Response to Tebuthiuron by Utah Juniper and Mountain Big Sagebrush Communities

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Abstract

The herbicide tebuthiuron was applied aerially in replicated parallel strips at rates of 0, 1.3, 2.0, and 2.7 kg/ha a.i. (active ingredient) in 40% pellets on a Utah juniper stand, and at rates of 0, 0.6, 1.0, and 1.3 kg/ha a.i. in 10% pellets on a mountain big sagebrush stand. Crown kill on Utah juniper was nearly 100% at application rates of 2.0 kg/ha or greater. Control of mountain big sagebrush was obtained at rates of 0.6 kg/ha and above. Antelope bitterbrush, hairy low rabbitbrush, and gray horsebrush responded to the herbicide similarly to Utah juniper. Rubber rabbitbrush was not controlled by tebuthiuron. Total understory production had changed little 3 years after application, although compensating decreases in production of perennial plants and increases in production of annual grasses occurred.

Seldom does rangeland offer an array of plants that is ideal for a particular purpose (Stoddart et al. 1975). The species mixes are often changing as part of successional trends and such changes are often not in the direction that the land user desires. In pinyon-juniper and sagebrush ecosystems, the trend is often an increase in woody plants at the expense of herbaceous plants useable as ruminant forage. Such a trend may occur as a result of some action by man or his grazing animals or may be part of a normal progression toward a climatic climax. If a rangeland is to be held at a particular stage, periodic manipulation of vegetation may be required to reset the successional clock.

Tebuthiuron (N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea) has shown promise for controlling many woody plants. South Texas mixed brush (Scifres et al. 1979), blackjack oak (*Quercus marilandica* Muenchh.) and winged elm (*Ulmus alata* Michx.) (Shroyer et al. 1979), sand shinnery oak (*Quercus havardii* Rydb.) (Pettit 1979), and various other hardwood species (Nolte et al. 1982) have been successfully controlled by tebuthiuron. Control of woody overstory species often has resulted in substantial increases in forage plants about 2 years after application of tebuthiuron (Scifres and Mutz 1978, Scifres et al. 1981b, Jones and Pettit 1982). Generally, the junipers have been unresponsive to tebuthiuron. Negative results have been reported on western juniper (*Juniperus occidentalis* Hook.) (Britton and Sneva 1981), eastern red cedar (*J. virginiana* L.) (Scifres et al. 1981a), and redberry juniper (*J. pinchotii* Sudw.) (Ueckert and Whisenant 1982). However, tebuthiuron has been shown to be effective in controlling Utah juniper (*J. osteosperma* (Torr.) Little) at rates of 2.2-4.5 kg/ha (Johnsen 1977, 1979). Sand sagebrush (*Artemisia filifolia* Torr.) has been effectively controlled (Jones and Pettit 1982). Control of big sagebrush has been obtained at rates of 1.1 to 2.2 kg/ha (Britton and Sneva 1983, Klauzer and Arnold 1975). Cool-season herbaceous plants typical of the Intermountain region appear to be sensitive to tebuthiuron and may be strongly repressed by rates of 2 kg/ha (Britton and Sneva 1981, 1983).

The pinyon-juniper zone, dominated by Utah juniper, and the sagebrush zone, dominated by big sagebrush (*Artemisia tridentata* Nutt.), are major plant types in the Intermountain region. Combined, they occupy 34% and 45% of Utah and Nevada, respectively (USDA Forest Service 1972). These plant types, whose historic use has been dominated by the grazing of livestock, have experienced increases in amounts of woody plants and diminished amounts of herbaceous forage plants. In an effort to reverse this trend, managers have tried fire, mechanical, chemical, and biological means to manipulate vegetation.

The objectives of this study were to determine the effectiveness of tebuthiuron in controlling woody plants on Utah juniper and mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana* (Rydb.) Beetle) dominated sites and evaluate response of herbaceous species.

Methods

The test sites were located in the northeastern portion of Millard County, Utah, on the Fishlake National Forest. Annual precipitation on the study area was estimated to average 36 cm. Precipitation falls predominantly in the cool portion of the year. The months of June through September each average less than 2.5 cm of rainfall. Weather records from nearby communities of Oak City and Scipio show that the 3 years after herbicide application (fall 1979) were wetter than usual. Water year 1980 (Oct.-Sept.) was 54% above the long-term mean, 1981 was 1% above the mean, and 1982 was 62% above the mean.

Surface soils were gravelly sandy loams to cobbly silt loams. Profile depths often approach 150 cm. The soils have developed on alluvium from the south end of the Canyon Mountains. Quartzite and some limestone were the parent rocks.

The juniper stands were dense with relatively little understory vegetation. The sagebrush area had been cabled and seeded approximately 25 years before the herbicide application, and it supported a good stand of Fairway wheatgrass (*Agropyron cristatum* (L.) Gaertn.) within the sagebrush community.

Tebuthiuron pellets were applied aerially in parallel strips 51 m wide and 0.4 km (sagebrush area) or 0.8 km (juniper area) long in October 1979. Buffer zones 30 m wide were located between the test strips. Application rates of 40% pellets on the juniper area were 0, 1.3, 2.0, and 2.7 kg/ha a.i. (active ingredient), each replicated twice for a total of eight strips. Application rates of 10% pellets on the sagebrush area were 0, 0.6, 1.0, and 1.3 kg/ha a.i., each replicated 3 times for a total of 12 strips. A randomized block experimental design was used for both areas.

Each juniper strip was sampled by 30 sets of nested temporary plots. A set consisted of 3 concentric circular plots—a 250-m^2 plot for sampling tree kill, a 100-m^2 plot for sampling shrub kill, and a 0.9-m^2 plot for sampling herbaceous vegetation and shrub leaf and twig production. Species, height class, and percent crown kill were recorded for individual trees, while only species and crown kill were recorded for individual shrubs. Established shrubs and shrub

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seedlings were recorded separately. Herbage production was determined by estimating wet weight. Herbage on every fifth plot was clipped, ovendried, and weighed as a basis for calculating dry weight from wet weight. The herbicide application strips in the juniper area (0.8 km long) crossed several sequences of ridge-drainage topography. This provided the opportunity to evaluate the relation of topographic position to herbicide effectiveness. Each plot was classified as a ridge, a slope, or a drainage bottom. The number of plots were 100, 98, and 42, respectively. An analysis of variance with non-additivity was conducted to determine if a herbicide rate-slope position interaction existed.

Each sagebrush strip was sampled with 2 clusters of four 10-m^2 permanent plots. Individual shrubs were evaluated for crown kill, distinguishing between seedlings and mature plants. Herbage production was determined on 0.9-m^2 plots centered within each of the 10-m^2 plots. No distinction of topographic position was made because the sagebrush treatment areas were primarily in shallow drainage bottoms.

Vegetation evaluations on both sites were conducted in the growing seasons of 1980, 1981, and 1982. In 1982, evaluation of crown kill on woody species other than sagebrush was expanded to include individual plants occurring throughout the entire strips. These were used to augment the number of treated plants used as a basis to graph response curves. All observations and measurements were completed by midsummer each year.

Results

Control of Woody Species

Juniper

Utah juniper responded rather slowly to tebuthiuron. Few symptoms were visible early in the first growing season; however, by midsummer the average percent of crown kill had exceeded 50% under the heavy rate (Table 1). By the second growing season, the proportion of dead crowns had nearly doubled. Crown mortality of Utah juniper continued into the third growing season. The application rates of 2.0 and 2.7 kg/ha achieved almost total control of Utah juniper, while the 1.3 kg/ha rate resulted in 80% crown control.

Table 1. Percent Utah juniper crown kill by tebuthiuron.

Year	Kg/ha active ingredient			
	0	1.3	2.0	2.7
1980	0^{a1}	39.0^{b}	41.2^{b}	52.5^{c}
1981	0^{a}	62.2^{b}	73.6^{c}	91.3^{d}
1982	0^{a}	80.1^{b}	97.7^{c}	99.1^{c}

[1]Values not followed by similar letters in the same row are significantly different at $P<0.05$.

A highly significant interaction ($P<0.01$) occurred between application rate and topographic position (Fig. 1). At the 1.3 kg/ha application rate crown kill was considerably greater on ridge tops than in drainage bottoms. Apparently, the more highly developed soils in lower slope positions have a greater ability to adsorb the active ingredient and therefore to reduce its effectiveness (Chang and Stritzke 1977).

A possible trend of reduced crown kill was noted in Utah juniper trees of less than 0.5 m in height, as compared to all other tree height categories (up to 4.5 m). Even though the highest application rate in the sagebrush area was similar to the lowest rate in the juniper areas, this apparent effect of less mortality in small trees did not occur in the sagebrush area. A contributing factor to this difference was that the juniper area was treated with 40% a.i. pellets while the sagebrush area was treated with 10% a.i. pellets. Ten percent pellets were applied at 4 times the number of pellets per unit area to achieve the same herbicide rate as 40% pellets. Very small trees with their smaller root systems would have less chance of encountering soil herbicide where fewer pellets of higher concentration were applied.

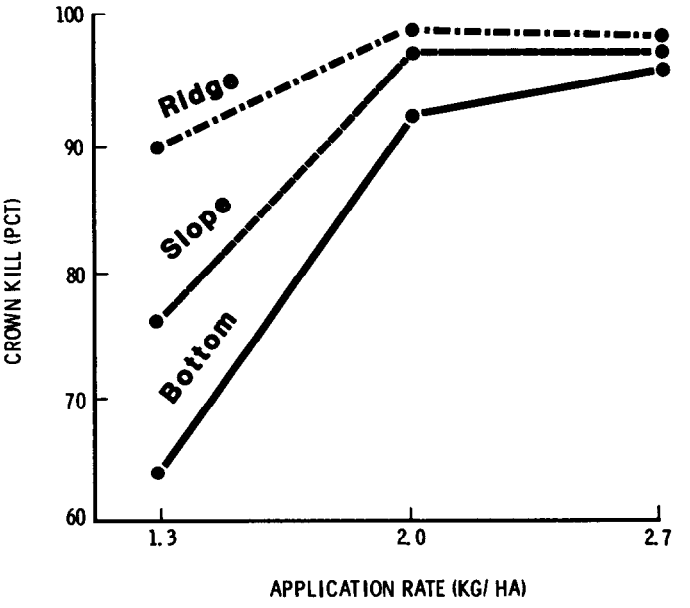

Fig. 1. *Interaction of tebuthiuron application rate and slope position on 1982 Utah juniper crown kill.*

Sagebrush

Mountain big sagebrush responded relatively quickly to tebuthiuron. The symptoms were evident early in the first growing season. Up to 79% of the sagebrush crown volume was damaged midway through the summer (Table 2). Crown mortality continued through the third growing season. A high proportion of control was obtained at the 0.6 kg/ha rate (~80%) and nearly complete control of the original sagebrush plants occurred at the 1.3 kg/ha rate (~93%). Sagebrush seedlings appeared to be less affected than established plants; perhaps their smaller root systems were less likely to encounter the soil herbicide. The average number of seedlings per 10-m^2 plot in the third growing season was:

Table 2. Percent mountain big sagebrush crown kill by tebuthiuron.

Year	Kg/ha active ingredient			
	0	0.6	1.0	1.3
1980	0^{a1}	59.5^{b}	64.4^{bc}	79.4^{c}
1981	0^{a}	75.2^{b}	84.0^{bc}	92.3^{c}
1982	0^{a}	79.9^{b}	91.2^{b}	92.6^{b}

[1]Values not followed by similar letters in the same row are significantly different at $P<0.05$.

Tebuthiuron rate	No. seedlings/ 10-m^2
0	1.3
0.6	1.3
1.0	1.0
1.3	0.6

Combined data 1982:

Several species of woody plants occurred in both the juniper and sagebrush treatment areas. This provided an opportunity to graphically evaluate the control success for these species across the entire range of application rates for the 2 areas by combining all available data. The additional survey of the entire sagebrush strips in 1982 facilitated these comparisons by increasing the number of plants evaluated for crown kill.

The amount of Utah juniper crown kill increased in a nearly linear fashion with increasing rates of tebuthiuron up to 2.0 kg/ha, reaching nearly 100% control (Fig. 2). This result is quite different from that reported for several other *Juniperus* spp. (Britton and

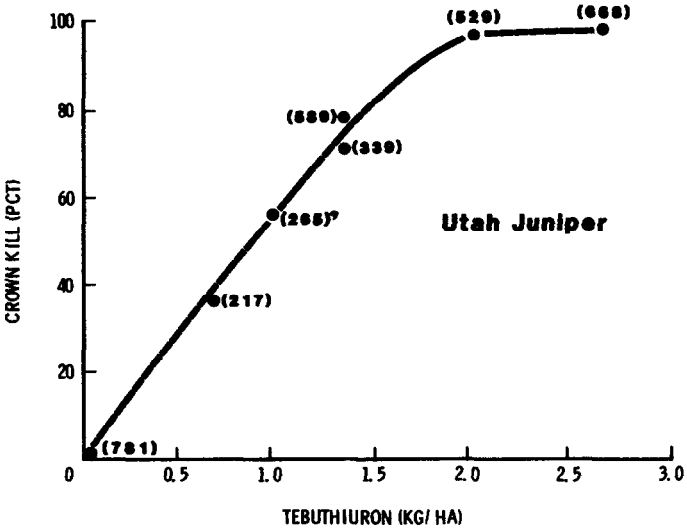

Fig. 2. *Response of Utah juniper in 1982 to tebuthiuron application rates. Numbers in parentheses indicate number of trees evaluated.*

Sneva 1981, Scifres et al. 1981a, Ueckert and Whisenant 1982), but roughly similar to that reported for Utah juniper in Arizona (Johnsen 1979).

Mountain big sagebrush was more easily controlled by tebuthiuron than Utah juniper; control occurred at application rates of about one-half that required for Utah juniper (Fig. 3). Similar rates

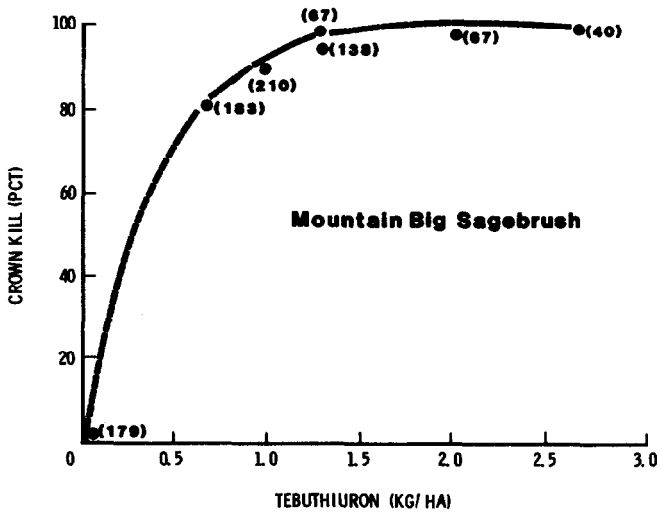

Fig. 3. *Response of mountain big sagebrush in 1982 to tebuthiuron application rates. Numbers in parentheses indicate number of plants evaluated.*

of big sagebrush mortality were reported by Britton and Sneva (1983) and Klauzer and Arnold (1975). Sand sagebrush has been successfully controlled at rates of 0.4 kg/ha (Jones and Pettit 1982).

Crown mortality of antelope bitterbrush (*Purshia tridentata* (Pursh) DC.) at varying rates of herbicide was similar to Utah juniper (Fig. 4). Comparison of Figures 3 and 4 suggests that most antelope bitterbrush (a browse species usually desired by land managers) could be retained while most big sagebrush could be removed if rates of 0.5–0.6 kg/ha of tebuthiuron were applied. Such a manipulation of shrub composition may be a management goal on sagebrush-dominated range, particularly if the sagebrush is a subspecies or accession of low palatability (Welch et al. 1981). Others have reported similar possibilities of herbicide applications to manipulate compositions of Intermountain shrub ranges (Blaisdell and Mueggler 1956).

Rubber rabbitbrush (*Chrysothamnus nauseosus* (Pall.) Britt.), a

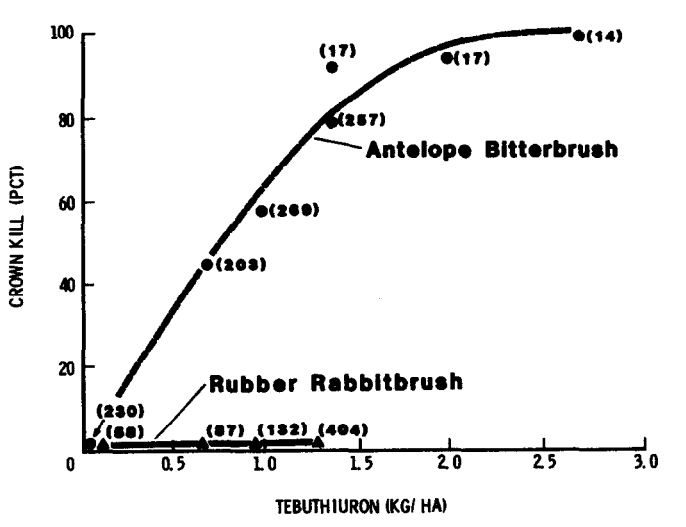

Fig. 4. *Response of antelope bitterbrush and rubber rabbitbrush in 1982 to tebuthiuron application rates. Numbers in parentheses indicate number of plants evaluated.*

species often difficult to control with herbicides (Stoddart et al. 1975), was not controlled by tebuthiuron at rates up to 1.3 kg/ha (Fig. 4). The few plants present on the highest rate juniper strip were dead, suggesting that rates above 2 kg/ha may have some success in controlling rubber rabbitbrush. However, too few plants were encountered to provide a reliable basis for conclusion.

Two other woody species occurred in the sagebrush strips in sufficient numbers to be evaluated (average >50 plants per species per treatment). Hairy low rabbitbrush (*Chrysothamnus viscidiflorus* ssp. *puberulus* (D.C. Eat.) H.M. Hall and C. Rem.) and gray horsebrush (*Tetradymia canescens* DC.) were successfully controlled by 1.3 kg/ha of tebuthiuron (Fig. 5). Britton and Sneva

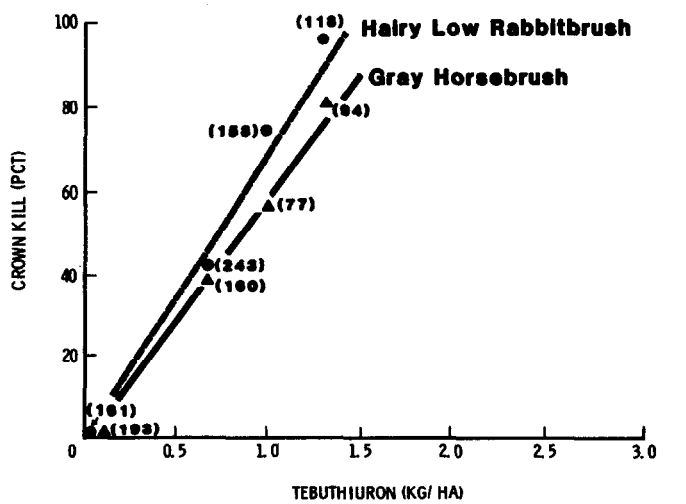

Fig. 5. *Response of hairy low rabbitbrush and gray horsebrush in 1982 to tebuthiuron application rates. Numbers in parentheses indicate number of plants evaluated.*

(1981) also found *C. viscidiflorus* (Hook.) Nutt. to be controlled by tebuthiuron.

Response of Understory Species

Juniper area

Total yield of understory plants was depressed in 1980 and 1981 by application rates of 2.0 and 2.7 kg/ha (Table 3). By 1982, the third growing season after treatment, total production in all treatment strips was similar to the control strips. Understory vegetation usually increases significantly by the second year after control of

Table 3. Production (oven-dry weight) by plant group for the Utah Juniper tebuthiuron treatment area.

Plant group	Year	Tebuthiuron application rate Kg/ha active ingredient 0	1.3	2.0	2.7
Annual grasses	1980	37a[1]	25b	11c	12c
	1981	11a	49b	8a	6a
	1982	68a	153b	139b	151b
Perennial grasses	1980	48a	88b	44a	43a
	1981	27a	7b	5b	2b
	1982	51a	28b	12b	16b
Forbs	1980	8a	3b	2b	2b
	1981	3a	0b	0b	0b
	1982	29a	4b	4b	3b
Shrubs	1980	9a	11a	2a	5a
	1981	6a	0b	0b	0b
	1982	40a	4b	1b	3b
Total	1980	102a	127a	59b	62b
	1981	47a	56a	13b	8b
	1982	188a	189a	156a	173a

[1]Values not followed by similar letters in the same row are significantly different at $P<0.05$.

Utah juniper (Clary et al. 1974, and data on file at the Shrub Sciences Laboratory, Provo, Utah 84601). Since total understory production had not responded by the third growing season, the release from Utah juniper overstory dominance was apparently still counteracted by the phytotoxic effects of the herbicide.

Broad composition shifts, as measured by production, did occur as a result of tebuthiuron application (Table 3). Annual grasses initially declined, then increased by 1982 in relation to the control strips. Perennial grasses in the treated strips were lower than the controls in 1981 and 1982. Herbicide application reduced forbs each year, and reduced shrubs in 1981 and 1982.

Approximately 60 plant species were present, but most produced little more than trace amounts of production. The largest decrease in production of an individual species following herbicide application occurred in bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. and Sm.) and largest increase was in cheatgrass brome (*Bromus tectorum* L.) (Table 4).

Sagebrush Area

Total production of herbage (including leaf and twig growth on shrubs) on the treated strips was not significantly different ($P>0.05$) from the control strip in the third growing season after sagebrush control (Table 5). There appeared to be some increase in annual grasses in the herbicide treated area such as occurred in the juniper area, but the trend was not significant ($P>0.05$). The most prominent change was a reduction of shrubs. Although a large reduction in mountain big sagebrush occurred, other shrubs such as broom snakeweed, rubber rabbitbrush, and antelope bitterbrush were more resistant to the effects of the herbicide. Fairway wheatgrass, which was present in the sagebrush area before herbicide application, was initially depressed by tebuthiuron (Table 4). By the third year Fairway wheatgrass had recovered, and the 0.6 kg/ha rate plots appeared to be moving ahead of the control plots in production although this apparent developing trend was not as yet significant ($P>0.05$). Most other individual plant species were present in such low amounts that meaningful evaluations of their response could not be made.

Table 4. Production (oven-dry weight) of the most abundant species in the juniper and sagebrush areas.

Species	Year	Utah juniper area—tebuthiuron (kg/ha) 0	1.3	2.0	2.7
Bluebunch wheatgrass	1980	42a[1]	75b	33a	31a
	1981	27a	2b	2b	2b
	1982	25a	20b	4c	4c
Cheatgrass brome	1980	36a	23b	11a	11a
	1981	11a	49b	8a	6a
	1982	65a	152b	136b	150b
		Big sagebrush area—tebuthiuron (kg/ha) 0	0.6	1.0	1.3
Fairway wheatgrass	1980	321a	205b	197b	109b
	1981	319a	352a	234a	160a
	1982	622a	948a	773a	628a

[1]Values not followed by similar letters in the same row are significantly different at $P<0.05$.

Table 5. Production (oven-dry weight) by plant group for the mountain big sagebrush tebuthiuron treatment area.

Plant group	Year	Tebuthiuron application rate Kg/ha active ingredient 0	0.6	1.0	1.3
Annual grasses	1980	7a[1]	4a	8a	1a
	1981	50a	31a	20a	34a
	1982	69a	149a	254a	143a
Perennial grasses	1980	361a	219ab	249ab	151b
	1981	347a	420a	359a	230a
	1982	768a	993a	881a	704a
Forbs	1980	1a	5a	10a	4a
	1981	0a	1a	0a	0a
	1982	68a	38a	55a	31a
Shrubs	1980	—	—	—	—
	1981	252a	46b	48b	13b
	1982	274a	3b	74b	47b
Total	1980	—	—	—	—
	1981	649a	498a	427a	277a
	1982	1179a	1213a	1264a	925a

[1]Values not followed by similar letters in the same row are significantly different at $P<0.05$.

Cattle grazing also may have affected the response of herbaceous vegetation following herbicide application. Late in the growing season of 1980 and 1981, cattle on the local forest grazing allotment were moved into the general area of this study. The cattle were strongly attracted to the vegetation in the tebuthiuron application strips and made extremely heavy use of the Fairway wheatgrass in these strips, while only moderately grazing surrounding wheatgrass. In 1981, a single-wire electric fence was constructed to protect the strips; however, the cattle quickly pushed through the fence to graze the herbicide-stressed forage. Scifres et al. (1983) found a similar attraction to cattle of tebuthiuron-affected forage, but the effect lasted only 1 year in their study. Crude protein appears to be increased in the affected forages, which probably accounts for some of the attraction to cattle (Masters and Scifres 1981).

Summary

Tebuthiuron effectively controlled the target species Utah juniper and mountain big sagebrush. Crown mortality continued to increase through the third growing season.

Antelope bitterbrush, hairy low rabbitbrush, and gray horsebrush were controlled at similar application rates as for Utah juniper. Control of mountain big sagebrush required approximately one-half the application rate as did the other major woody species on the study sites.

The application of tebuthiuron at rates of 0.6 kg/ha a.i. and higher decreased production of most shrub species. Application rates of 1.3 kg/ha and higher changed the herbaceous composition in the direction of fewer perennials and more annuals. On both the

Utah juniper and mountain big sagebrush study areas the total understory production in the treated strips had not significantly increased beyond the control strips after 3 growing seasons.

The heavy grazing use of herbicide-stressed Fairway wheatgrass points up the need to protect tebuthiuron-treated areas from grazing for 1 or more years if residual forage plants are to have an opportunity to respond.

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