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Effects of Leader Topping and Branch Pruning on Efficiency of Douglas-Fir Cone Harvesting With a Tree Shaker

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Abstract

In 1983, a study was conducted to evaluate the effects of leader topping and branch pruning on the efficiency of tree shaking to remove Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) cones. Removal efficiency for three topping and pruning treatments averaged 69 percent, whereas for the uncut control treatment it was 62 percent. The treatment combination that resulted in the greatest cone removal (70.8 percent) was cutting the last 2 years of growth from the leader but not pruning lateral branches. The pruning-topping effects were not additive, possibly because branch pruning several weeks prior to cone harvest resulted in premature removal of a portion of the most easily shaken cones.

Keywords: Cone collection, pruning, top pruning, pruning tools, Douglas-fir, tree shaker.

Harvesting conifer cones with mechanical tree shakers usually results in lower efficiency than is achieved with identical machines in harvesting deciduous nuts and fruits. Conifer cones are often attached to the branches with tough, woody stalks which necessitate a strong shake force to remove the cones. An attempt to induce abscission zone formation in the woody stalks by spraying abscission-inducing chemicals was tested in southern pine species, but the procedure was not successful (5). Similar abscission tests have not been reported for Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco).

Results from several field trials of harvesting cones of Douglas-fir with tree shakers have been reported (1, 2, 4, 11). In addition, two carefully controlled laboratory studies have been done to gather basic information on shaking characteristics of Douglas-fir. In the first study, detached cone-bearing limbs were shaken on a laboratory device that could vary both stroke length and frequency of shake (8); the second laboratory test simulated shaking two stems with different shapes (2).

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Results from tree shaking trials with Douglas-fir (2, 4, 11) and with other conifers (1, 10, 11) have been encouraging for use of this technique, but orchardists want more complete removal of cones. An average of 55 percent of Douglas-fir cones were removed when 7- to 9-m-tall seed orchard trees were shaken (4), and 52 to 70 percent were removed from larger forest-grown Douglas-fir (11). Attempts to evaluate the variables that influence the proportion of cones that can be removed indicate interactions of many factors: species (1, 2, 8, 11), clone (4, 10), stem diameter (3, 10, 11), tree height (1, 3, 4, 11), stem taper (1, 11), height to live crown (1, 3, 4, 11), physical characteristics of the wood (9), foliage density (1, 11), crown shape (11), branch size (2), branch angle (4), damage susceptibility (1, 10), cone distribution and size (1, 11), and cone maturity (1, 2). Sources of variation related to the tree-shaking machines themselves include factors such as length of shake stroke (7, 8, 11), number of shake cycles per minute (1, 4, 7, 8), amount of shake force or thrust applied to the bole (4, 11), type of thrust applied (4, 11), shake pattern (4, 7, 8), shaker head attachment height (1, 4, 10, 11), duration of shake (4, 7, 10, 11), and number of shakes (4, 8). The fact that many variables interact to influence cone removal is indicated by correlation coefficients (r^2) being less than 0.44 when cone removal is correlated with single variables, such as tree height, stem diameter, or height to live crown (1).

Results from the 1982 shaking test with Douglas-fir (4) suggest that crown shape and branch length can influence cone removal and crown damage. Cones could not be easily shaken from trees with long, pendent branches. Cones were most readily removed from short branches in the upper third of the crown. More shake energy appeared to be conducted to the ends of short, stiff branches. Cone removal was poorest from the lower third of the tree. The damping action of dense crowns on machine-induced vibrations and the propensity for excessive top breakage during shaking are both documented for Douglas-fir trees (1).

In 1983, I decided to test the effects of minor modifications of crown shape or structure of Douglas-fir on the shaking characteristics. The hypothesis was that trees with shorter, stiffer branches and less flexible tops would yield a greater percentage of cones and have less shaker-induced damage than untreated trees.

Objectives of the study were to determine (1) whether branch pruning and leader topping prior to tree shaking improves cone removal, and (2) whether topping results in less crown damage. A future objective is to evaluate harvest efficiency and tree vigor or health after the trees have been shaken in different crop years.

Methods

Sixty-eight trees growing in a Forest Service experimental plantation 24 kilometers north of Corvallis, Oregon, were chosen for study in 1983 because the planting closely approximated conditions in seed orchards. The trees all had normal crown form and foliage density and had good potential for cone production. Most trees had produced one or two cone crops during the preceding 4 years and 65 of the 68 trees were producing cones in 1983. The trees were in an area protected for research. Of the 68 study trees, 48 had been propagated as rooted cuttings in 1968 and had been planted in 1971; the other 20 trees were grafts made in 1973 on large, well-established rootstocks. Grafted trees were somewhat smaller in diameter and height than the cuttings (12.0 cm and 8.0 m vs. 15.8 cm and 8.9 m).

Leader topping and branch pruning were studied for their effect on cone removal efficiency and degree of top damage. Topping consisted of cutting off the top of each tree approximately 20 cm above the 1982 branch whorl. Pruning consisted of cutting off the distal end of major branches in each annual growth whorl. The amount cut from a branch varied according to branch age: all of the 1982 and 1983 increment was cut from the tip of branches 3 years and older; only the 1983 increment was cut from branches in the 1982 whorl.

The experiment was a 2 x 2 factorial of pruned vs. unpruned branches, and topped vs. untopped leaders in a randomized complete block design with 17 replications. Within each replication, each treatment was applied to one of four adjacent trees selected at random. Twelve replications consisted entirely of cuttings and five consisted of grafts. Pruning and topping were done in early August 1983; one worker on the ground used a pole pruner and another worker in the bucket of a lift truck used hand pruning shears.

Tree shaking was done the last week of August 1983 when the cones were mature. Cones had already begun to open on several trees. The Kilby Co.[1/] boom-type tree shaker described in the 1982 shaking study (4) was used. The same low energy, gentle shaking procedure developed in 1982 (4) was also used, except that clamping pressure of the shaker head was reduced from 750 to 500 lb/in^2 and the trees were shaken with the shaker in only one position rather than in two positions as in 1982. All 68 trees were shaken, including 3 trees that did not have cones. The 3 barren trees were given the same shaking treatment to collect crown damage information and to ensure that cumulative effects of shaking can be evaluated in future years on all 68 trees.

Each tree was shaken until it appeared that no more cones could be removed without increasing the shake energy to levels that would cause unacceptable upper crown breakage. The cones fell onto plastic tarps placed under each tree. The length of time each tree was shaken was recorded to the closest 5 seconds. Cones remaining attached to the trees after shaking were hand picked. Both the shaken and hand-picked cones were weighed with a spring scale immediately after collection. Tree measurements recorded included stem diameter, height before and after leader pruning, and height after shaking. Branch damage was recorded by noting the age of the oldest branch whorl on which broken tips occurred. Any external trunk damage to the bole was noted.

Data were analyzed for the 2 x 2 factorial by analysis of variance techniques. Percentage data were subjected to arcsin transformation prior to analysis. Cone removal data were analyzed for the 65 cone-bearing trees; and tree size, pruning length, and shaking data were evaluated for all 68 trees.

[1/]The use of company or brand names is for the convenience of the reader and does not constitute an endorsement by the U.S. Department of Agriculture.

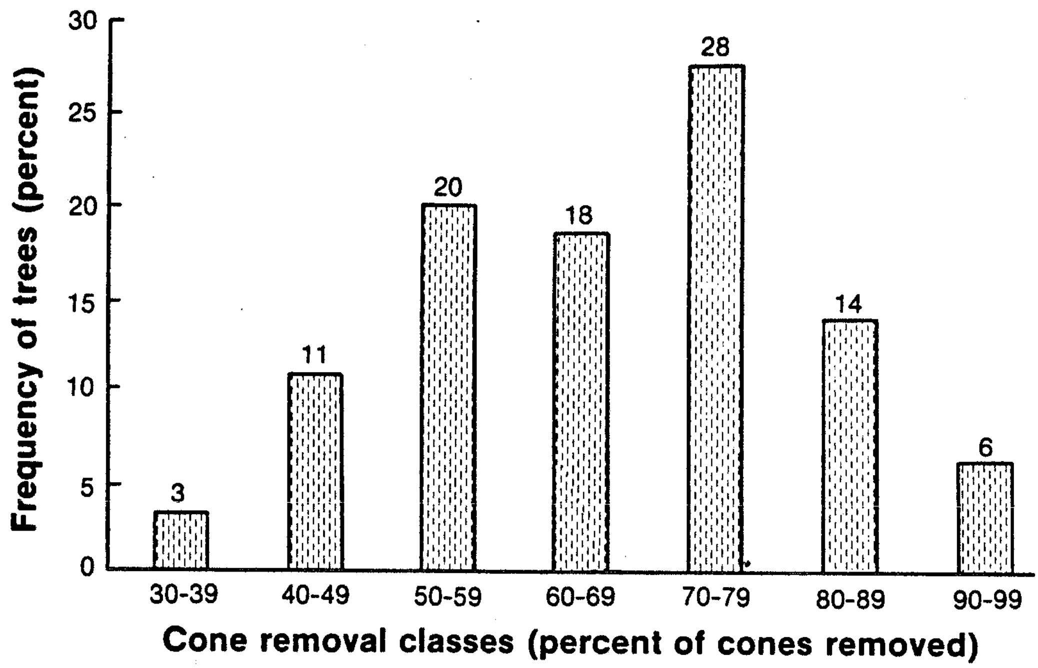

Figure 1.—Frequency distribution of study trees in various cone removal classes.

Results

Cone removal by shaking was successful with most trees: Only 14 percent of trees failed to drop at least 50 percent of their cones (fig. 1). Cone removal averaged 67 percent for all trees in the study (table 1). Trees subjected to topping or pruning treatments yielded more cones than did control trees. Controls averaged 61.5 percent, whereas pruned and/or topped trees averaged 68.7 percent. Analysis of variance tests showed neither pruning nor topping treatments to be significant at the 5-percent level, but the pruning-topping interaction was significant. The most effective treatment was topping without pruning; that treatment averaged 70.8-percent cone removal.

Effects of replication were significant at the 1-percent level for diameter, initial tree height, and total amount of height reduction because of the height and diameter size difference between grafts and cuttings (table 2). Randomization of treatments within replications was effective in that treatments were not significantly different for initial tree heights or stem diameters.

The two leader-topping treatments resulted in the mean removal of 1.4 and 1.7 meters from the upper crown of each tree. Total tree height reduction caused by topping and by shaker breakage averaged 0.5 meter more in topped trees than in untopped trees; the difference was significant at the 5-percent level. Leader breakage occurred in one-third of all leader-topped trees; that loss averaged 0.2 meter for all topped trees. The length of time the trees were shaken was not significant.

Damage to branches after shaking was confined to 1983 branch tips in the top one or two whorls. Fewer branches broke on pruned trees because the most fragile tips had already been removed. Leader topping did not appear to affect shaker damage to branches.

Table 1—Effect of leader topping and branch pruning treatments on weight and percentage of cones removed from Douglas-fir by shaking (means and standard errors), and analysis of variance

Branch and leader treatment	Number of trees	Average weight of cones per tree: Total	Average weight of cones per tree: Removed by shaking	Cones removed by shaking
		Kilograms	Kilograms	Percent
Cone removal:				
Leader topping--				
Brancn pruning	15	8.9 ± 0.8	5.9 ± 0.5	66.6 ± 3.5
No branch pruning	17	14.4 ± .9	9.5 ± .5	70.8 ± 3.3
Submeans		11.7	7.7	68.7
No leader topping--				
Brancn pruning	17	9.8 ± .8	6.7 ± .6	68.8 ± 3.1
No branch pruning (control)	16	11.2 ± 1.0	6.6 ± .6	61.5 ± 4.5
Submeans		10.5	6.7	65.2
Means		11.1	7.3	67.0

	Degrees of freedom	Probability
Analysis of variance:		
Replications	16	.02
Leader topping (T)	1	.31
Branch pruning (B)	1	.73
T x B	1	.05
Experiment error	45	

Table 2—Tree parameters (means and standard errors) before and after shaking Douglas-fir, and analysis of variance

Branch and leader treatment	Number of trees	Time shaken	Diameter	Original height	Leader length cut off	Length of top broken by shaking	Total reduction in height
		Seconds	Centimeters	Meters	Meters	Meters	Meters
Tree parameters:							
Leader topping--							
Branch pruning	17	44 ± 2.6	15.0 ± 0.7	8.6 ± 0.3	1.4 ± 0.1	0.2 ± 0.1	1.6 ± 0.1
No branch pruning	17	54 ± 3.8	15.0 ± .8	8.7 ± .2	1.7 ± .1	.2 ± .1	1.9 ± .1
Submeans		49	15.0	8.7	1.6	.2	1.8
No leader topping--							
Brancn pruning	17	47 ± 2.5	14.0 ± .8	8.5 ± .2	0 ± 0	1.3 ± .1	1.3 ± .1
No branch pruning (control)	17	49 ± 4.3	14.8 ± .7	8.5 ± .2	0 ± 0	1.2 ± .1	1.2 ± .1
Submeans		48	14.4	8.5	0	1.3	1.3
Means		48.5	14.7	8.6	--	--	1.5

	Degrees of freedom	Probability					
Analysis of variance:							
Replications	16	.45	0	0	--	.17	0
Topping (T)	1	.59	.18	.49	--	0	0
Pruning (B)	1	.14	.45	.52	--	.46	.34
T x B	1	.28	.52	.61	--	.46	.21
Experimental error	48						

Little bole damage was detected where the shaker head was attached to each tree. Three trees experienced slight bole damage (bark slippage) when the shaker was accidentally operated with less than 400 lb/in^2 clamping pressure. Inadequate clamping pressure allowed undesirable movement between the pads of the shaker head and the bole. A clamping pressure of 500 lb/in^2 was adequate for proper transfer of shake energy to trees that averaged 8.6 m in height but was not so strong that clamping pressure damaged the cambial tissues beneath the pads.

Discussion and Conclusions

Cone harvest by shaking was more effective in 1983 than in 1982. Average cone removal increased from 55 percent in 1982 (4) to 67 percent in 1983. The most effective 1983 treatment was to leader-top the trees without pruning branch tips. The 6.5-percent increase in yield of cones of control trees in 1983 over yield in 1982 is attributed primarily to increased skill of the machine operator. The additional 5- to 10-percent increase in cone yield in 1983 probably resulted from the branch-pruning and leader-topping treatments.

The pruning and topping treatments were not done until 2 weeks before shaking; consequently, some cones were removed when the branch tips were pruned. Cones located on the tips of branches in the top one-third of the crown could have been easily removed by the shaker. The cone loss prior to shaking is evidenced by the lower average total weight of cones on branch-pruned trees than on trees that were not branch pruned. A more practical seed orchard procedure would be to limit pruning to the branches that were more difficult to shake in the lower two-thirds of the crown. Another technique that would enhance yield would be to prune only when there is no cone production; that would eliminate cone loss, yet still shorten and stiffen the most difficult-to-shake lower branches.

Both leader topping and branch pruning had greater influence on cone removal when done separately than when combined, but neither treatment effect was significant at 5 percent. The significant pruning-topping treatment interaction indicates that although the two treatments did affect cone removal, their effects were not additive when used together on the same trees. Removal of cones by clipping branch tips in the upper crown prior to shaking may be the most likely cause of the significant topping-pruning interaction. Large standard errors suggest that other uncontrolled variables also had considerable influence. As previously stated, many variables—both plant and machine—interact to determine the proportion of cones that can be removed by shaking (11).

Predicting the actual point where untopped trees will break during shaking is difficult. The top two or three internodes of Douglas-fir trees are slender and very subject to breakage when energy applied is sufficient to remove a majority of cones. Leader pruning prior to shaking allows orchardists to determine final tree height more accurately. Topping removes the most break-prone portion prior to shaking and may allow the machine operator to safely shake leader-pruned trees with slightly more force than trees whose leaders are not topped. On the average, topped trees had 0.5 m greater reduction in total height than did untopped trees, but this will not result in a meaningful difference in the size over the productive life of a seed orchard. Shaker-induced breakage of the main leader averaged 0.6 m and occurred in only about one-third of the leader-topped trees, whereas breakage in untopped trees averaged 1.25 m and occurred in all untopped trees.

Shaking these same trees when the next cone crop is produced will likely yield results somewhat different from those in 1983 because branch pruning is not planned for at least 2 years and then only during a noncrop year. Leader-topping may not be necessary if cone crops are frequent enough that top breakage induced by tree shaking keeps the upper crown in proper shape.

Observations and growth measurements will be made in future years on each of the 68 study trees. Trees will be examined for unseen or delayed symptoms of lower bole damage. I do not expect adverse effects from shaking on tree vigor or cone production since none were found in slash pine 4 years after shaking (6). Cumulative effects on crown structure will also be evaluated to determine if repeated shaking will gradually improve cone removal efficiency by allowing the shaker operator to use greater shake energy without causing unacceptable damage.

English Equivalents

1 centimeter (cm) = 0.3937 inch (in)
1 meter (m) = 3.2808 feet (ft)
1 kilogram (kg) = 2.2046 pounds (lb)
1 kilometer (km) = 0.6214 mile (mi)
0.0703 kilogram per square centimeter (kg/cm^2) = 1 pound per square inch (lb/in^2)

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