Snow Damage

to Young Western Hemlock and Douglas-Fir

By Rudolf Kangur

Research Paper 21
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SUMMARY

Data collected from permanent sample plots at medium and high elevations in Oregon's coastal forest clearly indicate that snow damage adversely influences stand development.

Sapling stands of western hemlock and Douglas-fir were subjected to severe snow damage above 1,000 feet in the early parts of 1965 and 1966 and above 2,500 feet in the winter of 1968-69. These data were collected from thirty-two 1/10-acre plots in four locations in western Oregon. The plots, thinned and unthinned, were in site-quality classes III and IV. Damage varied among the locations and also among the plots in each location. The percentage of damaged trees ranged from 0 to 77.9. Damage was considered severe when 30 percent of the trees were injured in stands spaced about 4 by 4 feet, equivalent to about 2,700 trees per acre before the snowfall.

The study showed that:

Trees growing openly at seedling and early sapling stages offered more resistance to snow injuries than trees in densely stocked stands.

Sapling stands 21 years old, thinned 2 years before the snowfall, had more damage than an adjacent unthinned stand.

Extremely heavy snowfall caused severe damage in a dense, unthinned stand, but damage in an adjacent stand thinned 6 years before the snowfall was very light.

The percentage of damaged trees in sapling stands decreased with increase of tree diameter.

In mixed stands of saplings, Douglas-fir trees were more susceptible to snow injuries than western hemlock.

Early, heavy thinning is recommended to avoid damage from snow.

SNOW DAMAGE TO YOUNG MIXED FORESTS OF WESTERN HEMLOCK AND DOUGLAS-FIR

by
Rudolf Kangur

INTRODUCTION

Snow damage was evaluated in four forest management research areas in mixed stands of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) in the sapling stage and in one area where the stand was entirely western hemlock. Three other research areas shown in Figure 1 were not surveyed because, at their low elevations below 700 feet, snow was not damaging. The study focuses upon the degree of damage in thinned stands, the injuries caused by the snow, and the resistance offered by Douglas-fir and western hemlock to the mechanical action of snow. Biological factors in the trees that cause resistance or susceptibility to snow injuries also are discussed.

This study is, in effect, a post-mortem on damaged sapling stands on established research plots, to discover any information that would be helpful to land managers.

Snowfall at higher altitudes in the Oregon Coast Range normally occurs from December to April. In young forests, snow causes multiple injuries to the trees. Although the occurrence of snow damage is generally known because the evidence of the damage is traceable for many years, its effect in young stands has not been fully appreciated. Damage in dense sapling stands is unnoticed if no management activities take place in the stand. Also, some foresters believe that snow damage in young forests may serve as selective thinning (1,6). My observations suggest that snow is a poor thinning agent because of the unsatisfactory distribution of crop trees that results.

THE PLOTS SURVEYED

Snowfall. From January to May of 1965 and 1966, snowfall in the Oregon Coast Range caused extensive damage in young-growth forests. Damage also occurred in the winter of 1968-69. The damage was primarily at and above 1,000 feet in 1965 and 1966 and was extremely heavy above 2,500 feet in the winter of 1968-69. The research areas were inaccessible, so snow depth could only be inferred from limited data at stations as near as possible.

The two weather stations (Cherry Grove and Valsetz) nearest the Trask Research Area are at elevations of 780 and 1,135 feet. Maximum depths of snow on the ground were 18 and 26 inches in 1965, 20 inches at both stations in 1966, and 36 and 41 inches in 1968-69 (U.S. Weather Bureau). At 3,100 feet elevation on Mt. Hebo in the winter of 1968-69, maximum snow depth was estimated to be 150 inches by the Mt. Hebo Air Force Station. Depths at the research plots where damage occurred were assumed to be less than on Mt. Hebo, but more than at Valsetz.

Surveyed areas. Snow damage in stands of saplings was surveyed in detail in 1965 and 1966 on one-tenth-acre permanent sample plots where the elevation was 1,400 feet at Triangle Lake, but ranged from 2,300 to 2,800 feet for the other areas (Figure 1). Several thousand trees were observed in 26 plots, 23 of which were thinned from 2 to 4 years before the snowfall. Six additional thinned plots, established in 1965 in the fourth study area, were examined in the summer of 1966. Blue Lake I was entirely western hemlock; the other four areas had mixed stands of Douglas-fir and western hemlock. Snow damage also was examined

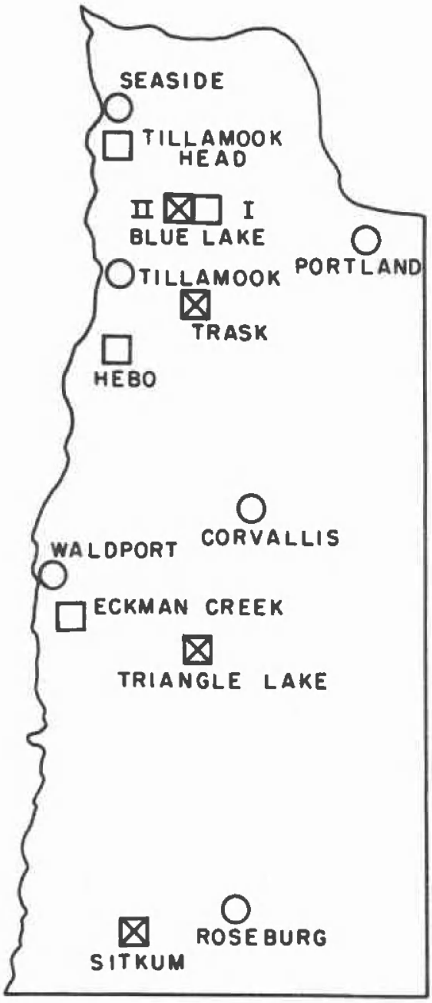

Figure Figure 1. Locations of permanent sample plots of western hemlock (open squares) and mixed western hemlock and Douglas-fir (squares with diagonals).

Figure 2. Snow damage in a dense, unthinned stand of Douglas-fir and western hemlock 26 years old. The opening was caused by a snowstorm in early spring of 1965 at the Blue Lake Forest Management Research Area.

in adjacent unthinned stands of the same age at the Trask Research Area and in a 12-year-old stand at Blue Lake. A detailed survey of damage was made in the same study areas in the spring of 1969.

Stand density and age. Initially, stocking ranged from 3,900 to 21,000 trees to an acre. Before the first snow damage, trees on thinned plots ranged from 440 to 2,960 to an acre. The age of the stands on the study plots ranged from 20 to 26 years in 1965.

Crown canopy. The original stands in each study plot had a dense canopy formed by many trees with narrow or thin crowns and flexible branches, and a few trees with widespread and long crowns with rigid branches. In all plots, the upper surface of the crown canopy before thinning was mesh-like, unbroken, and compact. The lengths of crowns and the lengths of the branches varied conspicuously among the trees. Also, many trees had asymmetrical or misshaped crowns.

Stem form. Except for a few dominant trees, each with a stem form resembling a tapering, free-growing tree, most of the trees in each plot had cylindrical stems without the basal enlargement of a broadened root collar, which suggests that the trees were poorly anchored to the ground.

Early damage. Evidence of prior snow damage, such as clumps of bent or broken trees or single trees broken or leaning, was found in each study area. Furthermore, many trees had a basal sweep, which is characteristic of trees damaged by snow at very early ages.

SNOW DAMAGE

Damage in Unthinned Stands

Three unthinned plots were surveyed, one each at Trask, Blue Lake, and Sitkum. There was no unthinned control plot at Triangle Lake.

In unthinned plots, damage in the consecutive years of 1965 and 1966 was not considered to be dangerously destructive. Losses were concentrated in small groups in which all trees were bent down, uprooted, or broken, regardless of the size of the tree, its position in relation to the canopy, or the properties of its stem and crown (Figure 2). In addition to groups of injured trees, damaged individuals occurred throughout the plots.

In an unthinned control plot at Trask, 22.9 percent of the trees were damaged during 1965 and 1966 (Table 1). Damage was particularly light in adjacent stands of the same age, but with considerably fewer trees to the acre. Although these trees had full crowns with rigid branching, the compact mesh-like canopies had not yet formed. Only a few trees to an acre had bent stems or were leaning, and a few trees had broken tops. Several Douglas-fir trees lost a few branches.

In a control plot, Blue Lake, with more than 80 percent western hemlock, 34.3 percent of the trees were damaged. In well-stocked, unthinned, 12-year-old stands in the vicinity of the study area, several trees were badly bent but had recovered. Only trees that grew in dense clumps were damaged beyond recovery. At Sitkum, the damage was 10.9 percent in 1965-66.

Snow in the winter of 1968-69 was extremely destructive to the unthinned plot at Trask; 77.9 percent of the trees were damaged. Damage extended to wide areas in adjacent unthinned stands at 2,500 feet and above. Most of the severe damage occurred in dense stands. Damage was obviously less severe in stands where the trees had room for expansion at early ages than in dense stands. In unthinned plots at Blue Lake and Sitkum, damage in the winter of 1968-69 was minor compared with damage at Trask. Trees were damaged around the edges of the openings caused by snow in 1965 and 1966. In the vicinity of both study areas at 2,500 feet and above, however, the damage was extreme in stands up to 15 years old.

Damage in Thinned Stands

Damage varied among different areas and also among the plots in each area. The severity of the damage was evaluated by comparing the number of injured trees to the total number of trees before snowfall and is expressed as a percentage. Damage was defined as severe when 30 percent or more of the trees were injured in stands spaced about 4 by 4 feet, and where haphazard spacing resulted in injured trees that impeded application of planned thinning schedules. Damage was considered moderate when it was between 15 and 30 percent and where injured trees were more or less evenly distributed over the plots. When fewer than 15 percent of the trees were injured, damage was considered light.

Douglas-fir and western hemlock trees suffered heavy damage in 1965-66 in plots at Trask. For plots thinned late in the summer of 1963, damage averaged 51.9 percent (Table 1). Although the number of trees and their average diameters were almost identical on each of the six plots before snowfall, the percentage of damaged trees ranged from 38.6 to 60.0 percent.

Table 1. Relation of Time After Thinning to Snow Damage in Thinned and Unthinned Stands of Mixed Douglas-Fir and Western Hemlock.

Time after thinning	Snow damage 1965-66	Snow damage 1969
Years	*Percent*	*Percent*
TRASK		
0	22.9	77.9
3	51.9	–
6	–	7.4
SITKUM		
0	10.9	11.6
3	18.0	–
6	–	4.1
BLUE LAKE I		
0	34.3	26.8
7	2.4	–
10	–	0.3
BLUE LAKE II		
0	34.3	26.8
3	17.6	–
7	–	1.6

Practically no damage was recorded in the plots at Blue Lake I. The plots were thinned twice at 2-year intervals before the snowfall of 1965. In adjacent stands at Blue Lake II that had two and one-half growing seasons between first thinning and snowfall, 17.6 percent of the trees suffered injuries. The severity of the damage among the plots ranged from light to moderate.

Damage was also light to moderate and averaged 18.0 percent on the plots at Sitkum, where the first thinning had been made late in the summer of 1963.

Snowfall in 1968-69 caused very little damage to any thinned stands under observation. Most damage occurred on plot 2 at Trask, where 12 trees of 63 were damaged.

Injuries

Damaged trees were classified by their appearance into two groups, according to their relation to the stand.

Trees lost to the stand. Trees in one group had injuries of a type and severity that eliminated them from the stand. Trees were severely bent or completely down or had broken stems. Downed or severely bent trees were mostly the codominant and taller intermediate trees with slender stems and hardly noticeable butt swells. The crowns of the trees had developed vigorously, but mostly expanded to one side. The typical injury, which showed up on bent trees as a longitudinal split on the lower part of the stem, was a stem fracture between base and breast height, or the tree was completely uprooted. A large percentage of the broken trees were dominants with broadened root collars, an indication that the trees were firmly anchored to the ground by extensive and deep root systems.

Trees growing but unsuitable as crop trees. Trees in the other group were leaners and trees with broken tops. Those with broken tops were mostly upper crown class trees with long crowns. After top breakage, the trees still had sufficient living crown for the development of new leaders. The leaning trees were not uprooted and had no visible injury to their stems. The stems were either slightly bent or root systems were lightly lifted. When the damage consisted only of light bending on the upper part of the stem, the trees recovered rapidly to a nearly normal position. Where the root system was lifted or the bend occurred in the lower part of the stem, the trees remained leaning and probably would develop sweeping stems with much compression wood. The leaners were mostly suppressed or intermediate trees with short, thin crowns and slender stems. Invisible defects, such as uplifted roots and longitudinal splits in lower parts of the stems, were difficult to assess, but the injuries undoubtedly will reduce the growth and vigor of the trees. Furthermore, the weakened trees are less resistant to infection by wood-decaying fungi.

In 2 years, the trees lost to the stand ranged from 72.5 to 98.2 percent of the injured trees in four study areas.

Relation of Damage to Tree Diameter

Obviously, the severity of damage in thinned sapling stands of mixed Douglas-fir and hemlock was not affected either by the density of the stand or the average diameter of the trees. Although the number of the trees and their average diameters in all plots in each location before the first snow damage were remarkably similar, the severity of damage among the plots was significantly divergent. Susceptibility to snow damage of single trees seemed to decrease with increase of the tree diameter at breast height (Figure 3). Of all the trees injured in 1965 and 1966 in thinned stands, 84.1 percent were 1.5 inches and less in diameter at breast height, and 15.8 percent were from 2.6 and 4.5 inches in diameter. In unthinned stands at Trask in 1968-69, however, these figures were 70.9 and 25.9 percent, respectively, and the remaining 3.2 percent were trees 4.6 inches and up.

The data suggest that in precommercial stands the combined resistance of the trees to the mechanical action of snow depends largely on the stem diameter of individual trees. Thus, the larger the breast-high diameter of the Douglas-fir and western hemlock trees at the sapling stage, the more resistance they offer to snow injuries.

Relative Susceptibility of Douglas-fir and Western Hemlock

After the plots were thinned, Douglas-fir and western hemlock were reasonably well distributed in each surveyed plot. The ratio of Douglas-fir to western hemlock, however, varied among the plots. Blue Lake I had no Douglas-fir. In the other four locations, the average ratio ranged from 0.15 to 1.38. Although the mixture was different in each stand, the percentage of injured Douglas-fir in all areas within the various diameter classes was higher than in western hemlock. The results are shown in Figures 4 and 5. Furthermore, based on data obtained in 1965 and 1966, the average diameter of all injured Douglas-fir trees was 2.2 inches, compared with 1.9 inches for western hemlock, although the differences ranged from 0.1 inch at Triangle Lake to 0.8 inch at Trask.

DISCUSSION

Causes of Damages

Snow damage to individual saplings results from the interaction of stresses in the crowns caused by both the weight of the snow and air movements and further influenced by the resistance offered by the tree stems. Damage is done in two steps—the interception and accumulation of snow by tree crowns and the bending, breaking, or uprooting of the tree. The properties of the tree crowns and atmospheric conditions directly affect the accumulation of snow. Nohara (11), Miller (10), and Saeki and Sugiyama (13) report that biological properties of tree crowns affect the weight of snow loads, and that snow loads on tree crowns are initiated and reinforced by slow wind speed and an air temperature just below freezing. Douglas-fir, with its dense, stiff foliage and large, horizontally spread crowns with upturned rigid branches and needles, can hold more snow than can western hemlock with flexible branches and short, soft needles that allow the snow to slide through.

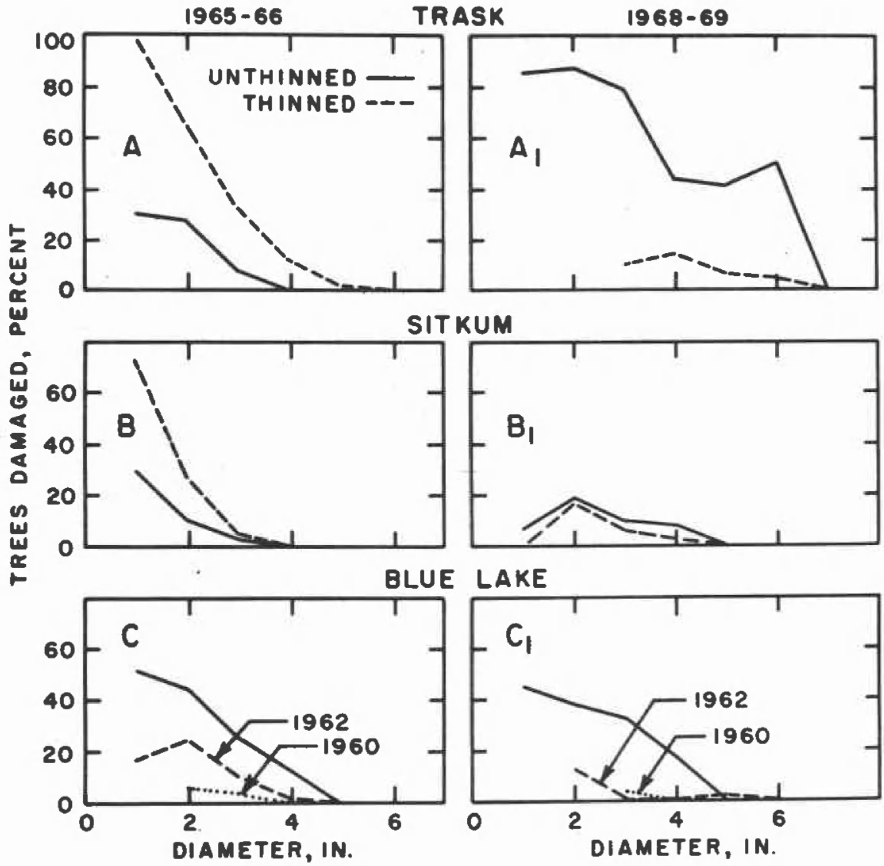

Figure 3. Relation of the percentage of trees damaged to stem diameter in thinned and unthinned stands. Stands at Trask and Sitkum, thinned 2½ growing seasons before the snowfall of 1965, suffered damage more severe than in unthinned stands (*A*, *B*); this was contrary to the situation at Blue Lake (*C*) where stands thinned 3 and 5 years before the snowfall of 1965 suffered less damage than the unthinned stands. At all three locations in 1968-69, the unthinned stands were damaged more severely than the thinned stands (A_1, B_1, C_1), especially at Trask.

Saeki and Sugiyama (13) found that damage to the trees is influenced not only by the weight of snow in the crowns but also by the resistance of the stem and the root system to that weight. The resistance of the tree is determined largely by the structure of the stem and root system and varies in different species and under different stand conditions. Tapered stems with broadened root collars, which are related to extensive root systems (Laitakari, cited by Larson, 8), offer maximum resistance to oppressive stresses. Trees with slender stems, shallow root systems, and no butt swelling were highly susceptible to injuries.

Both the tapered stem and extensive root system with broadened root collar have to be considered as influential factors in selection of prospective crop trees.

Relation of Damage to Stand Characteristics

That stand age, density, and condition of the crown canopy directly affect the severity of damage to groups of trees has been commonly reported (4, 5, 12).

Unthinned stands. In unthinned, young-growth forest such as described in this report, an excessively dense canopy forms early and is maintained for long periods as a mesh-like

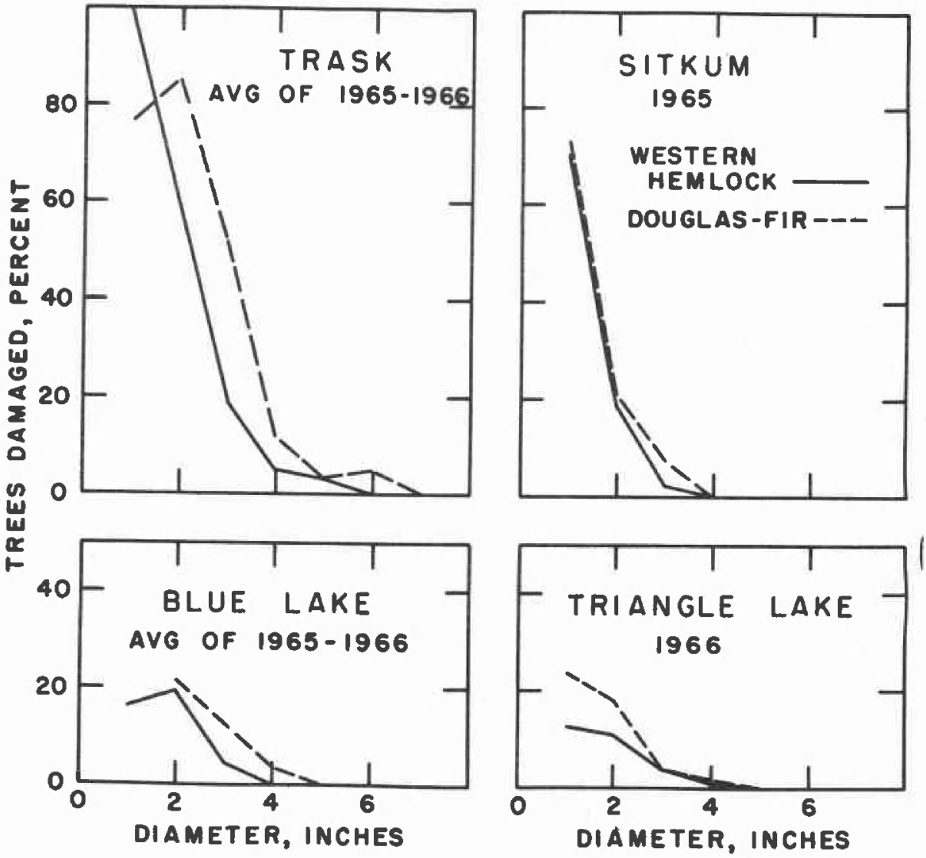

Figure 4. Relation of the percentage of damaged Douglas-fir and western hemlock to stem diameter in thinned stands.

structure. The flexible branches of western hemlock are interlaced with the more rigid branches of Douglas-fir, and thus the canopy acquires the characteristics of a receptacle with great ability to intercept snow and accumulate heavy loads. Furthermore, with too many trees to an acre, the inherited tapering of the tree stems has been modified to a more slender form that greatly impairs the stand's stability, according to Larson (8). The stand structure cannot function as a reliable support and makes the stand vulnerable to snow damage from seedling to pole stages. The trees are injured mostly in groups, which creates unevenly spaced openings of various sizes. These openings tend to enlarge during successive snowfalls to form stands where sporadic openings alternate with small clumps of trees. Because of this clumping effect, snow damage cannot be accepted as natural thinning to reduce density in heavily overstocked stands of Douglas-fir and western hemlock.

Thinned stands. In thinned stands, the pattern of snow damage was different from that in unthinned stands. Most of the damaged trees in thinned stands were scattered singly all over the area, with a small number of trees broken down in groups. Damage was more severe on those plots where thinning was completed shortly before snowfall when mutual support of the trees was temporarily weakened by thinning. The type of injury on free-standing trees and also the severity of the damage in thinned stands seem to be related closely to the properties of the crowns and structure of the stems. Therefore, such properties as length and density of the

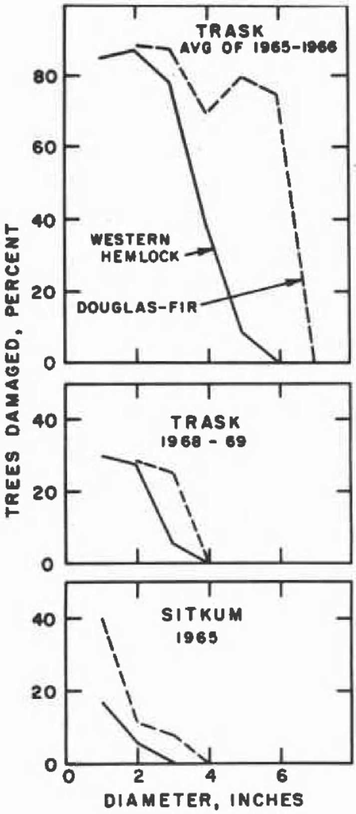

Figure 5. Relation of the percentage of damaged Douglas-fir and western hemlock to stem diameter in unthinned stands.

crown together with the rigidity of branches and needles are, again, decisive factors for accumulating heavy snow loads on tree crowns and exerting stresses on the stems. The vertical and lateral stresses on free-standing trees, with the critical points on the stem described by Chladek (2), will be increased significantly by the weight of heavy snow, particularly when the loaded crowns also are subjected to strong air movement. The free-standing trees may become uprooted, or the stems bent or broken. Severe injury occurs at the base of the tree, at the root system, or at the critical point of the stem where the least resistance is offered by the tree to the type of stresses exerted.

Preventive Measures

Snowfalls are inevitable. They cannot be manipulated, but the dangers arising from snow loads could be reduced by applying silvicultural techniques to increase resistance offered by the trees to damaging stresses and by mechanically decreasing the weight of the snow at the time of the snowfall.

Silvicultural. Thinning in sapling or early pole stands influences snow damage and is, therefore, recommended as a preventive measure. The relation of the age and species composition of the stand to the beneficial effects of thinning has not been tested thoroughly, however.

Snow damage in each 1-inch diameter class in mixed stands of Douglas-fir and hemlock that had been thinned shortly before snowfall was much higher than the damage in unthinned stands. Also, the percentage of damaged trees was higher in these thinned stands. When three or more growing seasons had elapsed after the first thinning, however, trees in thinned stands suffered less damage than trees in unthinned stands (Figure 3-C), and the difference was greatest with extremely heavy snow such as occurred in 1969. Similar results were reported by Roe and Stoeckeler (12) in stands of jack pine, 5 to 10 years old.

Grunig (5) reported damages are less severe in stands thinned at early ages than in unthinned stands or in stands where thinning had been delayed. Mracek and Chyba (9) found that, in stands of Norway spruce, trees up to 4 inches in diameter at breast height with slender stems and short crowns and the trees with excessively wide crowns were injured most frequently in thinned stands. Williams (14) reported snow damage in open stands of mixed Douglas-fir and hemlock at seedling stages and fast recovery of damaged trees in the next growing season.

My observations and the literature support the suggestion that trees grown in open stands in seedling and sapling stages develop characteristics that resist snow damage. When damages occur because of extremely heavy snow, and when the type of damage is stem bending, top breaking, or branch stripping, the trees recover rapidly. My data, as well as the literature, also suggest that light and repeated thinnings from below in overstocked stands of Douglas-fir and hemlock in seedling and sapling stands may reduce the danger of severe damage in later years. Thinning should be regarded as a major preventive measure to avoid snow damage in young stands of Douglas-fir and hemlock at seedling and sapling stages.

Mechanical. Flights with helicopters have been made in Germany to test whether air movement caused by rotors could sift dangerous layers of wet snow from tree crowns. Cramer (3) reported a flight over mature stands of spruce and silver fir. The snow was shaken from 6 to 9 feet of the crowns over a width of 30 to 40 feet in a once-over flight. Some 50 to 75 acres per hour could be treated. Konig (7) found that the flight must be about 9 feet above the canopy at a speed of 19 miles per hour for powdery snow. More research, however, is needed to test the full potentialities and limitations of helicopters to prevent snow damage in thinned stands at sapling stages.

CONCLUSIONS AND RECOMMENDATIONS

At high altitudes in the Oregon Coast Range, snow damage in young-growth forests should not be ignored. It can constitute a serious problem, if thinnings are made too late in sapling stands.

Snow damage apparently can be reduced substantially through early and repeated thinnings with the objective of developing individual trees that will withstand heavy snow loads. The thinning has to be applied when the crowns of trees start to form a compact canopy, regardless of stand age or density, and the thinning should create growing space for those trees that have the best potential to develop tapered stems and expanded root systems.

Repeated thinnings are necessary to develop the trees with growth characteristics suitable for resisting snowload. With early and repeated treatments, the mesh-like canopy characteristic of early ages can be avoided easily. The canopy can be kept open until the stem diameter at breast height reaches the size where the danger of uprooting, breaking, or bending by snow is diminished. If thinning is delayed until sapling or early pole stages, it should be done from below and should favor the dominant and codominant trees with tapered stems, broadened root collars, and well-developed root systems.

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