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Guying to Prevent Wind Sway Influences Loblolly Pine Growth and Wood Properties

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*Restraining young loblolly pine (*Pinus taeda *L.) trees from normal swaying in the wind markedly reduced radial growth in the immobilized portion of the bole and accelerated it in the upper, free-swaying portion. Guying also reduced specific gravity, numbers of earlywood and latewood tracheids, latewood tracheid diameter, and amount of compression wood, but not percentage of latewood.*

Wind is an important factor in the environment of trees, but its influence on tree development is not well understood. Jacobs *(6)* reported that radial growth of Monterey pine *(Pinus radiata* D. Don) was at a maximum at ground level in free-swaying trees and at the point of support in trees artificially restrained. Moreover, the difference in radial growth was much greater in a heavily thinned plot than in an unthinned plot.

In the present study, loblolly pines *(P. taeda* L.) were guyed, and effects on stem growth and some wood properties were observed. These properties included ring width, earlywood width, latewood width, number of tracheids along the radius in earlywood, latewood, and entire ring, average radial diameter of earlywood and latewood tracheids, frequency of compression wood, and specific gravity.

MATERIALS AND METHODS

Eight dominant 19-year-old loblolly pines from 7.3 to 8.9 inches d.b.h. and spaced at least 25 feet from their nearest neighbors were selected in March 1958. The stand, on an industrial forest in southern Arkansas,[2] had been heavily thinned 2 years earlier. The eight trees were paired on the basis of height growth, and one tree of each pair was randomly chosen for guying. Heights and diameters of these trees at the start of the study are given in table 1.

Table 1.—*Tree height and diameter (inside bark at breast height) at start of study in March 1958*

Pair No.	Height		Diameter	
	Free swaying	Guyed	Free swaying	Guyed
	– Feet – –		– Inches –	
1	46.4	48.2	5.74	6.67
2	47.4	46.4	7.10	7.06
3	46.6	52.5	6.57	7.51
4	49.0	50.6	7.46	7.14
Average	47.4	49.4	6.72	7.10

Jacobs' *(5)* method of attaching guy wires to trees was followed. Sets of three guys, spaced at 120° intervals around the circumference of the tree, were placed at points coinciding with the tops of the 1946 and 1950 height increments (roughly 18 and 32 feet). The wires were anchored by stakes driven into the ground and were attached to hooks screwed into the bole. Oscillation of the bole below the upper guy attachment was restrained by double staying. Wires frequently snapped in high winds, just as they did in Jacobs' experiments. In fall 1961, stout coil springs were attached to the wires to prevent breakage, but restraint with the springs did not appear to be sufficiently rigid.

In September 1962, one guyed tree blew down in a storm, and the remaining trees were cut the following March, at which time all eight trees were sampled throughout their lengths. Wood sample disks, 1 inch thick, were

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taken at stump level, breast height, and the midpoint of each annual height increment. A total of 14 disks were taken along the bole: six below the lower guys, four between guys, and four above the upper guys. Taking samples at shoot midpoints rather than specific heights permitted comparisons at bole positions which were equivalent with respect to number of rings from pith. The length of each annual height increment was recorded.

On each disk, measurements were made on the three annual rings formed immediately before and immediately after initiation of the study, the 1955-57 and 1958-60 increments. Although five post-treatment rings were available for measurement, the upper stems of these young trees did not contain five pretreatment rings. Restricting the comparison to these 3-year increments had the additional advantage of eliminating the 1961 and 1962 growth periods, when guys with springs provided insufficient restraint.

Cells and rings were measured on water-soaked disks with a dual-linear traversing micrometer *(12)* along two diameters at right angles to each other. In each ring, the widths of earlywood and latewood zones, according to Mork's *(9)* definition, were measured, and tracheids traversed in each zone were counted. From this information, average radial diameter of the tracheids in each zone was calculated. In addition, diameters of bolewood at the end of the 1954 growing season were recorded so that the cross-sectional area increments could be computed for the 1955 to 1960 annual rings.

Wedges were cut along each measured radius for specific gravity determinations. In these wedges, the volume of each ring in the specimen was proportional to the volume it occupied in the disk. The two parts corresponding to the 3 years before and after treatment were split away, and specific gravity of them, based on ovendry weight and water-soaked volume, was determined by the maximum-moisture method *(11)* after extraction with an alcohol-benzene mixture *(14)*.

To assess the occurrence of compression wood, radial surfaces of specific gravity specimens were smoothed with a microtome knife and examined microscopically for presence of checks in tracheid walls (an indication of compression wood). Five classes were recognized:

(1) Compression wood absent
(2) Isolated compression-wood tracheids
(3) Narrow bands of compression-wood tracheids
(4) Broad bands of compression-wood tracheids
(5) Compression-wood tracheids only.

Since the numerical designations approximate the proportions of compression wood present, these values were averaged for each annual rings examined.

In the analysis, data from separate radii and separate rings were averaged to give single values for the 3-year periods before and after treatment. In addition, effects of initial differences between trees were reduced by taking the difference between the values observed for the post- and pretreatment periods and expressing it as a percentage of the pretreatment value.

Separate statistical tests of treatment differences could be made for each of the 14 bole positions, but this probably would do more to obscure the trends than to clarify them. The data lend themselves better to graphical than statistical analysis, and graphs of results were prepared for each tree and wood character.

RESULTS

Stem Form and Taper

Guying decreased radial growth in the lower bole and increased it in the upper bole (fig. 1). The increase began just below the upper guy. Thus, taper was reduced relative to that in free-swaying trees. Height growth was not significantly influenced by treatment.

These radial growth results agree with those of Jacobs *(6)* for a heavily thinned plot of 16-year-old Monterey pine. He found a difference of 57 percent in bole diameter growth at stump level between free-swaying and guyed trees in the first 2 years after treatment. We found a 3-year difference of 35 percent. We found that radial growth was at a maximum at ground level in free-swaying trees and just above the upper guys in stayed trees and that radial growth in guyed trees exceeded that in free-swaying trees a short distance below the upper guys. These results also agree with those of

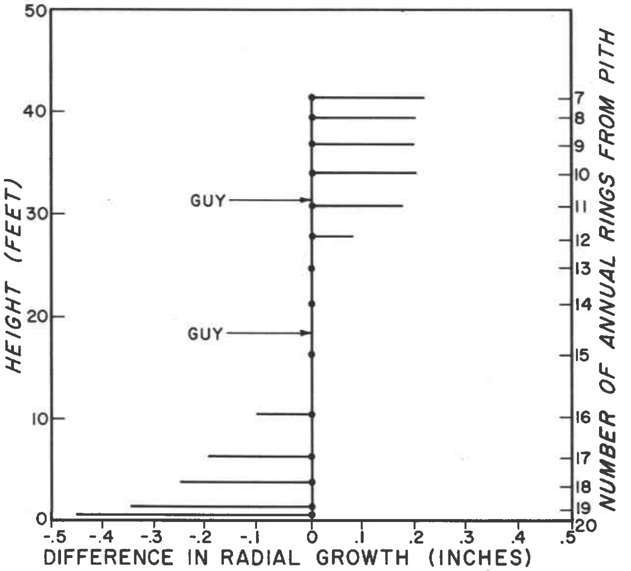

Figure 1.—*Differences in average stem wood radius between trees guyed for 3 years and free-swaying trees at 14 sampling positions.*

Jacobs *(6)*, who offered an explanation for the increased growth below the upper guys. He explained that when the upper stem of a guyed tree is deflected by wind, a sympathetic movement of the bole just below the guy attachment occurs—a repeated flexing.

Similar results also were observed by Larson *(7)* on 4-year-old free-swaying and stayed tamarack *(Larix laricina* Du Roi K. Koch) exposed for 120 days in a greenhouse to multilateral winds from oscillating electric fans.

Wood Characters

Ring width.—Guying significantly reduced average ring width between the stump and the lower guy and markedly increased it above the upper guy (fig. 2A). Earlywood (fig. 2B) and latewood (fig. 2C) zones responded to treatment in the same way as ring width, and in the same proportion. Thus, the trend in percentage of latewood along the bole was not noticeably affected by guying (fig. 2D). This result is not surprising, for Smith had earlier determined, through complete stem analyses of trees in an adjacent stand, that the percentage of latewood within an annual increment at any given position in the tree is a linear function of the number of rings from the pith and the environmental factor most limiting to growth, in this case soil moisture availability *(13)*. In the present study, both factors were controlled by comparing wood formed in the same calendar years, sampled at equivalent positions along the bole with respect to rings from the pith.

Our observations on the width of latewood zone are in partial agreement with Larson's *(7)*. He found the zone of thick-walled tracheids widest in free-swaying trees, thinner in stems restrained more rigidly, and thinnest in trees exposed to no wind at all. He did not find the same variation in latewood thickness along the length of the stem in response to treatment that we did. This lack of complete agreement may be due in part to differences in age class and species. Larson's 4-year-old tamarack stems probably consisted entirely of juvenile wood, while the lower 9 of our 14 sample disks per tree very probably were mature wood. In loblolly pine, the juvenile core consists of the first four to seven rings from the pith.

Radial tracheid count.—Counts of tracheids in earlywood and latewood (figs. 3A to 3D) show trends very similar to those for radial growth (figs. 2A to 2D). Compared with free-swaying trees, guyed trees produced fewer earlywood and latewood tracheids at the lower bole positions and more at positions above the upper guys. The change in number of earlywood tracheids produced in response to guying was accompanied by a proportional change in the number of latewood tracheids. Thus, treatment did not affect the percentage of latewood tracheids in trees (fig. 3D).

Average radial diameter of tracheids.—Although changes in earlywood and latewood widths are primarily explained by changes in numbers of tracheids, there are indications that guying slightly influenced latewood tracheid diameter. For instance, average radial diameter of earlywood tracheids appeared to be largely unaffected by guying (fig. 4A), whereas that of latewood tracheids was influenced to a small degree (fig. 4B). Under free-swaying conditions, the average diameter of latewood tracheids decreased with increasing height in the bole. In guyed trees, average latewood tracheid diameter decreased slightly (about 2 to 3μ) from stump to midway between the two guy positions, but above this point diameter increased somewhat. Thus, in con-

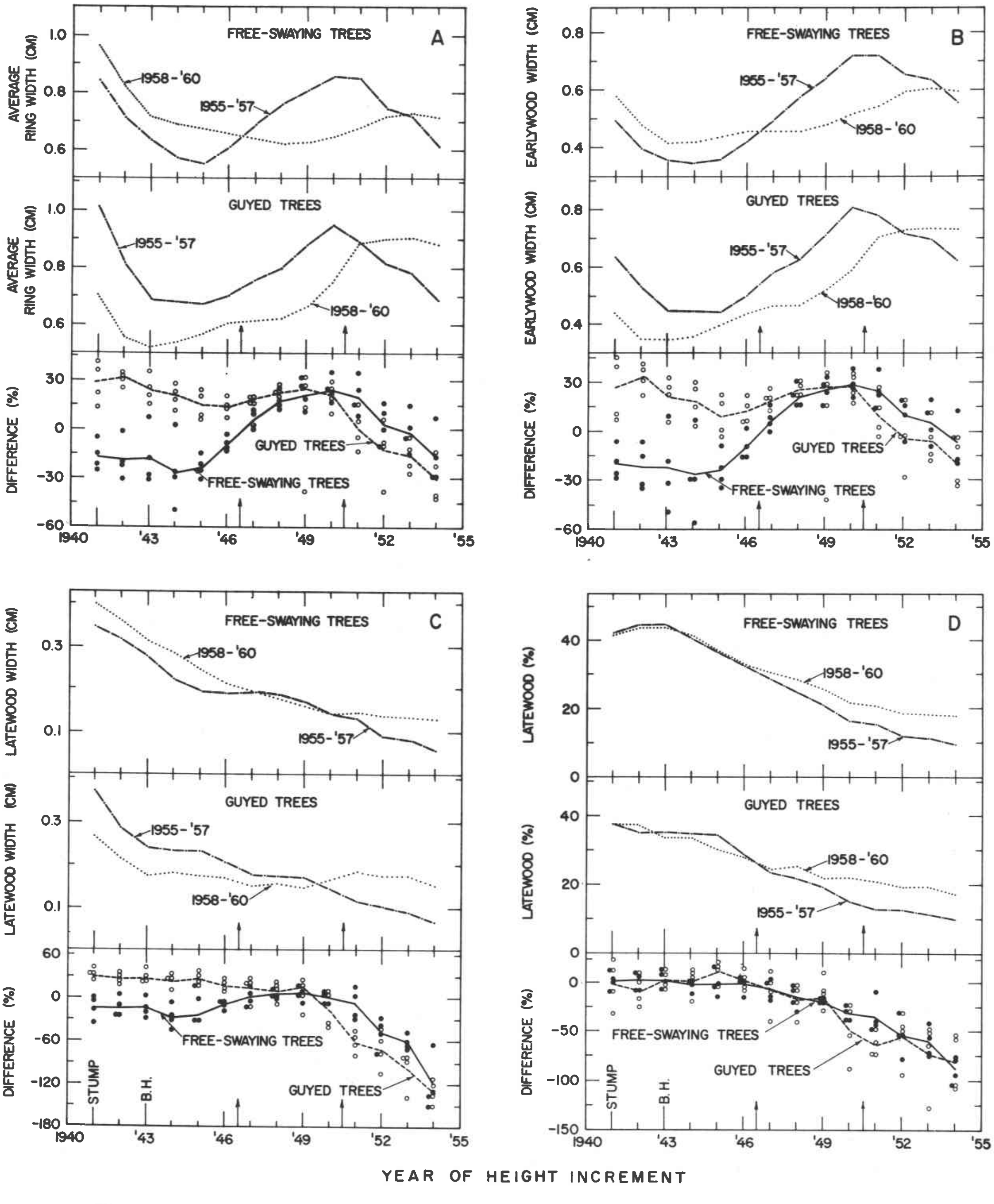

Figure 2.—*Average radial growth at 14 positions along the boles of free-swaying and guyed trees for the pre- and post-treatment years (1955-57 and 1958-60). In the upper and center portion of each block symbols represent the average of four trees. In the lower portion the differences in average radial growth of pre- and post-treatment years are expressed as a percentage of the former for individual trees (solid and open dots) and for the group averages (solid and broken lines). Relative positions of guys are indicated by arrow. A. Ring width. B. Earlywood width. C. Latewood width. D. Percentage of latewood in the annual ring.*

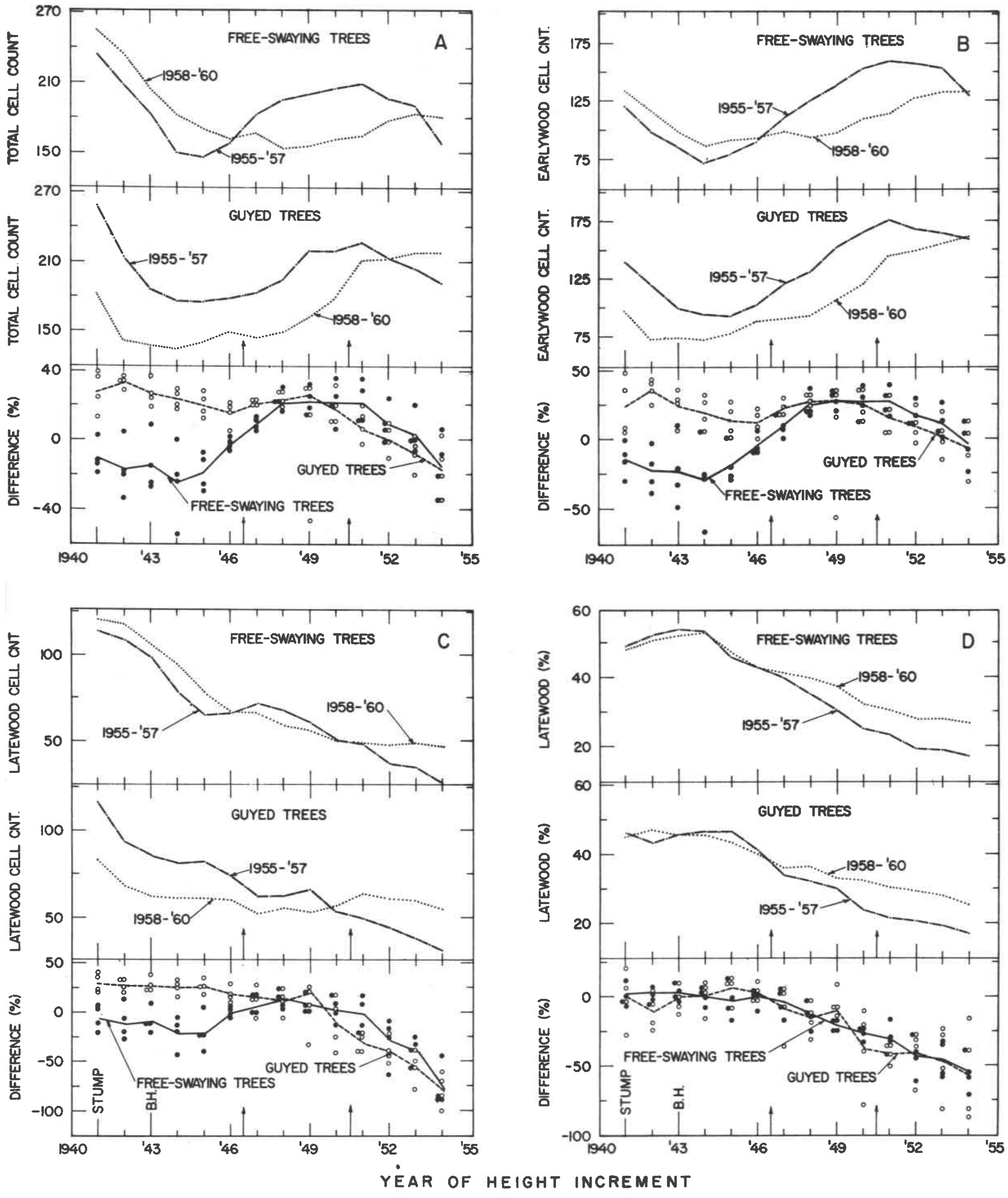

Figure 3.—*Average number of tracheids laid down radially at 14 positions along the boles of free-swaying and guyed trees for the pre- and post-treatment periods (1955-57 and 1958-60). Symbols in the upper and center portion of each block represent averages of four trees. In the lower portion of each figure the differences in number of tracheids formed during pre- and post-treatment years are expressed as a percentage of the former for individual trees (solid and open dots) and for the group averages (solid and broken lines). Relative positions of guys are indicated by arrows. A. Annual ring. B. Earlywood zone. C. Latewood zone. D. Percentage of latewood tracheids in the annual ring.*

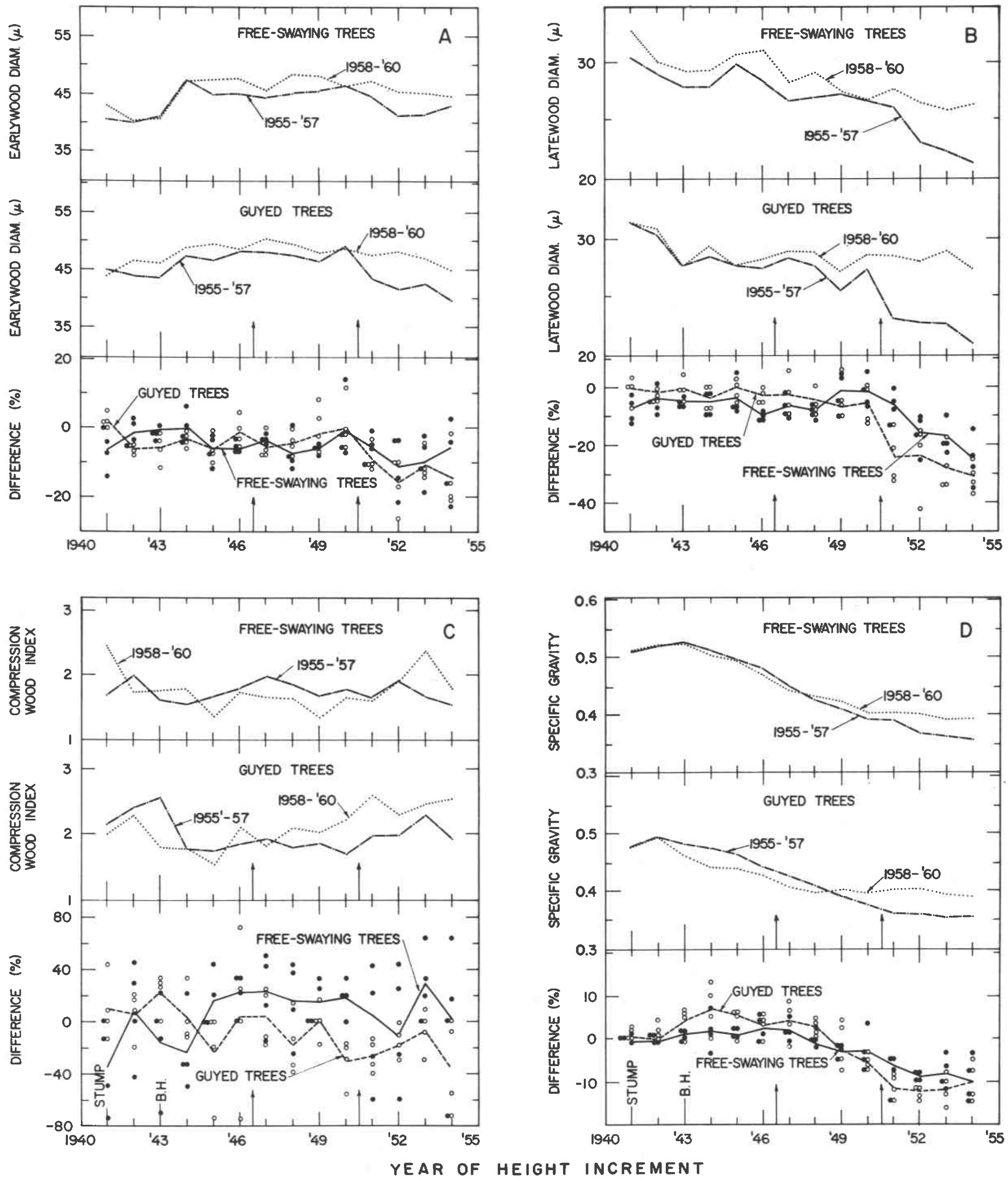

Figure 4.—*Four wood characters at 14 positions along the boles of free-swaying and guyed trees for the pre- and post-treatment periods (1955-57 and 1958-60). Symbols in the upper and center portion of each block represent averages of four trees. In the lower position of each figure the differences between the three pre- and post-treatment increments are expressed as a percentage of the former for individual trees (solid and open dots) and for the group averages (solid and broken lines). Relative positions of guys are indicated by arrows. A. Average radial diameter of earlywood tracheids. B. Average radial diameter of latewood tracheids. C. Frequency of occurrence of compression-wood tracheids. D. Specific gravity.*

trast to the normal trend, guying produced latewood tracheids with a relatively constant radial diameter at all positions along the bole.

One possible explanation for the observed trend in diameter of latewood tracheids in response to guying is the development of compression-wood tracheids, which are characteristically wider in diameter than normal latewood tracheids.

Compression wood.—Guyed trees produced fewer compression-wood tracheids at the lower bole positions and progressively more at increasing heights along the bole than free-swaying trees. This difference between the two groups of trees suggests that unequal tension on the guy wires may have slightly deflected the axes of the tree stems out of normal rest positions. The difference also supports the possibility that the presence of compression-wood tracheids explains the slight increase in average latewood tracheid diameter with height in bole of guyed compared with free-swaying trees.

Specific gravity.—For most utilization purposes, the single most important index of wood quality is specific gravity. In wood produced by guyed trees specific gravity was slightly but consistently lower (approximately 0.02) along the bole from breast height to midway between the two guy positions, above which it averaged slightly higher than in the free-swaying trees (fig. 4D). The difference in specific gravity between the two groups of trees cannot be explained by the differences in the percentage of latewood in the annual rings (fig. 2D), nor can it be explained by differences in the occurrence of compression-wood tracheids, because these usually have lower specific gravity than normal latewood tracheids. Guying may have brought about changes in the amount of cell wall material laid down. We made no attempt to explore this possibility.

DISCUSSION

The study was not designed to test any hypotheses, but to document effects of preventing wind sway on distribution and structure of wood increments. This treatment markedly reduced diameter growth in the lower bole of loblolly pine and accelerated diameter growth at and above the upper guy. Thus, maximum radial growth occurred at positions in the bole where sway tends to impose the greatest strength requirement: at ground level in free-swaying trees and at the upper point of support in trees artificially restrained. These results agree closely with those of Jacobs *(6)* for Monterey pine and Larson *(7)* for 4-year-old tamarack. The significant changes in stem form resulting from guying might lead one to expect equally significant changes in wood characteristics, but these did not occur. Trends in wood structure were observed, but they were small and indicate a conservative anatomical response.

Our observations of stem form and specific gravity distribution along the stem are in general agreement with mechanistic hypotheses. According to these hypotheses, the amount of wood *(8, 10)* and its specific gravity *(15, 16)* at any point along the bole beneath the live crown are proportional to the magnitude of the stress stimulus developed at that point. Accordingly, the shape of the stem is that of a cantilever beam of uniform resistance to bending.

Hall *(4)*, however, attempted to test the mechanistic hypotheses by measuring strain patterns along the red pine *(Pinus resinosa* Ait.) boles generated by natural and simulated wind loads. He concluded that the stems had not developed as beams of uniform stress in either the earlywood or latewood zones. Apparently, factors controlling increment distribution are complex. They may include a hormonal-electrical coordination system as suggested by Asher's *(1)* exploratory experiments on slash pine *(P. elliottii* Engelm. var. *elliottii)*. In a later experiment, Asher *(2)* observed an electrical "response" to leaf fascicle movement in young slash pine that appears to be typical of tissue depolarization. Duffield, in personal communication with Doerner *(3)*, proposed that the cambium is sensitized to hormones to a degree proportional to the amount of static stress and the frequency of application of external loads such as wind. In the present study, guying to restrain the lower bole from sway increased the static load in proportion to the tension on the guy wires. However, we cannot suggest a physiological mechanism for our results until we understand the relationship between mechanical loads and the intermediate biochemical processes of wood formation.

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