

PACIFIC SOUTHWEST Forest and Range Experiment Station

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REDUCING FIRE HAZARD IN PONDEROSA PINE THINNING SLASH BY MECHANICAL CRUSHING

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1969. **Reducing fire hazard in ponderosa pine thinning slash by mechanical crushing.** Berkeley, Calif., Pacific SW. Forest & Range Exp. Sta. 9 p., illus. (U.S.D.A. Forest Serv. Res. Paper PSW-57)

Precommercial thinning in ponderosa pine stands in the Western United States is a growing practice. Thinning slash can, however, be a serious fire hazard in dry areas. Crushing and compacting this slash may be one way of reducing the hazard. Three types of mechanical crushers were tested on the Deschutes National Forest, Oregon. Results indicate that at least one of these methods of mechanical crushing is effective for lessening the fire hazard in thinning slash, and can be done at reasonable costs.

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Retrieval Terms: Pinus ponderosa; precommercial thinning; hazard reduction; fuel treatment; slash disposal; forest protection; fire prevention.

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Precommercial thinning of ponderosa pine (*Pinus ponderosa* Laws.) stands is a widespread practice in the Western United States and more acreage is being thinned than ever before. In the pine stands of the Pacific Northwest, thinning can increase diameter growth of crop trees by 30 to 150 percent. And it usually accelerates height growth.¹ Thinning will usually eliminate trees in poor form or of undesired species. Costs of thinning may well be repaid by shortening the time required to grow merchantable trees.

But the slash from thinning, if allowed to accumulate, can be a serious fire problem. In areas of low rainfall and low humidity, it can be a high to extreme fire hazard for 5 years or longer.^{2,3} If the benefits of precommercial thinning are to be realized, stands must be protected from fire. An effective, economical method of treating slash is needed. One method of

treating slash may be to crush and compact it.

This paper reports a study of mechanical crushing on the Deschutes National Forest in central Oregon. Three types of mechanical crushers were compared for their effectiveness in reducing fire hazard in ponderosa pine thinning slash. Data on costs and time required in both green and red slash by each method were collected.

In this study, the specific aims of slash treatment were (a) to interrupt the fuel continuity and scarify the ground to reduce rate of fire spread and resistance to control,⁴ (b) to break up slash into smaller fuel components to hasten decomposition, (c) to compact the fuel so as to increase chances for decay, (d) to provide greater access to stands, (e) to make the forest more esthetically pleasing, and (f) to accomplish these aims without excessive damage to the residual stand.

EQUIPMENT TESTED

For this study, we had to use equipment that was expected to accomplish our objectives in fuel treatment and, at the same time, to maneuver between residual trees without causing excessive damage. We tested the following equipment:⁵

Caterpillar Tractors, D-7 and D-6

A D-7 crawler tractor was used for crushing the green slash. A D-6 was used on the 1-year-old red slash. Neither tractor had any special attachments. The weight of the tractors and the action of their grousers were used to crush and compact the fuel. Both tractors were rented locally, with operators.

"Tomahawk" Compactor-Cutter-Crusher

The "Tomahawk"⁶ is a dual-purpose machine (*fig. 1*). It is designed for crushing and compacting in roadwork or, with alternate compaction and brush-cutter rings, for brush-clearing operations. It has been used for preparing fuel-breaks in southern California with good results. But the "Tomahawk" had never been tested on logging or thinning slash.

In this study, the "Tomahawk" was attached to the blade of a D-6 tractor. The model used was 6-feet wide and weighed 2,740 pounds. Other widths are manufactured, but the 6-foot model was selected because of its availability.

¹Mowat, Edwin L. *Thinning ponderosa pine in the Pacific Northwest*. U.S.D.A. Forest Serv. Res. Paper PNW-5, Pacific NW. Forest & Range Exp. Sta., Portland, Ore. 24 p. 1953.

²Fahnestock, George R. *Fire hazard from precommercial thinning of ponderosa pine*. U.S.D.A. Forest Serv. Res. Paper PNW-57, Pacific NW. Forest & Range Exp. Sta., Portland, Ore. 16 p., illus. 1968.

³Wilson, Kenneth O. *Piling and burning slash in Oregon eastside pine*. (Paper presented at fall meeting, California-

Nevada Forest Fire Council, Lake Tahoe, Calif., October 24-25, 1967.)

⁴As defined in *Glossary of terms used in fire control*. U.S. Dep. Agr. Handb. 104, U.S. Govt. Printing Office, Washington, D. C. 1950.

⁵Trade names and commercial enterprises and products are mentioned solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied.

⁶Manufactured by the Young Corporation, 2917 E. Marginal Way, S., Seattle, Washington.

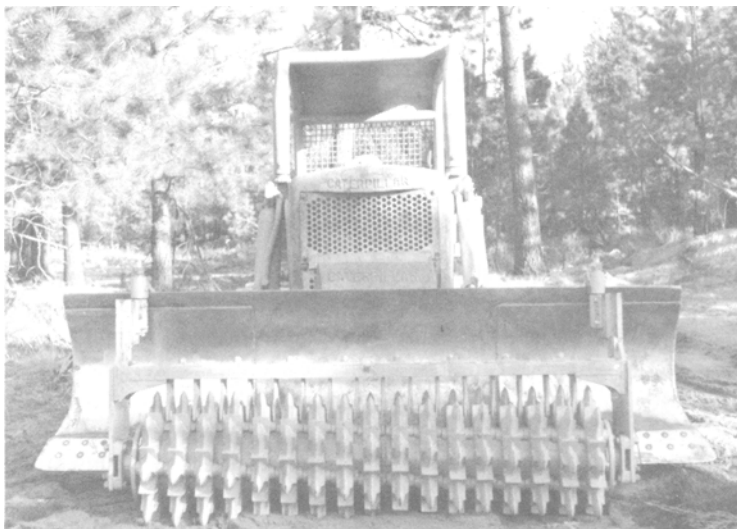


Figure 1.—The "Tomahawk" crusher has 17 alloy steel rings keyed in a spiral. Rings are 24 inches in diameter, with eight half-round cutter segments protruding 2-1/2 inches above 16 crusher segments. Weight per ring is 89 pounds.



Figure 2.—The Marden brushcutter has been used extensively for land clearing in southeastern United States and, more recently, in lodge-pole pine logging slash in the West.

Marden Brushcutter

The Marden brushcutter⁷ is a hollow steel cylinder, with cutting blades on the rolling surface (*fig. 2*). Brushcutters and similar equipment are designed for a variety of land clearing and cultivating uses. Larger

tractors are required for hauling this equipment.

The Model SB-8 used in this study was towed behind the D-7 tractor. It is 8 feet wide, has a drum diameter of 5 feet, and a water (or diesel) holding capacity of 1,100 gallons. It weighs more than 16,000 pounds when empty, about 25,000 pounds filled.

PROCEDURE

The study was conducted in spring of 1968 in thinning slash on a 40-year-old ponderosa pine stand. Eight 5-acre study plots were set up in fairly

homogeneous slash on generally level ground. Fuel treatment by mechanical crushing was applied under two different fuel conditions: (a) three plots of

⁷Manufactured by the Marden Manufacturing Company, 205 Denton Avenue, Auburndale, Florida. Equipment similar to the Maiden brushcutter is manufactured by several other

companies, including: Fleco Corporation, Jacksonville, Florida; Tom Billings Company, Orlando, Florida; and Rockland Company, Winter Garden, Florida.

current (green) thinning slash, and (b) three plots of 1-year-old (red) thinning slash. The other two plots—one in each fuel condition—were not treated, and served as controls. The green slash areas were thinned to 20- by 20-foot spacing, with about 110 leave trees per thinned acre. The red slash area was originally thinned to 16- by 16-foot spacing, with about 170 leave trees per acre. Before thinning, general stand density ranged from 3,000 to 5,000 trees per acre. Using Fahnestock's⁸ thinning slash weight tables, we determined fuel weights to be between 35 and 45 tons per acre.

In addition to these eight plots, we also set up three 1-acre test areas in rocky, rough, and sloping slash areas where effectiveness of each piece of equipment under adverse operating conditions was evaluated.

The mechanical crushing equipment used in the study was required to make two passes over each plot—one perpendicular to the other. The time required for each treatment and costs were recorded.

Fuel Hazard Rating

Rate of fire spread and resistance to control conditions were determined for each plot, both before and after treatment, by four local fire control specialists. The fuel type identification system of the Forest Service's Pacific Northwest Region⁹ was used to determine the degree of fire hazard and its reduction as result of treatment. In this system, fuels are classified by one of four rate-of-spread and one of four resistance-to-control categories, making 16 possible fuel-type combinations. The four categories in both classifications are: (a) Extreme (E), (b) High (H), (c) Moderate (M), and (d) Low (L). Thus, a fuel type designated by the symbol EH, means *Extreme High* for an *Extreme* rate of spread and *High* resistance to control. Fuel hazard ratings were based on what the evaluators could observe from a fixed point located in the center of each plot.

Plot Sampling

Sampling to determine number and vertical distribution of woody stems was done before and after treatment on 22 square-yard, vertical-plane sub-plots located along a line transect in each 5-acre plot. A measuring device (fig. 3) was designed for this purpose. We recorded the number of stem intercepts by the vertical plane in which they occurred. Fuels were classified by these diameters: (a) up to .50 inch,

(b) .50 inch to 4 inches, and (c) 4 inches and more.

Exposed soil intercepted on each plot was recorded before and after treatment to determine effects of scarification. The amount exposed was estimated as a percentage of the 3-foot line that fell below the lowest cross-stick on the plot measuring device.

Damage Appraisal

On 1-acre sub-plots in each treatment, we recorded the number of residual trees damaged or killed by one or more of these categories: (a) bark skinned off bole, (b) broken limbs, (c) tree knocked askew but still alive, (d) visible root damage, and (e) tree definitely killed (uprooted, etc.).

Equipment Evaluation

Equipment performance and maneuverability in the thinned stand was evaluated subjectively for each treatment.



Figure 3.—A plot measuring device was used, before and after treatment, to measure fuel amount and distribution at 1-foot intervals on a vertical plane. A die was cast at each plot measuring point to determine orientation of the plane in relation to the transect line.

⁸See footnote 2.

⁹U.S. Forest Service Pacific Northwest Region. *Guide for fuel type identification —Region 6*. Portland, Ore. 48 p., illus. 1968.

RESULTS

Reduction of Fire Hazard

Fuel hazard ratings were made three times in each plot: (a) before treatment, (b) after one pass of the equipment, and (c) after two passes. In all instances, except one, a single pass reduced at least one component of the hazard rating. In three of the six instances, the second pass reduced the rating further. A rating of MM was achieved on three of the six test plots. This rating is considered an acceptable hazard level for ponderosa pine thinning slash areas in the Pacific Northwest Region.¹⁰

The most obvious effect of all three methods of treatment in both green and red slash was the change in vertical distribution of the fuels. We found that crushing had compacted to within 1 foot of the ground more than 90 percent of fuels tallied above the 1-foot level before treatment (*table 1*). Cutting and chopping the slash into smaller components was difficult for the D-6 or D-7 alone. With the "Tomahawk" attached to the D-6, however, slash breakdown was considerably improved.

Fuel treatment with the "Tomahawk" crusher most nearly met the six objectives of the study. The attachment proved effective in treating green thinning slash. It lowered the hazard rating in this fuel from HH to MM (*table 2*). In heavier loadings of red slash, it changed the rating from HE to MM (*fig. 4*). The "Tomahawk" treatment was the most effective for mulching finer fuels with soil and for redistributing fuels over a larger ground area. It could cut and chop fuels up to 4 inches in diameter. The larger fuels, 6 to 8 inches in diameter, were scarred, de-limbed, and compacted close to the ground.

The D-7 tractor did not prove satisfactory in crushing green slash because it could not break up and mulch small fuels. This treatment made some changes in the fuel (*fig. 5*), but not enough to reduce the original rating (HM). In red slash, however, two passes with the smaller D-6 tractor reduced a heavy fuel concentration from EE to HM. The more complete breakdown of the red slash was attributed to its dry, brittle condition. The tractors by themselves did not prove as effective for chopping the fuels into smaller components as they did when the "Tomahawk" and Marden units were attached.

The Marden brushcutter was effective for crushing and breaking up thinning slash where it could

Table 1.—Percent of fuels compacted to within 1 foot of the ground

Equipment tested	Green slash	Red slash
Tractor	¹ 99	² 93
D-7 tractor with Marden brushcutter	98	89
D-6 tractor with "Tomahawk"	97	97

¹D-7 tractor.

²D-6 tractor.

Table 2.—Fuel hazard ratings¹ for 5-acre study plots, before and after mechanical crushing

Equipment used and slash condition ²	Before treatment	After one pass	After two passes
Tractor: green slash red slash	HM FE	HM HH	HM HM
D-7 tractor with Marden brushcutter: green slash red slash	EE HM	HH MM	HM MM
D-6 tractor with "Tomahawk": green slash red slash	HH HE	HM MM	MM MM

¹ H = high, M = medium, and E = extreme.

² D-7 tractor used in green slash, D-6 tractor in red slash.

operate, but its size caused handling difficulties in close quarters. It could chop through fuels in the 6- to 8-inch category—cutting them into 1- and 2-foot lengths. Fuel type classification in green slash after this treatment dropped from EE to HM. In red slash, the rating was changed from HM to MM (*fig. 6*).

Ground Scarification

Both the "Tomahawk" and the Marden brushcutter did a more effective job of ground scarification than the tractors (*table 3*). The tractors failed to penetrate the soil deep enough with their tracks and, therefore, could not produce the "mulching" effect of the "Tomahawk" or Marden.

¹⁰Wilson, K. O. Memo to Forest Supervisors, Division Chiefs, and Rangers. R-6, 5150 Prescribed Burning (slash treatment policy), October 23, 1968.



Figure 4.—Treatment of slash by the "Tomahawk" crusher reduced the fire hazard rating from HE (high, extreme), top, to MM (moderate), bottom.

Damage to Residual Trees

The Marden brushcutter injured more of the leave trees than either the two tractors or the D-6 tractor with "Tomahawk" attached. It did most of the damage by scarring tree boles. Only five trees on the 1-acre sub-plot were knocked askew. Considerably fewer trees were damaged in the 20- by 20-foot spacing than in the 16- by 16-foot spacing (*table 4*).

Equipment Performance

The "Tomahawk" attachment in no way impaired the maneuverability of the D-6 tractor in the close spacing of the thinned stand. The assembly was simple to transport and handle—requiring only 5 minutes to attach or detach from the tractor blade. This attachment also proved quite durable on rocky ground, and showed almost no wear after the study was completed. On the rough 1-acre testing ground, the D-6 with "Tomahawk" functioned efficiently both up and down slope. Contouring on steep slopes,

Table 3.—Percent of mineral soil exposed on measured sub-plots

Equipment used and fuel condition ¹	Before treatment	After treatment
Tractor: green slash red slash	10 18	25 6
D-7 tractor with Marden brushcutter: green slash red slash	25 9	31 32
D-6 tractor with "Tomahawk": green slash red slash	14 4	50 26

¹ D-7 tractor used on green slash, D-6 tractor in red slash.



Figure 5.—Tractor crushing in fresh, green slash modified the vertical distribution of the fuels somewhat, but not enough to change the original hazard rating. Top, before treatment; bottom, after two passes by the tractor.

however, was not effective with any of the equipment.

In the plots in which tractors alone were used, the D-7 showed no advantages in fuel treatment over the smaller D-6. The smaller tractor has a size advantage, and handles well in the thinned stand. Caterpillar tractors were used in this study, but similar size equipment, such as Allis Chalmers' HD 11, International Harvester's TD-15, or Euclid's 103-B, would probably perform equally well.

The Marden brushcutter did a good job of fuel treatment, but because of its size and poor maneuverability in the thinned stand, we do not recommend it

for this work. It handled favorably on slopes to 35 percent, but its cutting knives were nicked and broken by the numerous rocks on the test area. A complete reconditioning, costing more than \$200, was necessary after the study was completed. Movement of the Marden brushcutter from job to job is expensive, and requires special handling equipment.

The small stumps from thinned trees (*fig. 3*) did not prove to be obstacles to any of the equipment we tested. However, some caution was required to avoid larger stumps where recent commercial logging had preceded thinning—and where thinning slash obscured the stumps.

Figure 6.—The Marden brushcutter was effective where it could reach, but had difficulty treating slash close to leave trees, as shown in the bottom photo.



Time and Cost Factors

Cost figures from this study (*table 5*) reflect the rental rates we paid for the prime movers only. No effort was made to pro-rate costs for the "Tomahawk" or Marden assemblies that we obtained on loan. Nor are hauling or reconditioning costs for the Marden brushcutter included.

The "Tomahawk" in the study cost \$3,270 retail. The manufacturer claims that only minor maintenance is necessary to keep the equipment opera-

tional, and that it has an estimated life span of 10 years with frequent rough use. The other attachment tested, the Marden brushcutter, cost about \$8,000.

Fuel treatment with the "Tomahawk" required only slightly more time per acre than the other equipment. Condition of the slash (green or red) made little difference in time required for treatment with any of the equipment. On the rough-ground test areas, however, more time was needed by each piece of equipment in order to negotiate steep slopes and avoid rocky outcroppings.

Table 4.—Number of leave trees damaged on 1-acre sub-plots, by type of damage and equipment used

Equipment	Skinned bole	Broken limbs	Tree knocked askew	Visible root damage	Tree killed	Total	Percent leave trees damaged
20- BY 20-FOOT SPACING (110 LEAVE TREES PER ACRE)							
Tractor ¹	7	0	1	0	0	8	7.3
D-7 tractor with Marden brushcutter	19	0	1	0	0	20	18.2
D-6 tractor with "Tomahawk"	2	0	0	0	0	2	1.8
16- BY 16-FOOT SPACING (170 LEAVE TREES PER ACRE)							
Tractor ²	20	0	1	0	0	21	12.4
D-7 tractor with Marden brushcutter	26	0	1	0	0	27	15.9
D-6 tractor with "Tomahawk"	11	0	1	0	0	12	7.1

¹ D-7² D-6

Table 5.—Time required for treatment and costs, by type of equipment tested and condition of slash

Equipment	Condition of slash	Time required		Cost	
		Per acre	5-acre total	Per acre	5-acre total
	<i>Hrs./min.</i>			<i>Dollars</i>	
D-7 tractor ¹	Green	0:50	4:10	12.42	62.08
D-6 tractor ²	Red	0:52	4:20	15.16	75.83
	Red ³	1:15	--	21.87	--
D-7 tractor with Marden brushcutter ¹	Green	1:05	5:25	16.14	80.70
	Red	0:45	3:45	11.17	55.87
	Red ³	1:15	--	18.62	--
D-6 tractor with "Tomahawk" ²	Green	1:05	5:25	18.96	94.79
	Red	1:10	5:50	20.42	102.08
	Red ³	1:40	--	29.16	--

¹Rental charges: \$14.90 per hour, including operators' wages, maintenance and operation.²Rental charges: \$17.50 per hour, including operators' wages, maintenance and operation.³1-acre test plots located on uneven ground with slopes to 35 percent.

DISCUSSION AND CONCLUSIONS

Even a single pass of a crusher over slash can reduce its fire hazard, and may suffice to meet minimum fire control standards. Any additional passes further contribute to improved access and better appearance of the treated area. Intensity of treatment will depend on management objectives.

In extensive areas of continuous thinning slash, where total fuel treatment may not be feasible, a modified "fuel-break" system might be considered. Mechanically crushed strips or lanes could be located through the fuel complex to break up slash continuity, restrict free movement and spread of wildfire, and allow a line of defense for fire control work.

A "Tomahawk" crusher mounted on the blade of a D-6 tractor was the most useful tool tested for reducing fire spread potential and resistance to control of both green and dry thinning slash. It readily crushed and broke up small diameter slash and left it compacted close to the ground without interfering with maneuverability of the tractor, or causing damage to "leave" trees. We had no repair or maintenance problems.

The Marden brushcutter did a good job of fuel treatment on flat ground, but its cutting blades were damaged in rocky areas. Because of its large size and poor maneuverability in the thinned stand, this unit caused excess damage to leave trees and left consider-

able uncrushed slash close to them. The equipment is also expensive to move from job to job.

Tractors, by themselves, were satisfactory for crushing the brittle red slash, but were not effective in green slash. Neither were they as effective as the other equipment in mulching small fuels.

The "Tomahawk" attachment is available in several sizes. A 10-foot-wide assembly is recommended for future testing. This size will allow a wider swath to be treated on each pass, without hindering tractor maneuverability in the thinned stand. A dual tandem "Tomahawk" unit, or a larger diameter arbor assembly, might also increase effectiveness and should be tested.

The crawler tractor plays an important role in compacting the slash—whether used alone or with the "Tomahawk" unit attached. It would be advantageous, therefore, to test various tractors with different treads and grousers to determine which types are most effective for cutting and crushing thinning slash.

Future research on the study plots is aimed at determining (a) the effect of treatment on slash decomposition (compared with controls), (b) changes in fire hazard conditions on treated and untreated areas over a period of several years, and (c) ecological effects of treatment over a period of time.



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