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NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
Folwell Avenue, St. Paul, Minnesota 55101

GROSS BASAL AREA GROWTH OF NORTHERN WHITE-CEDAR IS INDEPENDENT OF STAND DENSITY OVER A WIDE RANGE

ABSTRACT. — A 20-year study in a Wisconsin swamp stand of northern white-cedar indicates that after a second thinning gross basal area growth is independent of stand densities ranging from 90 to 225 square feet of basal area per acre. Mortality, net growth, and ingrowth were also independent of density in the thinned plots.

Little is known about the effect of various stand densities on the growth of northern white-cedar (*Thuja occidentalis* L.) despite the fact that this swamp conifer occupies over 1½ million acres of commercial timber land in the Lake States. Data for the first decade following an initial thinning in one Wisconsin stand show that gross basal area growth was greater at high densities than at low densities.[1] However, data now available for this same stand during the second decade, following a second thinning, indicate that gross growth is independent of stand densities ranging from 90 to 225 square feet of basal area per acre. Other growth characteristics also show differences between the decade following the first thinning and that following the second.

Procedures

The study area is in a fertile swamp near Pembine in northeastern Wisconsin.[2] The area is dominated by an essentially even-aged stand of northern white-cedar and a few balsam fir (*Abies balsamea* (L.) Mill.) and black spruce (*Picea mariana* (Mill.) B.S.P.). When the stand was first thinned in 1947, most of the trees were about 65 years old, 5 inches in diameter, and 30 feet tall. The site index is 37 feet at 100 years, which is average for swamp stands of white-cedar.

The study consists of twenty ½-acre compartments, four of which are check areas which have never been thinned. These uncut compartments had an average basal area of 181 square feet per acre in 1947, 224 square feet in 1957, and 253 square feet in 1967. The other 16 compartments form four groups which were originally thinned in 1947 to the following average basal areas: 90, 110, 130, and 150 square feet per acre. The second thinning in 1957 reduced the basal area in these compartments to the same levels. In both thinnings an attempt was made to leave a vigorous and uniformly spaced stand of well-formed, dominant and codominant white-cedar (fig. 1). Growth data were obtained in 1957 and 1967 by remeasuring the single 1/10-acre sample plot within each compartment.

Gross Growth

During the decade following the first thinning, gross basal area growth was lower on the lower density compartments (90 to 110 square feet of basal area per acre) than on those at higher densities (130 to 180 square feet). In contrast, during the decade following the second thinning, gross growth was independent of stand density, which ranged from 90 to 225 square feet (fig. 2). However, the overall rate

[1] *Skilling, D. D. Growth of swamp conifers following an improvement cut. U.S. Forest Serv., Lake States Forest Exp. Sta., Sta. Paper 71, 10 pp., illus. 1959.*

[2] *Grateful acknowledgement is due Wisconsin's Division of Conservation for providing part of the Miscauno Wildlife Area as the study area and for assistance in the field.*

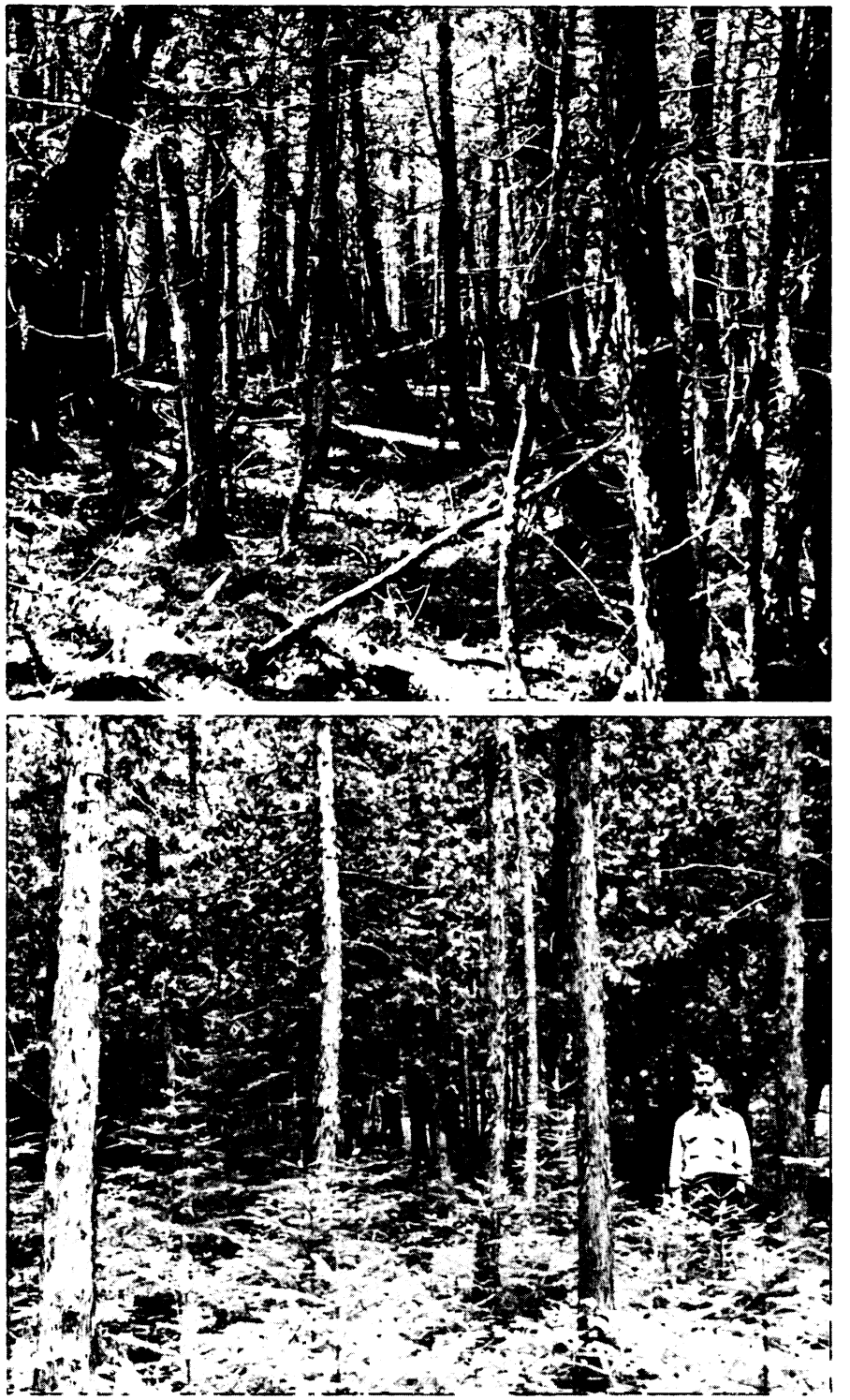

Figure 1. — Views of the northern white-cedar stand in 1967 showing an unthinned check plot (top) and a plot thinned to 90 square feet of basal area per acre (bottom). Note the larger and straighter stems on the thinned plot. (F-518212 - 518213)

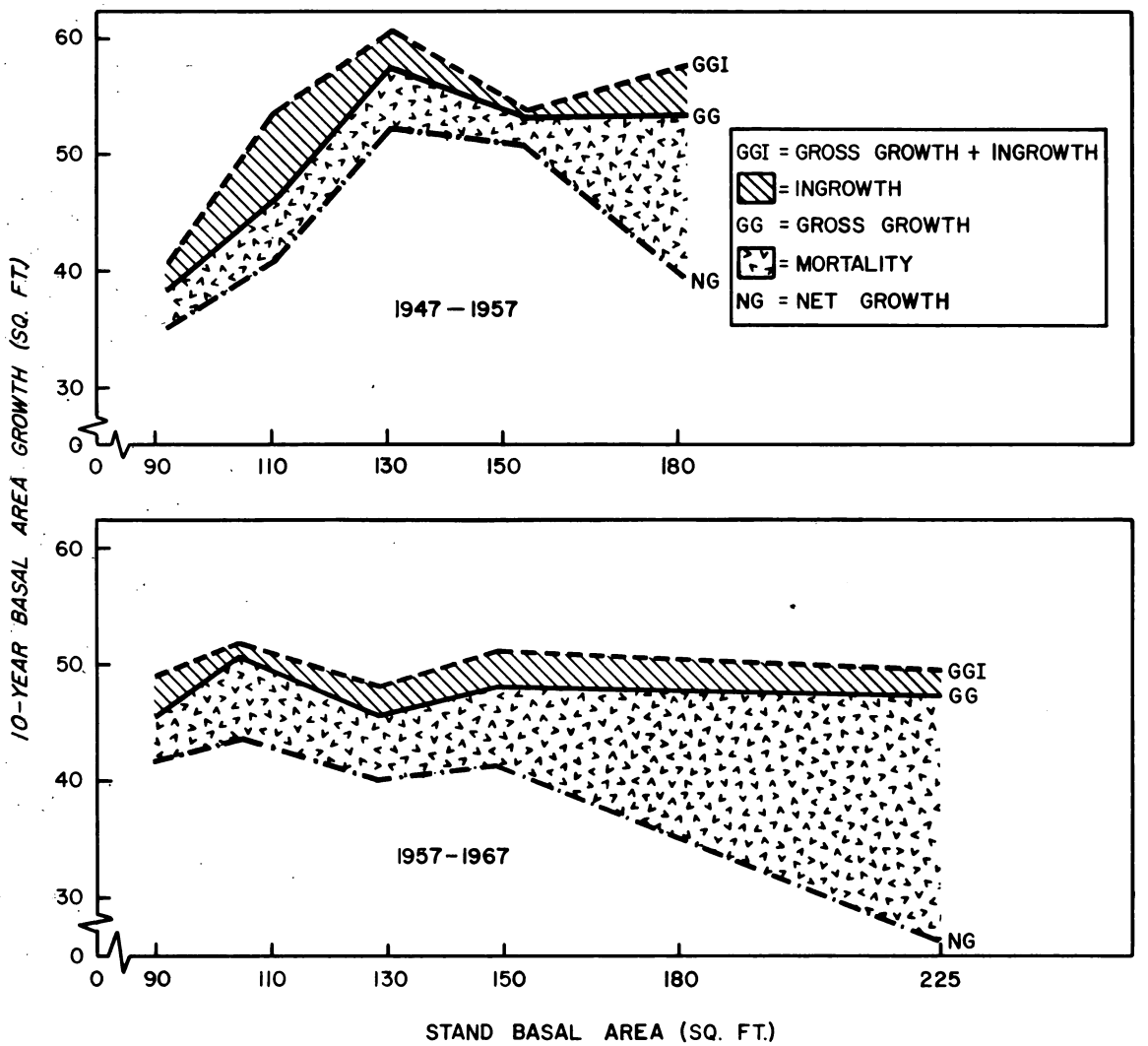

Figure 2. — Average 10-year growth per acre of the northern white-cedar stand as related to average density during the decades following an initial thinning in 1947 (top) and a second thinning in 1957 (bottom).

of gross basal area growth declined during the second decade.

As suggested by Kramer and Kozlowski[3], gross growth may have been less at the lower stand densities than at the higher densities after the first thinning because sudden exposure of the trees increased total respiration more than total photosynthesis. After a decade, however, the crowns of trees growing at the lower densities had apparently enlarged enough to respond quickly to a second thinning. As evident in this study, these differential responses to thinning mean that growth-density relations can be unreliable when based only on data from an initial thinning in a dense stand approaching maturity.

The decrease in the overall rate of gross basal area growth between the first and second decade is most likely due to increasing stand age. Now over 85 years old, the stand has probably passed its point of maximum basal area growth. It is therefore likely that gross growth will continue to decline in subsequent decades.

In contrast to basal area growth, diameter growth was maintained at about the same rate during the second decade. As reported for the first decade[4], diameter growth during the second decade was greatest on the larger trees in the lower density compartments. For example, a 7-inch tree grew an average of 1.4 inches in diameter between 1957 and 1967 on plots having 90 to 110 square feet of basal area, compared to 0.9 inch on plots with 130 to 150 square feet.

Mortality

Since the thinned plots had relatively little mortality[5] in basal area during both decades, net growth was not much less than gross growth on these areas (fig. 2). Thus mortality and net growth are apparently independent of density in thinned stands of northern white-cedar. In contrast, the much higher mortality on the denser, unthinned compartments greatly reduced their net basal area growth, particularly during the second decade (fig. 2).

The relatively high mortality in the unthinned compartments is due to the greater proportion of old-growth balsam fir. For example, fir contributed 60 percent of the total mortality on the unthinned plots during the second decade; whereas white-cedar, which made up 85 percent of the basal area, accounted for less than 30 percent of the mortality, most of which occurred in suppressed trees. Of course, death of the old-growth fir and suppressed white-cedar is to be expected with increasing stand age, because neither has the life expectancy of vigorous white-cedar.

Ingrowth

Data for both decades indicate that total ingrowth in basal area (minimum diameter 2.6 inches) is independent of stand density (fig. 2). However, the ingrowth of northern white-cedar tended to increase with density whereas the reverse was true for balsam fir. White-cedar ingrowth was greater at the higher densities because more small trees were left on the denser plots. Ingrowth of balsam fir came from advance reproduction which grew best on the lower density plots. Thus these plots had more stems of balsam fir that reached the minimum diameter than did the higher density plots.

Conclusions

The findings of this 20-year study indicate that after an initial thinning stands of northern white-cedar can be rethinned to a basal area at least as low as 90 square feet per acre without diminishing gross growth or increasing mortality. For middle-aged stands growing in swamps, it also appears that good diameter growth can be maintained through successive thinnings which favor dominant and codominant white-cedar. Assuming a market exists for small products, thinning will not only increase total yield but also will result in obtaining a final harvest of higher quality.

BRUCE W. FOLTZ
Associate Silviculturist
WILLIAM F. JOHNSTON
Associate Silviculturist

[3] *Kramer, Paul J., and Theodore T. Kozlowski. Physiology of trees. P. 516. New York: McGraw-Hill Book Company, Inc. 1960.*

[4] *See footnote 1.*

[5] *Only two plots (basal area 130 square feet) had heavy wind-caused mortality during the second decade; this loss was apparently due mainly to location of the plots and thus is disregarded in the text and in figure 2.*