Effects of manual application method on application time, thoroughness, and tebuthiuron outlays

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Abstract

Small-plot trials of effective herbicides for manual woody-weed treatments should be validated on large tracts where rapidity, thoroughness, and efficiency of application are integral to operational-scale recommendations. A 7.9 hectare woodland chaining in Utah, with 248 *Juniperus osteosperma* Torr. (Little) and *Pinus monophylla* Torr. & Frem. saplings per ha, was divided into nine 25-m by 350-m strips for timed tebuthiuron (*N*-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N,N'*-dimethylurea) manual application trials in fall 1986 and summer 1987. About 1 ha was treated per hour, and 6 to 15% of the trees were missed. Three application methods differed in total and aggregate time outlays, accuracy, and tediousness, but were highly similar in formulated tebuthiuron expenditures of 1.5 to 2.0 kg/ha (0.21 to 0.28 kg/ha tebuthiuron a.i.). Time expenditures were moderately predictable (r^2 = 0.62) from treated tree density and mean tree height, whereas percent trees missed was unrelated to density or method. Placing herbicide particles at the stem base and basing dosages on stem height are preferable to dripline applications and crown-volume based dosage estimations.

Key Words: *Juniperus osteosperma, Pinus monophylla,* range improvement planning, brush removal, woody weed control

Large areas of western U.S. rangeland support woody vegetation that hinders forage production or livestock management. Thousands of hectares have been manually treated with individual-plant herbicide methods (Johnsen and Dalen 1984). Research on herbicide formulations, dosage rates, and manual placement is usually conducted on small plots, resulting in substantial time devoted to each target plant relative to its size. Treatments on larger, more heterogeneous areas minimize time spent in travel and at each target plant. Plot-based recommendations to brushland managers need validation on large areas, where rapidity, thoroughness, and efficiency of treatments are crucial to treatment and enterprise success. Mediocre control or ambiguous outcomes are often due to application shortfalls, rather than to ineffective herbicide formulations (Johnsen and Dalen 1984, Ueckert and Whisenant 1982). Thoroughness is closely tied to the need for repeated attention ('reweeding') and reinvestment.

Previous studies have used hired labor. Fitness, training, motivation, and supervision must affect outlays, thoroughness, efficiency, and consistency, but these factors are rarely controlled experimentally. In extreme cases, shirking means that practically no control results from some of the man-hours nominally invested (Johnsen and Dalen 1984). When ranchers or others with an economic stake in the results have treated brush or trees on foot or horseback, outcomes are more favorable and less ambiguous (Evans and Young 1986).

Our study objectives were: (1) to develop preliminary estimates of the labor time and herbicide quantities required to treat a representative tract of tree-dotted Intermountain rangeland; (2) to test time and quantity differences among 3 effective application methods; and (3) to assess thoroughness of first-time treatments, as percent trees left untreated. The research goal was to improve tactical planning for tree reduction and forage rejuvenation (Scifres 1987).

Study Area and Methods

A 7.9 ha (19.4 ac) rectangular plot was established on a west-facing bajada of the East Tintic Mountains, 58 km (32 mi) SW of Provo, Utah. The privately owned site, known as the Jordan macroplot, lies on a gentle, almost planar slope at about 1,858 m (6,100 ft) elevation. The soil is Borvant gravelly loam, classified as a fine-loamy, mixed, mesic shallow Aridic Calcic Palexeroll. The mountain front was double-chained in 1964, but tree control was poor. Major plant species present were *Juniperus osteosperma* (Torr.) Little (Utah juniper), *Pinus monophylla* Torr. & Frem. (singleleaf pinyon), *Artemisia tridentata* spp. *tridentata* Nutt. (basin big sagebrush), *Purshia tridentata* (Pursh) DC. (antelope bitterbrush), and *Tetradymia canescens* DC. (spiny horsebrush) (Welsh et al. 1987).

Nine 25-m by 350-m strips, similar to those used in aerial applications, were demarcated, running downhill. Strips were temporarily outlined with mason's line and removable posts. All trees were then tallied by species. The height in decimeters (dm) of every other tree was measured. Tree stem aggregation for the whole plot was quantified using the Pielou index (Goodall and West 1979), based on a stratified-random sample of 210 tree coordinates. Tree, understory vegetation, and soil surface cover were estimated from fifty 40-m line intercepts randomly established and oriented throughout the macroplot (Canfield 1941).

Equally effective treatment methods (rate and placement choices) were derived from results of nearby tebuthiuron (*N*-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N,N'*-dimethylurea) research (Van Pelt and West 1989). Method 1 consisted of applying one Graslan™ Brush Bullet (1.8 g clay briquettes; .25 g tebuthiuron a.i.) per 3 dm (1 ft) of total tree height to the stem base. In Method 2, one briquette per 3 dm height was also used, but briquettes were placed at equal intervals at the crown margin or "dripline". Method 3 used the same placement as Method 2, but with one briquette per 100 dm^3 estimated crown volume. Each method was randomly assigned to 3 strips. Timed tebuthiuron application trials were conducted on 10 and 11 Oct. 1986, and repeated on 29 and 30 July 1987. Ambient temperatures were 0 to 2° C (32 to 36° F) in 1986, and 25 to 32° C (78 t 89° F) in 1987. The applicator traversed the length of a strip top to bottom, using one of the methods for all trees encountered therein. Briquettes were dispensed from a tree-planter's belt bag containing 2.0 kg (4.4 lb) of Graslan (1986) or a placebo (1987). Each strip was only treated once with tebuthiuron, and no strip was given a particular minimum, ideal, or maximum total dosage. The applicator maintained a brisk pace, with primarily diagonal and lateral movement between single trees or clumps. Some backtracking occurred, but no "hunting" of trees within or

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just off the strip was permitted. All treated trees were marked with spray paint. Time elapsed was recorded after the applicator had traveled midway into the strip and after completion of the strip. After all strips had been treated, missed trees (unmarked) were tallied on both occasions by species and size (seedling or sapling) while the applicator slowly walked uphill through each strip. Thoroughness was expressed as percent of trees missed by method and strip or half-strip.

After the number of treated trees per sector was determined, times elapsed were calculated and expressed as total time for all sectors and strips allocated to each method, and as average time per area by method. An identical procedure was followed for herbicide outlays in 1986. Supplemental data were obtained on time spent treating and traveling between individual trees with Methods 1 and 2 (n=100).

To assess differences between prescribed and actual dosages applied to trees treated with Method 3, 35 trees of all sizes were relocated and the briquettes beneath them were counted. Crown volume of each tree was estimated from crown height and the average of 2 perpendicular crown width measurements (Tausch 1980). The median amount that should have been applied (one briquette per 100 dm^3) to each tree was compared with the actual median amount using the two-sample rank sum test at $p = 0.05$ (Steel and Torrie 1980). Either or both the 1986 and 1987 treatment occasions and all macroplot strips were used in 5 linear and nonlinear multiple regressions of time spent against tree density and estimated mean tree height (SAS Institute, Inc. 1982).

Results

The 9 strips allocated to herbicide treatments contained a total of 1,960 trees (1,307 juniper, 653 pinyon), with from 161 to 280 trees per 25- by 350-m strip. The macroplot supported 165.4 juniper per ha (67.4/ac) and 82.7 pinyon per ha (33.6/ac), for an overall density of 248.1 trees/ha (101.0/ac). Live tree cover was estimated as 3.3% (Table 1). Trees allocated to Method 1 (stem base/scaled to height) had a mean height of 18.7 dm (CV = 38.4%; n = 315), trees allocated to Method 2 (dripline/scaled to height) averaged 17.5 dm (CV = 41.5%; n = 304); whereas trees for Method 3 (dripline/scaled to crown volume) had a mean height of 17.9 dm (CV = 44.7%, N = 298). These means were not significantly different (p>0.05). The height distributions of the populations for each method were similar (Fig. 1). The macroplot dispersion index (1.01) for the species combined was not significantly (p>0.05) different from random.

Table 1. Cover estimates obtained from 50 40-meter line intercepts within the entire macroplot.

Estimated cover parameter	Mean (1 SE)
	(%)
Bare ground	25.6 (1.3)
Plant litter	22.2 (1.3)
Grass crowns	12.5 (1.1)
Big sagebrush	13.0 (0.8)
Bitterbrush	16.7 (1.4)
Spiny horsebrush	0.4 (0.1)
Live Utah juniper	2.1 (0.4)
Live singleleaf pinyon	1.2 (0.3)
Other plant species	1.9 (0.3)
Tree debris	3.9 (0.5)

The cover of big sagebrush and antelope bitterbrush plants was uniform (Table 1). Maximum heights of these shrubs were about 1.2 m (x = 0.7 m) and 1.1 m (x = 0.8), respectively. These and other understory species and debris made foot travel somewhat indirect.

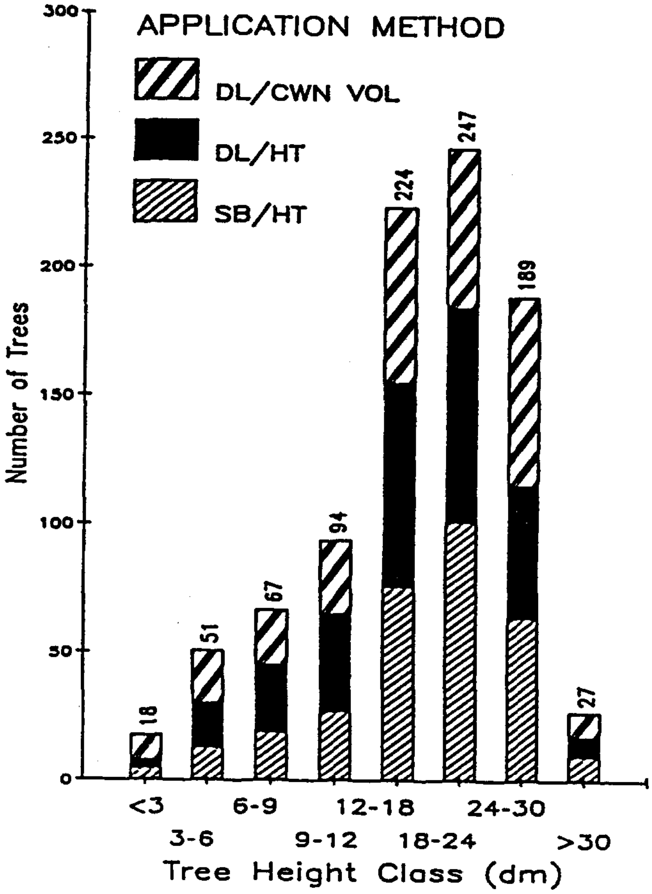

Fig. 1. The estimated height structure of the sapling stand in the Jordan macroplot, showing the contributions of trees assigned to each of the 3 application methods (DL = dripline; HT = height; SB = stem base). Top of bars, Method 3; middle, Method 2; bottom, Method 1.

The times required to work through 9 strips were 8 hours, 7 min in Oct. 1986 and 8 hours, 49 min in July 1987. Numbers of trees treated and times spent per strip and sector were variable (Table 2). The number of trees treated differed little among methods, and the differences within a method between the 2 occasions were slight (Table 3). Differences between methods in time expenditures were small and mostly not significant (p>0.05). Similar amounts of herbicide were used in all methods, but appeared to be slightly greater for the methods 2 and 3, which utilized the dripline placement (Table 3). In all methods, from 0.21 to 0.28 kg/ha (0.18 to 0.25 lb/ac) of active ingredient was expended, corresponding to 1.5 to 2.0 kg/ha (1.3 to 1.8 lb/ac) of formulated tebuthiuron. The trees missed were usually seedlings and small saplings with crowns that did not extend above shrubs (Table 2). Those and larger trees missed were mostly at the sides of the strips. No species bias was evident. The methods were indistinguishable in thoroughness, and percent missed was unrelated to density (Table 2).

In the supplemental individual-tree applications, Method 2 was slightly but not significantly (p>0.05) more time-consuming than Method 1 (8.2 sec vs. 7.1 sec; CV = 38.7 and 44.0%, respectively). This difference was very similar to that revealed by the main timed trials (Table 3). Using Method 1, about 54% of the applicator's time was spent in treating and painting the trees, whereas about 46% was consumed in inter-tree travel.

Relocating briquettes beneath trees treated with Method 3 showed that applicator-in-motion estimates of tree volume resulted in severe underestimates of the briquettes to apply, particularly for

Table 2. Trees treated and missed, the incidence of missed trees, and time expenditures by application method and strip sector. October 1986 occasion. Means and times rounded to the nearest integer. One SE in parentheses.

Sector and strip	Trees treated	Number missed	Percent missed	Total time used (min)
Method 1				
Strip A				
upper	102	12	10.5	27
lower	65	9	12.1	12
Strip C				
upper	96	6	5.8	23
lower	73	8	9.9	21
Strip G				
upper	118	16	11.9	31
lower	114	20	14.9	24
Total, all sectors	568	71	——	138
Mean, all sectors	95 (8.8)	12(2.2)	11.1(1.2)	23(2.6)
Method 2				
Strip D				
upper	61	7	10.3	21
lower	83	10	10.7	21
Strip F				
upper	75	9	10.7	22
lower	132	15	10.1	29
Strip H				
upper	124	14	10.1	35
lower	119	14	10.3	38
Total, all sectors	594	69	——	166
Mean, all sectors	99(12.1)	11(1.3)	10.4(0.1)	28(3.0)
Method 3				
Strip B				
upper	73	9	10.9	28
lower	69	13	15.8	238
Strip E				
upper	76	9	10.5	20
lower	111	18	13.9	25
Strip I				
upper	125	11	8.0	39
lower	131	13	9.0	48
Total, all sectors	585	73	—	183
Mean, all sectors	98(11.5)	12(1.4)	11.0(1.2)	30(4.4)
Grand total	1747	213	——	487
Grand mean	97(5.9)	12(0.9)	10.9(0.5)	27(2.0)

larger trees. The amounts put out in Method 3 were not significantly different ($p>0.05$) from the amount prescribed by height (Methods 1 and 2). These results agree with the finding of no differences in herbicide quantities (Table 3) among methods despite contrasting tree-dimension "cues".

The correlation between treated-tree density and time spent was significant ($r = 0.56$ to 0.62; $p < 0.05$; n = 18 to 36). A log e transformation of tree density did not improve the equations' predictive value, nor did mean tree height. The resultant multiple regression equations tended to overpredict time outlays in sparse sectors, and both over- and underpredicted times for the most dense sectors. Mean time per tree appeared to decrease with increasing density because less travel time was needed between application motions.

Discussion and Conclusions

The study site was not easy to traverse, and contained many tall saplings. Nonetheless, all strips were readily treated, about 10% of the trees were consistently missed, and overall cool and warm season time outlays only differed by 9%. About 1 hectare could be treated per hour. Tebuthiuron outlays were conservative for all 3 methods and did not vary significantly among them (Table 3). The amounts would have been smaller had the stand not been dominated by trees 1.5–2.7 dm (5 to 9 ft) tall. Most Intermountain and southwestern chainings are occupied by shorter trees (Dalen and Snyder 1987).

Excluding marker setup time, the macroplot could have been treated by 1 person in an arduous day, or by 2 persons in about 5 hours. An equivalent tract with few or no shrubs would have required an hour or 2 less, as would a project that only utilized the least tedious method (stem base/scale to height, Method 1). An adult applicator on foot or horseback can comfortably carry 10 kg (22 lb) of herbicide, enough to last until a lunch break or to the end of the workday in stands this dense. Walking briskly with a 10 kg load requires about 3.5 kcal of output, less than the level (5.0 kcal) necessitating rest periods (Oglesby et al. 1989:247-248).

Applicators should be afforded a simple, effective method and encouraged to work rapidly through strips, not searching for every tree. Even carrying 10 to 15 kg of herbicide, fit persons will not exceed 35% of their maximum aerobic power, and they can maintain that pace for several hours without discomfort (Levine et al. 1982). Because thorough applications are more mentally than physically taxing, psychologically encouraging conditions should be selected: well-demarcated areas for each crew member, minimal obstacles (including debris windrows), clear sight lines, and cool and/or cloudy weather. Spot-painting trees adds to a sense of accomplishment. It also enables followup work, which a supervisor could do (Herbel et al. 1958). Followup is optional, depending on the miss rate, the character of the untreated trees, and the desired future stand condition. Total control (no initial misses, or thorough followup) is rarely economicaly justifiable (Scifres 1987).

Time outlays, thus labor costs, are not tightly predictable from an exact knowledge of tree density and mean tree height. More terrain and stand variables would be needed in a valid multivariate predictor, but the cost of isolating and measuring them may be worthwhile only in research contexts (e.g., Hazard and Pickford 1984). Approximate coefficients for undergrowth and slope may suffice in adjusting cost estimates to a project setting.

Future rangeland researchers could work with labor specialists to devise ways of training and motivating hired seasonal, semi-skilled, and/or youthful workers. Productivity and worker com-

Table 3. A comparison of time and tebutiuron (a.i.) expenditures among methods and occasions.

Comparison and occasion	Application Method		
	Method 1	Method 2	Method 3
Total time, min			
Oct. 1986	138	166	183
July 1987	156	167	206
Mean time/ha, min			
Oct. 1986	51.8a	61.8ab	69.2b
July 1987	59.3a	61.8b	79.0c
Mean time,tree, sec			
Oct. 1986	14.6a	16.8ab	18.8b
July 1987	16.4a	16.8b	21.2c
Total A.I. Expended, 1986			
KG	0.6a	0.7a	0.7a
Lb	1.4a	1.5a	1.5a

[1]Means in a row having the same letter are not significantly different ($p>0.05$).

mitment must be sustained over periods long enough to achieve real gains in brush reduction. Long-term fatigue and boredom are poorly understood aspects of worker satisfaction, safety, and productivity (Oglesby et al. 1989), which we did not address in this study.

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