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Tree Shaking Machine Aids Cone Collection in a Douglas-Fir Seed Orchard

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Abstract

A boom-type tree shaker was used in a Douglas-fir seed orchard to remove cones from 7- to 9-meter tall grafted Douglas-fir trees. An average of 55 percent of the cones were removed by shaking, while damage inflicted to the upper crown was confined primarily to branch and leader breakage in the top three internodes. Damage to the lower bole, where the shaker head attached to the tree, occurred only once. Shaking a significantly greater proportion of cones from 7- to 9-m tall Douglas-fir trees without drastically increasing top damage is not likely. Much of the cone crop on small trees is found on the difficult-to-shake lower half of the trees; energy levels sufficient to remove those cones would cause severe breakage in the upper crown. The shaking procedures outlined in this report were relatively gentle, yet they resulted in the harvest of over half the cone crop in a rapid and efficient manner. It should be possible to machine-harvest cones from approximately one tree per minute when a tree shaker and mechanical catch frame are used in seed orchards that have cones on a majority of the trees. Handpicking the cones remaining on the trees after shaking will still be necessary, but that job should be much easier than picking cones from unshaken trees; more than half the cones will have already been removed, including most of the difficult-to-reach cones from high in the trees. A combination of machine harvesting and hand picking of cones should considerably shorten the time required to complete the cone harvest and the cost per bushel should be reduced because of increased efficiency.

Keywords: Cone collection, field equipment, Douglas-fir, *Pseudotsuga menziesii.*

Introduction

It is difficult to complete cone harvest in Douglas-fir seed orchards prior to natural seedfall. Orchards today contain several thousand trees of various sizes, and picking cones by hand becomes more difficult as tree size increases. Physically climbing and using ladders or lift devices are slow and inefficient methods of harvest. Such methods also involve an element of risk to cone pickers. Slow production, high labor costs, and the purchase or rental of expensive equipment combine to make low-cost cone collection difficult. Surprisingly, hand picking is still the only method used in today's Douglas-fir orchards.

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Cone harvest would probably be safer and less expensive if existing commercial nut and fruit harvesting machines could be used to harvest Douglas-fir cones. Trials with other conifers indicate that many species do not readily drop their cones when shaken because no abcission zones are formed in the woody stems that attach the cones to the branches.[1] Tree shaking machines have been used successfully in the southern United States to harvest cones in slash pine orchards. Shakers have not been used in Douglas-fir orchards of the West, but trials were conducted in Idaho and in southwest Oregon on large forest trees.[2] In the tests, Douglas-fir trees were shaken with encouraging results for wildland collections, but the lower bole and the upper crown of the shaken trees were often severely damaged. Extensive top damage resulted from the extremely vigorous shaking, which was needed to effectively remove tightly held cones. Such severe crown damage is not acceptable in seed orchard trees because they must repeatedly be harvested.

Orchard managers are reluctant about using shakers until it can be demonstrated that such mechanized harvesting methods are nondestructive. We decided to conduct a shaker trial in a Douglas-fir seed orchard during the 1982 cone harvest to determine if mature cones could be harvested from 7- to 9-m tall orchard trees without causing excessive tree damage. Specific evaluations were percentage of cone removal, amount of top breakage, the relationship of cone removal with amount of top breakage, and effect on cone removal and top breakage of balanced versus unbalanced weights in the shaker head.

Methods

Tree shaking was carried out at the Beaver Creek seed orchard of the USDA Forest Service near Corvallis, Oregon, during the last week of August 1982. Ninety-two trees were shaken. Evaluation of percent cone removal and top damage is reported on 10- to 14-year-old grafted Douglas-fir trees. Trees ranged in height from 7- to 9-m and had stem diameters that ranged from 9 to 25 cm as measured 30 cm above the graft unions. The orchard consisted of ten 2-ha blocks, but trees in only four of the blocks were shaken. Each block contained approximately 300 trees, or 10 to 15 ramets of 25 clones. Some trees produced good cone crops, but the proportion of producing trees were small. The same clones were not present in more than one block, so comparisons of treatments between blocks are limited.

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[1] McLemore, B. F. Chemicals fail to induce abcission of loblolly and slash pines. Res. Note SO-155. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1973. 3 p.

[2] Anon. An evaluation of two tree shakers for harvesting cones. Equipment development and test report. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Equipment Development Center; 1972. 27 p.

The machine used in the trial was a Kilby Company, four-wheel drive, boom-type shaker with a scissors clamp shaker head. [3] Maximum opening width of the head was 53 cm (21 in.). The head contained two 41-cm (16-in.) energy wheels adjusted to produce a six-sided, star-shaped shaking pattern. Blocks 2, 3, and 4 were shaken with balanced weights attached to each energy wheel (30 kg), whereas block 5 was shaken with unbalanced weights: 26 kg weights on the upper energy wheel and 30 kg on the lower wheel. Clamping pressure between the shaker head and the tree was measured at 750 psi. The amount of shake energy or force applied to a tree was a function of the weights used on the energy wheels of the shaker head and the number of times the shaking pattern repeated each second. Any combination of heavier weights and more shake cycles per second resulted in increased shake force or energy.

One person on foot helped the machine operator determine where to attach the shaker head on each tree, and how much power (cycles per second) to use and for how long. The duration and frequency of the shake were varied according to the physical characteristics (angle and length of branch, and size of tree), number of cones, and ease with which the cones were shaken from each tree. Proper shaking methods were perfected as work progressed the day of shaking. Only limited prior information existed on proper techniques for small conifers. The shaking procedures we tested were limited to those which were not likely to cause extensive crown damage.

Efficiency of cone removal was determined both from visual estimates and from actual measurements of cone weight. One person visually estimated the percentage of cones shaken from each tree. To check the accuracy of the visual estimates, weight of cones shaken and weight of cones remaining on each tree after shaking were determined by hand picking the cones remaining on 28 of the 92 trees. Weight data for all 92 trees could not be made because of limited staff and time. The cones were mature and picking had to proceed rapidly. The amount of top breakage was determined by measuring tree height before and after shaking. The number of growth internodes broken off was also recorded.

Data on percent cone removal were subjected to arc sine transformation before regression or analysis of variance. Regression analysis of data for estimated and actual percentages from 28 trees in blocks 4 and 5 was made so that the estimated values for all 92 trees would be more accurate. Corrected values were calculated from the formula $y = a + bx$. In the formula, values for y, a, b, and x stand for corrected percentage, intercept, slope, and original estimated percentage, respectively. These estimates were then used for analysis of variance tests of relationship of top breakage by percent of cone removal and top breakage by orchard blocks. A polynomial comparison was used to evaluate linear effects. It should be noted that statistical tests based on adjusted values that do not contain sampling error are not exact, but in this case are thought to illustrate the differences fairly accurately.

Results

Average shake time was 1.5 minutes; individual trees were shaken for as short a period as 25 seconds and for as long as 3 minutes. The average time for the whole operation of clamping, shaking, and moving to a clamping position on the next tree was 3 minutes.

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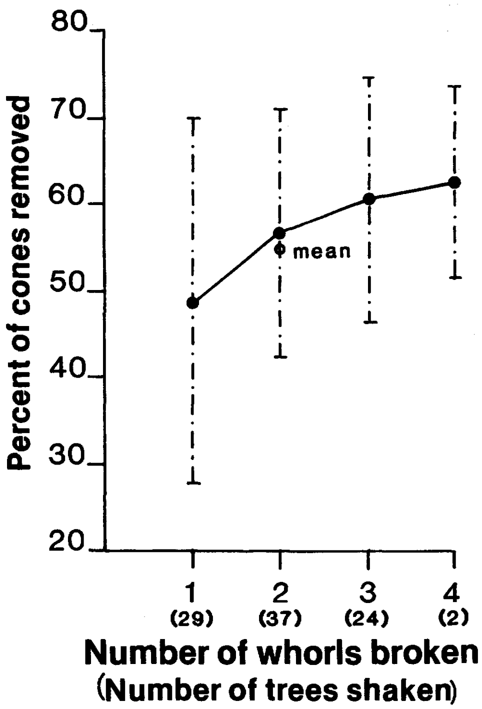
[3] The use of company or brand names is for the convenience of the reader and does not constitute endorsement of the product by the U.S. Department of Agriculture.

An average of 55 percent of the cones were shaken from each tree (fig. 1). considerable tree-to-tree variation existed; individual trees varied from almost 0- to 95-percent cone removal. Percentages of removal among all orchard blocks were similar.



'Figure1.—Percentage of cones removed by shaking.

Estimates of cone removal in blocks 4 and 5 were found to closely correlate with actual percentages derived from weighing cones ($r = 0.80$). The uncorrected visual estimates averaged 5 percent higher (table 1). Values presented in figure 1 are for all 92 trees in blocks 2, 3, 4, and 5 have been corrected by the regression formula derived from the relationship between estimated and actual data in table 1. The regression formula $y = a + bx$ provided the corrections, where y = the corrected percentage value, a = intercept value of 9.127, b = slope 0.771, and x = the original estimated percentage value.

When the percentage of cone removal is compared to amount of top damage, the law of diminishing returns is evident (fig. 1). As more of the top is broken by increased shaker energy (more cycles per second), lesser percentage of increase in cone removal (8, 4, and 2 percent) is obtained with each increase in breakage (whorls 2, 3, and 4). Even though the correlation ($r = 0.27$) between cone removal and degree of top breakage was significant at the 0.05-level, there were large differences in cone removal between trees in the same damage class. Some trees with low percentages of cone removal occurred independently in all four damage classes.

Table 1—Estimated and actual percentages of cones removed by shaking 28 trees in a Douglas-fir seed orchard by number of whorls broken

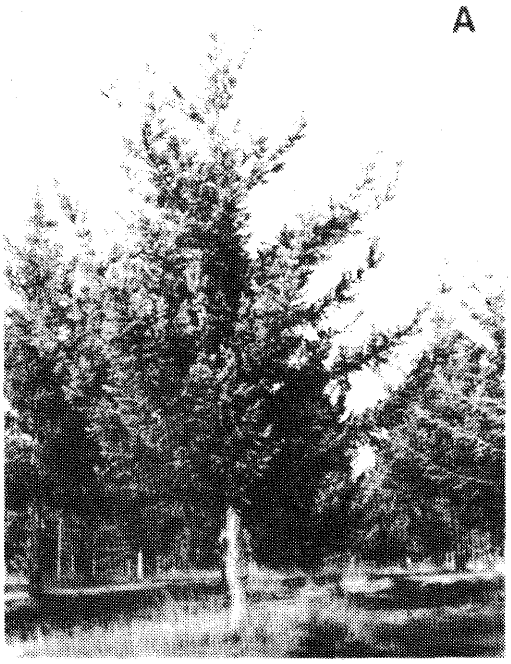
Orchard block and item	Number of growth whorls broken				Total or average
	1	2	3	4	
Block 4:					
Number of trees shaken	2	9	3	0	14
Estimated percentage of cones removed [1]	35	60	82	0	61
Actual percentage of cones removed [2]	31	53	75	0	56
Block 5:					
Number of trees shaken	2	6	6	0	14
Estimated percentage of cones removed [1]	45	52	70	0	59
Actual percentage of cones removed [2]	45	47	69	0	56
Total or average for both blocks:					
Number of trees shaken	4	15	9	0	28
Estimated percentage of cones removed [1]	40	57	74	0	60
Actual percentage of cones removed [2]	38	51	71	0	55

[1] Uncorrected visual estimates.
[2] Derived from weighing the cones.

Some damage to the upper crown occurred at any shake frequency powerful enough to remove cones. Minimal damage resulted when the number of shake cycles per second was kept low. By either halting, reducing, or sustaining the energy applied to the shaker head when leader breakage first occurred, it was possible to confine breakage within the top three whorls in all but 2 of the 92 trees (fig. 2). Damage thought to be unacceptably severe for seed orchard trees (breaking 4 years or more of growth from the top) occurred in only two trees when they were intentionally shaken excessively hard to see if additional cones could be removed. An average of 2 years of growth was broken from the top of the trees (table 2). Approximately one-third of the tops broke in each of the first, second, or third internodes.

Significantly more severe physical damage occurred to the trees in blocks 4 and 5 where larger segments of top were broken than in blocks 2 and 3 (table 2). Unbalanced weights in the shaker head were used for trees in block 5 but the same balanced weights used in blocks 2 and 3 were also used in block 4. Little difference in damage occurred between trees of blocks 4 and 5, so the unbalanced weights were not responsible for increased breakage. There was no apparent advantage to using unequal weights.

Other observations were made when a number of shaking techniques were tried in an effort to perfect the shaking process. Results from those observations cannot be analyzed statistically but are presented simply as observations to aid others who may wish to use shakers for cone collection in Douglas-fir seed orchards.



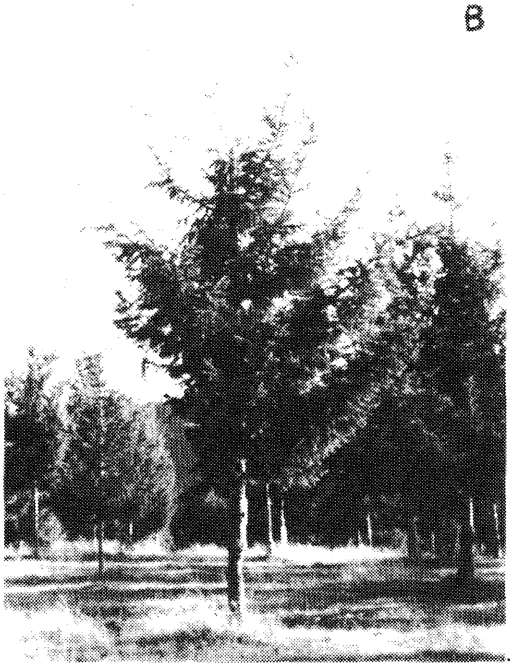


Figure 2.—Top breakage in seed orchard trees 7-9 meters tall: A, acceptable amount (confined within the top three whorls); B, unacceptable amount (4 whorls or more).

Table 2—Characteristics of and damage to trees shaken for cone removal in a Douglas-fir seed orchard by orchard block number

Characteristic of and damage to trees	Orchard block number				Total or average
	2	3	4	5	
Number of trees shaken	20	28	21	23	92
Average diameter (cm)	19.3	16.8	19.1	21.0	19.3
Average height (m)					
Before shaking	8.7	9.2	9.3	9.3	9.1
After shaking	7.6	7.3	7.4	7.0	7.4
Percentage growth whorls broken:					
1 whorl	57	46	14	9	33
2 whorls	30	32	52	43	39
3 whorls	13	18	29	48	26
4 whorls	0	4	5	0	2
Average amount of top breakage (number of whorls)	1.6	1.8	2.2	2.3	2.0

Observations on methods to reduce top damage indicated that the least damage occurred when shaking was started with the machine at idle speed for 5-10 seconds, and then the power was gradually increased until no more top breakage could be tolerated. Shaking was sustained at the maximum acceptable power level until no more cones were removed. Low energy at the start of the shake removed cones from the upper whorls where, otherwise, a combination of heavy cone weight and strong shake force could break the top unacceptably low in the tree.

Most trees were shaken twice: the machine was repositioned 90 degrees after the first shake and reshaken for a few seconds from the new position. The change in direction yielded extra cones which would not have fallen if the trees were shaken from only one side. A slight burst of power at the end of each shake was often beneficial in removing additional cones, but it was difficult to control crown damage when power bursts were applied; crown damage was easier to control when power was gradually increased to the highest acceptable level and then sustained until no more cones were removed.

Shaking action in the upper crown was dampened when the shaker head was attached less than 0.5 m above the ground. Such low attachment also caused an undesirable amount of root disturbance or movement. The best shaking action and most time-efficient procedure was to clamp the shaker head 1 to 2 m above the ground; that height at the Beaver Creek seed orchard was at or just above the graft union. Attaching the head 3 to 5 m above the ground did not aid in removing any more cones from the 7- to 9-m tall trees than when the trees were shaken lower on the bole. Shaking high in the crown was also a more time-consuming procedure because of the necessity of positioning the head between the whorls of branches.

Only one tree sustained trunk damage where the shaker head attached to the lower bole. In that case the bark was removed from two-thirds of the tree's circumference because the rubber pads on the shaker head were not adequately greased. Extremely low clamping pressure of 750 psi was used because the shaker head often attached to the tree where the bark was alive and green. The lower pressure appeared to eliminate pressure damage, yet it was high enough to allow proper shaker head operation on the small trees. No other external bole damage was seen.

Some trees had physical characteristics that either hindered or promoted removal of cones by shaking. Trees with long, pendant branches and dense foliage did not yield a high percentage of cones. Long branches in the lower crown which had a heavy mass of cones at their tips were nearly impossible to effectively shake. The easiest trees to shake were those with short, stiff horizontal branches. Ramets of the same clone tended to have more similar percentages of cone removal than did comparisons made between ramets of different clones. It was also possible to shake some incompatible trees more vigorously than was possible with healthy trees and still not break the crowns below the top three internodes. No problems occurred with breakage in incompatible graft unions.

Discussion

A commercially developed nut and fruit tree shaker appears suitable for harvesting cones in Douglas-fir seed orchards where trees are 7- to 9-m tall, but some upper crown damage is unavoidable if significant nuymbers of cones are to be removed. It was evident that a portion of each tree's cone crop will remain on the tree even if sufficient power is used to cause extensive breakage to the upper crown. When low energy shaking (low cycles per second) was used, good cone removal occurred from the upper third of the crown, whereas results were varied for the middle third and were poor for the lower third of the crown. Yet an average of more than 50 percent of the cones were shaken from each tree. It is thought that an acceptable balance between gain from cone removal and loss from top breakage was obtained in this trial.

Tree size and shape had a definite effect on how many cones were removed by shaking. Future research is needed on the effects on crown shaping or branch pruning in order to produce trees that can be shaken more effectively. Trees less than 10 m tall are probably more difficult to effectively shake than larger Douglas-fir trees because a greater proportion of the cone crop in small trees is located in the hard-to-shake, lower half of each tree. Large trees tend to have a greater proportion of cones in the upper third of the crown, where they can be most easily shaken; thus, it is likely that the percentage of cones that can be removed will increase as the orchard trees get larger.

Shaking removed the highest, most difficult-to-reach cones from each tree. Cone pickers in the Beaver Creek seed orchard found that hand picking cones remaining on shaken trees was easier and faster; consequently, shaking should be less expensive than when ladders or lift devices are used to collect cones from unshaken trees. Gentle shaking removed a significant portion of the cones, yet the shaking caused only minimal upper crown damage. Our results indicate more than half the cone crop could be machine-harvested from 7- to 9-m tall trees. The 3-minute average per tree obtained in this shaking test was much slower than could be done in a production operation. We spent considerable time experimenting with different heights at which to attach the shaker head, positions around the trees from which to shake , and often used longer and slower shakes than were really necessary. We estimate that about one tree per minute could be harvested during good cone crops if a shaker and mechanized catch frame are used. An additional advantage of tree shakers is that they are not restricted to gentle terrain as are most lift devices. A combination of machine harvesting and hand picking will speed up cone harvest considerably and will greatly reduce collection costs per bushel.

English Equivalents

1 centimeter (cm) = 0.39 inch
1 meter (m) = 3.28 feet
1 kilogram (kg) = 2.20 pounds
1 hectare (ha) = 2.47 acres