PURCHASED BY THE AGRICULTURAL RESEARCH SERVICE, U. S. DEPARTMENT OF AGRICULTURE FOR OFFICIAL USE

Reprinted from the
Proceedings of the First International Rangeland Congress
1978 • Pages 647-650

Soil Applied Herbicides for Brush Control in Southwestern United States and Northeast Brazil

HOWARD L. MORTON, EL. LAMAR SMITH, MARTINIANO OLIVEIRA, AND HERBERT M. HULL

Highlight

Undesirable woody plants are a serious problem on many rangelands of the southwestern United States and northeastern Brazil. While some species are controlled by broadcast sprays of phenoxy herbicides, resistant species are also present and must be controlled with other herbicides. Basal trunk sprays of picloram and 2,4,5-T and granular and pelleted formulations of picloram, tebuthiuron, karbutilate and bromacil give excellent selective control of a number of woody plants when applied as broadcast or individual plant treatments. Granular and pelleted herbicides can be applied broadcast with little danger of drift to adjacent crops. They are also easily applied by unskilled laborers.

Unwanted woody plants constitute the most serious management problem confronting land management personnel in the southwestern United States and northeastern Brazil. Many species in each country can be controlled with herbicides; however, economic parameters and the presence of adjacent susceptible crops limit the application of broadcast herbicidal sprays in many instances. In some situations, herbicides can move in runoff water and with sediment to become an off-site pollutant. In this paper we report the results of herbicidal evaluation studies for the control of woody plants carried out in Brazil and the United States, and discuss the factors involved in transferring information from one country to another.

The interior of northeastern Brazil is characterized by a semiarid and tropical climate with annual rainfall of 300-800 mm, normally occurring almost entirely from about January to May. Rainfall varies greatly from year to year and severe droughts occur an average of one year in 10. Vegetation consists of a broadleaf, deciduous tropical scrub, the "caatinga." Woody vegetation ranges from sparse to very dense and from 2 to 10 m in height, depending on rainfall and soil and land use history. Soils vary greatly but the most typical are either fairly deep, well-drained red latosols or shallow solonetzic soils which are often waterlogged in the wet season and hold little available stored moisture in the dry season.

Livestock production is an important land use throughout the area. Cattle are raised for commercial markets while sheep, goats, and hogs are primarily raised for local consumption in rural areas.

The three most important invader species are marmeleiro (*Croton hermiagyreus* Muell, Arg.), jurema preta (*Mimosa acutistipula* Benth.), and mofumbo (*Combretum leprosum* Mart.). All three are aggressive seral species that form a minor component of the climax caatinga understory or exist in shallow stands in the more open drier region. Marmeleiro is a shallow-rooted single-stemmed species which reaches a height of 2-4 m and spreads by seed or root suckers. It sprouts readily from the stump and/or roots. Jurema preta is also usually single-stemmed, very thorny, and somewhat larger and more deep-rooted than marmeleiro. It spreads by seed and sprouts from the stump when cut. Mofumbo is less wide-spread than the others. It is deep rooted and forms a multistemmed bush up to 3 m tall and perhaps 4 m across. The bark is smooth and the waxy leaves often remain on the tree into the dry season. It reproduces by seed and sometimes by layering from its long, almost vine-like branches. It also sprouts vigorously from the stump.

Rangelands of the southwestern United States are characterized by a semiarid climate with annual rainfall ranging from less than 200 mm at lower elevations to more than 500 mm at some of the higher elevations. Although the temperatures are mild and a long frost-free period is experienced over much of the area, growing seasons are short due to low soil moisture. In most years, significant amounts of forage are produced only during the summer rainy season (July, August, and September).

Major changes have taken place in the natural vegetation during the past 80 to 100 years. The most conspicuous change has been the increase in woody plants on desert grasslands (Fisher et al. 1959, Glendening and Paulsen 1955, Hastings and Turner 1965, and Martin and Cable 1974). The most abundant and most agressive invader of grasslands is mesquite [*Prosopis juliflora* (Swartz) DC.]. In Texas honey mesquite [*P. juliflora* var. *glandulosa* (Torr.) Cockrell] infests approximately 25 million ha; in western Texas, New Mexico and eastern Arizona, western honey mesquite (*P. juliflora* var. *torreyana* L. Benson) is reported to infest from 6 to 8 million ha; and in southern Arizona, velvet mesquite [*P. juliflora* var. *velutina* (Woot.) Sarg.] infests approximately 2.8 million ha. Creosotebush [*Larrea tridentata* (DC.) Coville] has also invaded extensive portions of the desert grassland type and is estimated to infest between 14 and 18 million ha of desert grassland in the southwestern United States and northern Mexico (Hull et al. 1971).

Mesquite usually occurs as the dominant species once it has invaded a rangeland; however, it seldom occurs without one or more understory species being present. Some of the more abundant understory species are catclaw acacia (*Acacia greggii* A. Gray), wait-a-minutebush (*Mimosa biuncifera* Benth.), lotebush, [*Condalia obtusifolia* (Hook) Weberb.], burroweed [*Haplopappus tenuisectus* (Green) Blake] and snakeweed [*Gutierrezia sarothrae* (Pursh) Britt. & Rusby]. Mesquite can be controlled with aerial sprays of 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid]; however, many of the understory species are resistant to 2,4,5-T. A mixture of picloram (4-amino-3,5,6-trichloropicolinic acid) and 2,4,5-T will control mesquite and has shown promise for control of some species which are resistant to the phenoxy herbicides (Bovey et al. 1970). Many rangelands cannot be treated with herbicical sprays because of their close proximity to susceptible crops and the danger of injury from drift or transport in runoff and associated sediment.

Methods

The test sites were located in the Alambre Valley on the Papago Indian Reservation and the Santa Rita Experimental Range, both in southern Arizona. The Alambre Valley is in the desert grassland type

The authors are Research Leader, Science and Education Administration, USDA, Tucson, Arizona 85719, U.S.; Associate Professor of Range Management, University of Arizona, Tucson; Research Scientist, Empressa Brasileira de Pesquisa Agropecuaria, Recife, Pernambuco, Brazil; and Plant Physiologist, Science and Education Administration, USDA, Tucson, Arizona.

This paper reports the results of research only. Mention of a pesticide in this paper does not constitute a recommendation by the USDA nor does it imply registration under FIFRA.

which became infested with velvet mesquite. Efforts to control the velvet mesquite with 2,4,5-T and mechanical chaining were relatively successful, but catclaw acacia and wait-a-minutebush were not controlled and subsequent to the control of mesquite, formed dense stands. Small mesquite plants were growing on the site at the time of treatment. The soil was a coarse sandy loam with a pH ranging from 5.1 at the surface to 6.7 at a depth of 38 cm.

A 7.6 m tractor-mounted boom was used to apply broadcast spray treatments in August 1969 to plots 7.6 m by 266 m. The butoxyethanol ester of 2,4,5-T was applied at 1.12 and 2.24 kg ae/ha in diesel oil-water (1:7 v/v) carrier at a total volume of 94 l/ha. A 1:1:1 mixture of the triethanolamine salt of 2,4,5-T, dimethylamine salt of dicamba (3,6-dichloro-*o*-anisic acid), and potassium salt of picloram; a 1:1 mixture of triethylamine salts of picloram and 2,4,5-T; a 1:2 mixture of the triisopropylamine salts of picloram and 2,4-D were applied at 1.12 and 2.24 kg ae/ha rates of total herbicide in water carrier with 0.2% (v/v) blended nonionic surfactant at a total volume of 94 l/ha.

A study was initiated in September 1969 to evaluate granular and pelleted herbicides for their efficacy in controlling velvet mesquite, catclaw acacia, and wait-a-minutebush in the Alambre Valley test site. A 2% granular formulation of the potassium salt of picloram was applied at rates of 1.12, 2.24, and 3.36 kg ae/ha, a 10% pelleted formulation of bromacil (5-bromo-3-*sec*-butyl-6-methyuracil) was applied at rates of 1.12, 2.24, and 4.48 kg ai/ha, and a 10% granular formulation of karbutilate [*tert*-butylcarbamic acid ester with 3(m-hydroxyphenyl)-1,1-dimethylurea] was applied at 4.48 kg ai/ha. All treatments were broadcast by hand.

During 1972 and 1973 we determined the toxicity of karbutilate, picloram, bromacil, and tebuthiuron (*N*- 5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl -N,N'-dimethylurea) to catclaw acacia and wait-a-minutebush when applied during the winter and the beginning of the summer rainy season. The herbicides were applied as broadcast treatments at rates of 1.12 and 5.60 kg ai/ha and as individual plant treatments at rates of 1.5 and 3.0 g ai/plant. Wettable powders were applied as broadcast sprays in water using a hand-3-nozzle boom attached to a 12-liter compressed air sprayer. Total volume applied was 95 l/ha. All of the pelleted and granular herbicides were applied by hand.

A study was initiated on the Santa Rita Experimental Range in May 1974 to evaluate the toxicity of tebuthiuron and karbutilate to creosotebush. Both herbicides were applied at rates of 0.56, 1.12, and 2.24 kg ae/ha to plots 30.4 m square. Tebuthiuron formulations were pellets containing 10, 20, and 40% active ingredient applied at the same equivalent volume to achieve the desired rates. Karbutilate formulations were spheroid "brush balls" containing 25 or 50% active ingredient. The tebuthiuron pellets were applied by hand as broadcast treatments. The karbutilate "brush balls" were applied by hand on 1.8 or 3.6 m grids.

Several experiments on brush control were begun in 1968 in cooperation with the Federal University of Ceara. All of those reported here were carried out at the University's experiment station near Pentecoste. Rainfall at the station averages about 800 mm and the brush is very dense.

Another experiment was started in 1969 to compare results of foliar application of 6 herbicide formulations at 3 rates. The brush was predominantly marmeleiro and jurema preta. Application was made with a hand sprayer running off a PTO pump mounted on a tractor. Herbicides used were potassium salt of picloram (.24 kg ae/l), 2,4,5-T, (.48 kg ae/l), a mixture of the triisopropanolamine salt of picloram (5.7%), 2,4-D (21.2%), and silvex (.48 kg ae/l) all in water except one treatment of 2,4,5-T, which was in 10% diesel oil and 90% water. Total spray solution was 300-400 l/ha.

Due to lack of aerial spray equipment in the region and the impossibility of foliar application on tall, dense brush by hand or motorized spray equipment, another study was started in the dry season of 1968 to evaluate basal-trunk application of herbicides. The study was designed to test several herbicides at various rates and seasons of application.

Results

The ester of 2,4,5-T defoliated all species at both rates but did not give satisfactory control of any (Table 1). Only those herbicides containing picloram killed significant amounts of catclaw acacia and wait-a-minutebush; and only the 1:1 mixture of 2,4,5-T and picloram killed significant numbers of velvet mesquite. Although the ester of 2,4,5-T is generally effective for the control of velvet mesquite, timing the application is critical for optimum effectiveness and the late August treatment date is not the optimum time. The resistance of the other two species to the 2,4,5-T treatments is evident from the data in Table 1 as is their susceptibility to picloram.

Table 1. Percentage of catclaw acacia, wait-a-minutebush, and velvet mesquite plants killed by foliar sprays of four herbicides at two rates on August 22, 1969, in the Alambre Valley, Arizona[1].

Herbicide[2]	Rate[3] (kg ai/ha)	Catclaw acacia	Wait-a-minutebush	Velvet mesquite
Ester of 2,4,5-T	1.12	0	1	5
Ester of 2,4,5-T	2.24	0	7	6
Amine salts of picloram, dicamba and 2,4,5-T	1.12	52	54	0
Amine salts of picloram, dicamba and 2,4,5-T	2.24	85	73	0
Amine salts of picloram, and 2,4,5-T	1.12	59	69	28
Amine salts of picloram and 2,4,5-T	2.24	85	67	15
Amine salts of picloram and 2,4-D	1.12	38	35	0
Amine salts of picloram and 2,4-D	2.24	63	40	0
Species average	—	48	43	7

[1]All treatments evaluated September 30, 1972.
[2]Amine salts applied in water with 0.2% (v/v) nonionic surfactant. Ester of 2,4,5-T was applied in diesel oil-water (1:7 v/v) carrier.
[3]All sprays applied at total volume of 94 l/ha.

Results after 2 years from time of foliar treatment of marmeleiro and jurema preta are shown in Table 2. This study also shows the resistance of these species to the phenoxy herbicides and their susceptibility to picloram. In studies in both southern Arizona and northeastern Brazil, the greater the proportion of picloram in the herbicidal mixture, the more effective was the herbicide in controlling undesirable woody plants.

Table 2. Percentage of woody plants killed two years after foliar treatment with six herbicides at three rates to mixed brush at Fazenda Experimental do Vale do Curu, Ceará[1]. (Araujo, et al. 1971a).

Herbicide[2]	Rates 0.75 kg/ha	1.50 kg/ha	3.00 kg/ha
Ester of 2,4-D	0	0	0
Ester of silvex	0	23	22
Ester of 2,4,5-T	0	33	47
Ester of 2,4,5-T in 10% diesel oil	17	12	50
Triisopropanolamine salt of picloram and 2,4-D	28	60	88
Potassium salt of picloram	57	87	98
Rate average	17	36	51

[1]Woody plants consisted primarily of marmeleiro and jurema preta, with mofumbo present as a minor component. All treatments evaluated 2 years after treatment.
[2]All herbicides applied in water, except as indicated, at total volume of 300-400 l/ha.

Picloram, karbutilate, and bromacil treatments gave good control of catclaw acacia and wait-a-minutebush (Table 3); however, only karbutilate gave significant control of velvet mesquite. This study illustrates the susceptibility of catclaw acacia and wait-a-minutebush to picloram, karbutilate and bromacil applied to the soil and the relatively high resistance of velvet mesquite to all of these herbicides except karbutilate.

Table 3. Percentage of catclaw acacia, wait-a-minutebush, and velvet mesquite plants killed by broadcast application of three soil-applied herbicides on September 1, 1969, in the Alambre Valley, Arizona[1].

Herbicide[2]	Rates (kg ai/ha)	Catclaw acacia	Wait-a-minutebush	Velvet mesquite
Potassium salt of picloram 2% G	1.12	71	54	2
Potassium salt of picloram 2% G	2.24	92	55	11
Potassium salt of picloram 2% G	3.36	89	72	14
Karbutilate 10% G	4.48	100	85	100
Bromacil 10% P	1.12	64	62	0
Bromacil 10% P	2.24	85	44	4
Bromacil 10% P	4.48	100	100	2

[1]All broadcast treatments applied by hand.
[2]G = granular formulation, P = 3.2 mm pelleted formulation.

Results of the basal trunk application of these herbicides are shown in Table 4. Season of application had little effect. Diesel oil alone was fairly effective, especially on jurema preta, and would probably have been better if higher rates had been used. Low concentrations of 2,4,5-T improved the kills on all species. Picloram and the mixture of 2,4-D and picloram were effective only at higher concentrations and gave higher kills on marmeleiro than on jurema preta. Other studies conducted subsequently have shown that the most effective and practical system using liquid herbicides is to clear the brush by hand in the dry season and burn it. The fire will kill some of the plants. The mixture of 2,4-D and picloram is then applied by hand sprayer to individual resprouting clumps or seedlings. This has been fairly effective on jurema preta and more erratically effective on mofumbo. The procedure is less effective on marmeleiro because of the large number of small resprouts and seedlings. The reason for choosing this herbicide mixture and method of control are: The herbicide is readily available commercially, whereas other picloram formulations have not been; picloram is more effective than phenoxy herbicides used alone; herbicides are very expensive in Brazil, but hand labor is cheap, and therefore, considerable hand labor can be invested to reduce the quantity of herbicide needed.

Table 4. Percent mortality one year after basal trunk application of three herbicides at four concentrations and at two dates at Fazenda Experimental do Vale do Curu, Ceara.[1] (Araujo, et al. 1971b).

	Marmeleiro		Jurema preta		All species	
Herbicide and concentration[2]	W	D	W	D	W	D
Diesel oil — check	16	52	73	54	38	44
2,4,5-T ½% in diesel oil	73	99	63	84	80	89
2,4,5-T 1% in diesel oil	86	100	100	70	87	89
2,4,5-T 2% in diesel oil	99	92	84	100	80	87
2,4,5-T 4% in diesel oil	100	100	100	100	93	100
Picloram ¼% in water	0	3	0	0	0	4
Picloram ½% in water	4	33	17	7	13	8
Picloram 1% in water	28	40	22	39	24	21
Picloram 2% in water	63	66	8	15	50	43
2,4-D + picloram 1% in water	2	0	0	0	2	2
2,4-D + picloram 2% in water	0	24	7	0	4	23
2,4-D + picloram 4% in water	11	34	0	5	12	20
2,4-D + picloram 8% in water	75	87	63	42	67	59

[1]W = wet season treatments
D = season treatments
[2]% refers to concentration of commercial formulation in spray solution on volume basis.

Data in Table 5 show that broadcast treatments of tebuthiuron at 1.12 kg/ha killed at least 50% of the catclaw acacia plants at all seasons of application and the 5.6 kg/ha rate killed all plants at both dates of treatment. Wait-a-minutebush was slightly more susceptible to the July application of 1.12 kg of tebuthiuron than was acacia. Picloram granular formulation gave inconsistent results from broadcast application at the 1.12 kg/ha rate but always killed more than 50% of the plants of each species at 5.6 kg/ha. Karbutilate broadcast treatments of both formulations at 5.6 kg/ha generally gave good control of both species. Bromacil killed all plants of catclaw acacia at both rates but was effective against wait-a-minutebush only at the 5.6 kg/ha rate.

Treatments of tebuthiuron, karbutilate, and bromacil applied at rates of 1.5 and 3.0 g/plant killed nearly all plants of both species at all dates of treatment (Table 5). Picloram was highly effective at both rates against catclaw acacia but gave inconsistent control of wait-a-minutebush, especially at the lower rate.

Tebuthiuron was very toxic to both creosotebush and velvet mesquite, killing 77 and 78%, respectively, of the plants of each species at the 0.56 kg/ha rate (Table 6). The higher rates killed nearly all of the creosotebush plants and all of the velvet mesquite. Injury to grass plants was negligible 3 years after treatment except at the 2.24 kg/ha rate where injury to bushmuhly was still evident. Karbutilate was less effective than tebuthiuron for control of creosotebush; however, the 1.12 and 2.24 kg/ha rates both gave satisfactory control of velvet mesquite.

Karbutilate is generally more toxic to velvet mesquite than is tebuthiuron, but in this experiment, karbutilate was applied in a grid pattern whereas tebuthiuron was applied as an overall broadcast treatment. Although both creosotebush and velvet mesquite have extensive root systems, it is possible that uptake of the karbutilate from the "brush balls" placed at discrete intervals across the plots was not as efficient as the uptake of tebuthiuron from pellets distributed uniformly over the plots. Both herbicides caused injury to grasses; however, most of the plants had recovered after 3 rainy seasons.

Discussion

There has been relatively little experience with soil-applied herbicides in northeastern Brazil. Some applications of picloram as the 10% pelleted formulation were made in Brazil in 1969 on uncut stands and resprouts. Initial results appeared to be favorable and there is ample evidence of herbicide effect on trees up to 10 m from the point of application.

Pelleted and granulated formulations of picloram, tebuthiuron, and dicamba are not available in Brazil and are not registered for use on all rangelands in the United States. However, the efficacy of these herbicides in controlling woody species in the southwestern United States, many of them botanically related to woody species in northeastern Brazil, indicates that the herbicides could be used in Brazil for brush control.

The use of soil-applied herbicides should offer many advantages in northeastern Brazil. Spraying would be impractical in many cases due to the proximity of cropland, as is true in many instances in the southwestern United States. Hand spraying of individual plants, whether as basal-trunk applications or foliar applications on resprouts, is very time consuming due to the large number of plants per hectare and the likelihood of missing many plants. In addition, the control of rate and uniformity of application is difficult due to an unskilled, often illiterate, labor force.

Soil-applied herbicides could be broadcast either on standing brush or resprouting cleared areas with little danger of crop damage. It would be easy to instruct laborers how much to apply, thus avoiding such problems as mixing herbicides and clogged nozzles. The biggest advantage is that resprouts missed would ultimately be killed by root uptake.

Aerial application of pelleted herbicides is becoming a practical reality, and for large areas densely infested with unwanted woody plants, application by aircraft is the only practical method of control. On other areas in which the density of infestation is low (less than 125 plants per ha), individual plant treatment is a practical and economical method of control in both countries.

Table 5. Percentage of catclaw acacia and wait-a-minutebush plants killed by four soil-applied herbicides at four dates in the Alambre Valley, Arizona.

		Date of treatment							
		March 22, 1972		July 26, 1972		January 3, 1973		July 9, 1973	
Formulation[1]	Rate[2] (kg/ha)	Catclaw	Wait-a-minute	Catclaw	Wait-a-minute	Catclaw	Wait-a-minute	Catclaw	Wait-a-minute
				Broadcast treatments[3]					
Tebuthiuron 80 WP	1.12	100	10	100	100	50	50		
Tebuthiuron 80 WP	5.60	75	—	100	100	95	100		
Tebuthiuron 10% P	1.12	100	90	50	70				
Tebuthiuron 10% P	5.60	100	100	100	100				
Picloram 2% G	1.12	85	10	0	0				
Picloram 2% G	5.60	100	90	100	50			100	70
Karbutilate 10% P	1.12	60	0	30	20	30	0	20	0
Karbutilate 10% P	5.60	100	95	100	50	80	100	100	100
Karbutilate 50% P	1.12	—	—	20	60	50	60	20	20
Karbutilate 50% P	5.60	—	—	100	100	100	90	85	100
Bromacil 10% P	1.12	100	10	100	0	—	—	—	—
Bromacil 10% P	5.60	100	100	100	100	—	—	—	—
				Individual plant treatments (g/plant)					
Tebuthiuron 10% P	1.5	100	100	100	100				
Tebuthiuron 10% P	3.0	100	100	100	100				
Picloram 2% G	1.5	100	30	100	100	100	0	70	50
Picloram 2% G	3.0	100	100	100	100	100	0	100	85
Karbutilate 10% P	1.5	100	100	100	100	100	100	100	90
Karbutilate 10% P	3.0	100	100	100	100	100	100	100	100
Karbutilate 50% P	1.5	—	—	100	100	100	100	100	100
Karbutilate 50% P	3.0	—	—	100	100	100	100	100	95
Bromacil 10% P	1.5	100	100	100	100	—	—	—	—
Bromacil 10% P	3.0	100	100	100	90				

[1]P = pelleted, G = granular
[2]Rates are based on active ingredient per ha for broadcast treatments and active ingredient per plant with canopy of 1.2 in diameter.
[3]Wettable powders were applied in water as broadcast sprays using compressed air sprayer attached to 3-nozzle boom at a total volume of 94 l/ha. All pelleted and granular formulations were applied by hand.

Table 6. Percentage of creosotebush, velvet mesquite, dropseed, bush-muhly, and plains bristlegrass plants killed on plots treated with tebuthiuron or karbutilate on May 1, 1974, on the Santa Rita Experimental Range, Arizona[1].

Herbicide	Rate (kg/ha)	Creosote-bush	Velvet mesquite	Drop-seed	Bush-muhly	Plains-bristlegrass
Tebuthiuron	0.56	77	78	3	3	7
Tebuthiuron	1.12	97	100	2	7	3
Tebuthiuron	2.24	99	100	3	13	7
Karbutilate	0.56	25	33	0	3	0
Karbutilate	1.12	37	87	3	7	3
Karbutilate	2.24	77	90	3	7	3
Check	0.0	3	8	0	3	0

[1]Evaluated on November 16, 1976.

Literature Cited

Araujo, Filho J. A., E. L. Smith, J. Jackson, and L. Albuquerque. 1971a. Applicacao foliar de herbicidas en plantas lenhosas no estado do Ceara, Brasil. Ciencias Agronomicas 1(2):105-108.

Araujo, Filho J. Ambrosio, J. Jackson, L. Albuquerque, and E. L. Smith. 1971b. Concentracao e epoca de aplicacao basal de herbicidas en plantas lenhosas no estado do Ceara. Paper presented at VIII Reuniao Annual De Sociedade Brasileira de Zootecnia, Rio de Janeiro, July, 1971.

Bovey, R. W., J. R. Baur, and H. L. Morton. 1970. Control of huisache and associated woody species in south Texas. Journal of Range Management 23:47-50.

Fisher, C. E., C. H. Meadors, R. Behrens, E. D. Robison, P. T. Marion, and H. L. Morton. 1959. Control of mesquite on grazing lands. Texas Agricultural Experiment Station Bulletin 935, 24 pp.

Glendening, G. E., and H. A. Paulsen Jr. 1955. Reproduction and establishment of velvet mesquite as related to invasion of semidesert grasslands. U.S. Department of Agriculture Forest Service Technical Bulletin No. 1127. 50 pp.

Hastings, J. R., and R. M. Turner. 1965. The changing mile. Tucson. University of Arizona Press.

Hull, H. M., S. J. Shellhorn, and R. E. Saunier. 1971. Variations in creosotebush (*Larrea divaricata*) epidermis. Journal of the Academy of Science 6:196-205.

Martin, S. C., and D. R. Cable. 1974. Managing semidesert grass-shrub ranges. Vegetation responses to precipitation, grazing, soil texture, and mesquite control. U.S. Department of Agriculture Forest Service Technical Bulletin No. 1480. 45 pp.