the number of live plants of each species in ten 44-m² plots on each of 3 treated plots in 1984 and at the time of treatment. The 95% confidence intervals for binomial distribution were determined for each mean based on the size of sample use to calculate mortality.
[3]Land imprinting treatments were not applied at these locations in 1981.

treatments were applied only at SRER in 1981 and at all sites in 1982. Tebuthiuron was applied in May both years.

Shrub populations were estimated before treatment and in the fall of 1984 on 10 randomly placed 44-m² quadrats, excluding a 5-m perimeter. Brush mortality was calculated by species on each plot from densities at the time of treatment and the fall of 1984. Confidence intervals for binomial distribution (95%) were calculated for each mortality value based on the sample size (Steel and Torrie 1960). Confidence intervals were used to show mean differences rather than analyses of variance because of shrub population variability at each location.

The rail consisted of three 2.65-m lengths of railroad steel bolted together to form a triangle and weighted with rocks (approximately 770 kg). The rail was pulled over the plot twice in opposite directions. A standard 3-bottom disk plow on a 3-point hitch weighing 500 kg was used at the Mexican sites, and a pull-type 3-bottom disk plow weighing 1,000 kg was used at the SRER. Both disk plows had 64-cm disks which penetrated soils to 30 cm. A border disk constructed contour furrows at 10-m intervals.

The land imprinter, fabricated from 1.27-cm steel plate, consisted of 2 non-directional geometric forms (V-pitter and pit-digger) welded on separate 1- by 1-m cylinder capsules. Capsules were linked on an axle shaft. Capsules were filled with water, and iron boxes located at the front and rear were filled with rock to improve soil penetration (Dixon and Simanton 1980). Total weight was approximately 4 metric tons (Fig. 2).

Native perennial grass forage production was estimated in the

Fig. 2. Land imprinter pulled by track tractor. Note iron box filled with rocks mounted on frame and V-pitter geometry of left capsule and pit-digger geometry of right capsule.

fall of 1983 and 1984 using a weight estimate technique (Pechanec and Pickford 1937). Twenty 30.5 by 61-cm quadrats were randomly placed in each plot excluding a 5-m band on the perimeter to eliminate treatment effects from adjacent plots, and forage weights visually estimated. Plants in 5 quadrats were clipped at the soil surface. Clipped forage was dried at 40° C for 48 hours in a forced-draft oven, and dry weights from unclipped field samples calculated using regression techniques (Campbell and Cassady 1949). We hypothesized that the treatments would increase forage production above that on untreated plots. When F values were significant, the forage on treated plots was compared with the forage on untreated check plots by Dunnett's one-sided procedure (Steel and Torrie 1960).

Brush control programs are expected to increase forage production. To test this assumption we calculated linear correlation coefficients (r) and linear regression equations between shrub density and forage production in 1984 on all plots at each of the 4 locations. At Los Pozos and El Toro 43 degrees of freedom were used to evaluate the significance of correlation coefficients because land imprinting treatments were not applied in 1981. At La Reforma 42 degrees of freedom were used because the land imprinting treatments and 1 disking with furrowing treatment were not applied in 1981. At SRER 46 degrees of freedom were used because all treatments were applied in both years.

Results and Discussion

Total precipitation at all Chihuahuan locations was below long-term means in 1981, 1982, and 1983 (Fig. 1). Precipitation was 25 and 59% of long-term means during summer 1982 at La Reforma and Los Pozos, respectively. At El Toro total precipitation was 70% of long-term mean in 1983, but July and August precipitation was near normal (117 mm versus 120 mm). Precipitation was above average at all Chihuahuan locations in 1984. At SRER precipitation was above average in all years.

Creosotebush Mortality

Tebuthiuron usually killed about 60% or more of the creosotebush plants at all rates and locations (Table 2). Across all locations and years creosotebush mortalities averaged 72, 87, and 93% at 0.5, 1.0, and 1.5 kg ai/ha, respectively. Creosotebush mortalities from all tebuthiuron rates averaged across both years at La Reforma, Los Pozos, El Toro, and SRER were 77, 85, 93, and 82%, respectively. Land imprinting killed 13% or less of the creosotebush and was the least effective control method. Average creosotebush mortalities across all locations from 2-way railing treatments in 1981 and 1982 were 31 and 36%, respectively. Highest mortality of creosotebush from 2-way railing was 62% at Los Pozos from the 1982 treatment and least mortality of creosotebush was 7% at SRER in 1981. Disking and disking with furrowing across all locations and years each killed an average of 68% of creosotebush plants. Disking treatments were more consistently effective at El Toro than at the other locations (Table 2). In 1981 mechanical treatments at SRER were applied immediately after 20 mm of rainfall to moist soil, but in 1982 they were applied before summer rains to dry soil. The higher soil moisture content in 1981 prevented desiccation of roots and crowns and contributed to the lower mortality rate of creosotebush in 1981 than in 1982 at the SRER location.

Associated Shrub Mortality

At La Reforma whitethorn acacia was less susceptible to low rates of tebuthiuron in 1981 than was creosotebush, but at Los Pozos whitethorn acacia populations declined by 89% or more on tebuthiuron plots (Table 2). All rates of tebuthiuron killed nearly all of the tarbush, shrubby senna, javelina brush, mariola, and desert zinnia plants. Honey mesquite was less susceptible to tebuthiuron than creosotebush at El Toro; however, at SRER tebuthiuron caused higher mortalities of velvet mesquite than creosotebush (Table 2).

Land imprinting in 1982 killed 48 and 42% of the whitethorn acacia plants at La Reforma and Los Pozos, respectively; but land imprinting was not an effective control measure for tarbush, shrubby senna, and honey mesquite. Both mariola and desert zinnia appeared to be marginally susceptible to land imprinting if treated when the soil was dry.

Two-way railing was less effective in controlling whitethorn

Table 3. Forage production in 1983 and 1984 after 3 tebuthiuron and 4 mechanical treatments were applied in 1981 and 1982 at 4 locations in the Chihuahuan and Sonoran Deserts.

Location	Treatment year	Tebuthiuron kg ai/ha 0.5	1.0	1.5	Land imprinting	Two-way railing	Disk plowing	Disk plowing with furrowing	Untreated check
		kg D.M./ha							
		(Production in 1983)							
La Reforma	1981	182*	248*	258*	—[1]	162	290**	409**	104
	1982	166**	206**	117	89	190**	142**	149**	105
Los Pozos	1981	94**	101**	104**	—	62	65	68	56
	1982	95**	78	77	107**	73	84*	101**	70
El Toro	1981	575	411	402	—	313	311	388	665
	1982	427	371	301	236	106	118	186	334
SRER	1981	393**	308**	270**	280**	404**	137	171	104
	1982	422	297	289	280	411	117	120	380
		(Production in 1984)							
La Reforma	1981	842*	1127**	1414**	—	84	295	253	279
	1982	986*	1263**	1376**	448	603	689	636	390
Los Pozos	1981	488	747*	868*	—	147	80	308	135
	1982	545	351	556*	255	211	230	380	133
El Toro	1981	731	766	680	—	898	899	805	1029
	1982	1028*	583	1119*	486	154	186	376	501
SRER	1981	554	1138*	778	153	509	283	199	213
	1982	938	392	1091	699	1177	709	730	330

*Significantly greater than check ($P \leq 0.05$) according to Dunnett's one-sided procedure.
**Significantly greater than check ($P \leq 0.01$) according to Dunnett's one-sided procedure.
[1]Treatment not applied at these locations in 1981.

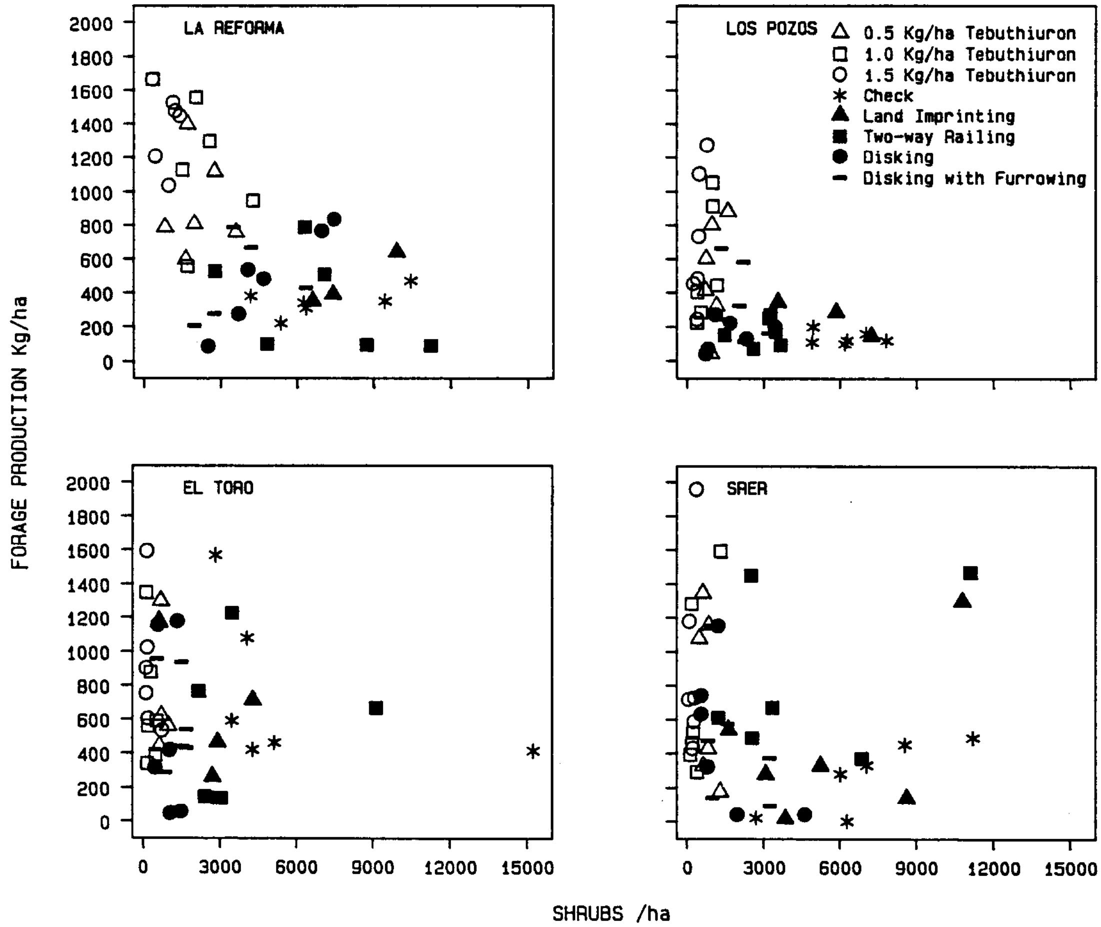

Fig. 3. Forage production in 1984 at different shrub densities on plots receiving 3 chemical and 4 mechanical treatments at 4 locations in 1981 and 1982.

acacia, tarbush, shrubby senna, and mariola in 1981 than in 1982 due to low rainfall in 1982. This low rainfall probably contributed to desiccation of the plants and higher mortality of these species in 1982 than in 1981.

Disking and disking with furrowing gave erratic control of whitethorn acacia, velvet and honey mesquite, and shrubby senna; but they consistently controlled javelina brush, mariola, and desert zinnia when applied to dry soil.

Forage Production

Forage production in 1983 on untreated plots at La Reforma and Los Pozos was between one-third and one-half what it was in 1984 due to low June to September precipitation in 1983. In 1983 forage production on most treated plots at La Reforma and Los Pozos was significantly greater than on untreated check plots, but not at El Toro (Fig. 1 and Table 3). Total precipitation at El Toro was 70% of long-term mean in 1983; July and August precipitation was near normal. This indicates that competition for moisture between shrubs and forage grasses was not a factor at El Toro in 1983. At SRER all plots treated with tebuthiuron in 1981 and some plots mechanically treated in 1981 produced significantly more forage than the untreated check plots.

Forage production in 1984 was significantly greater on one half of the plots treated with tebuthiuron than on untreated check plots but not on any plots treated mechanically (Table 3). Figure 3 shows that because tebuthiuron caused high mortality rates, shrub densities at all locations were reduced to less than 4,000 plants/ha, but the mechanically treated plots often supported shrub densities only slightly lower than untreated check plots.

Linear correlation coefficients between shrub density and forage production were significant ($P\leq0.01$) for La Reforma and Los Pozos but not for El Toro and SRER (Table 4). The lack of a significant correlation between shrub density and forage production at El Toro and SRER in 1984 is attributed to low shrub density

Table 4. Correlation coefficients (r) and linear regression equations for shrub density (X=plants/ha) and forage production (Ŷ=kg D.M./ha) in 1984 on plots treated with 3 tebuthiuron and 4 mechanical treatments at 4 locations in the Chihuahuan and Sonoran Deserts.

Location	Correlation coefficient	Linear regression equation
La Reforma	-0.607**	Ŷ=1128-0.096X
Los Pozos	-0.459**	Ŷ= 511-0.063X
El Toro	-0.158	Ŷ= 729-0.024X
SRER	-0.119	Ŷ= 667-0.010X

**Significant at the 1% level of probability.

and timeliness of summer rains. All but 3 plots at El Toro had 5,000 or fewer shrubs/ha; consequently, the effect of high shrub density was not measured. Forage production was highest at all locations only where shrub density was less than 3,000 plants/ha (Fig. 3), but forage production was not always high where shrub densities were low. On some of the plots forage plants were not present when the study began. On other plots mechanical or chemical treatments injured or destroyed forage grasses so that they were unable to respond significantly to reduced competition from shrubs. July and August rains in 1984 at both El Toro and SRER apparently were sufficient to fulfill the needs of both grasses and shrubs.

Conclusions

We found that mortalities of creosotebush from tebuthiuron at 0.5 and 1.0 kg ai/ha were often 60% or more, and at 1.5 kg ai/ha tebuthiuron always killed 80% or more of the creosotebush plants. Whitethorn acacia and honey mesquite mortalities from the 2 low rates of tebuthiuron were often less than 65% but at 1.5 kg ai/h tebuthiuron usually killed 80% or more of these shrub species. Mortality of tarbush, shrubby senna, mariola, javelina brush, and desert zinnia were at least 80% from all rates of tebuthiuron. Land imprinting and 2-way railing seldom gave shrub mortalities greater than 60%. Disking and disking with furrowing each killed an average of 68% of creosotebush plants and destroyed perennial grasses.

When shrub density was less than 3,000 plants/ha grass forage production was highest at all locations. Low shrub density and high forage production were more consistently achieved with tebuthiuron than with mechanical treatments, because the most effective mechanical treatments destroyed perennial grasses as well as shrubs. We conclude that forage production on semiarid grassland in northern Mexico and southwestern United States with shrub densities greater than 6,000 plants/ha and a remnant of perennial forage grasses will increase after shrub removal. Forage production on semiarid grasslands with shrub densities below 6,000 plants/ha probably will not increase significantly after shrub control.

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