Effect of THINNING *on Height and Diameter Growth of* OAK & YELLOW-POPLAR SAPLINGS

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U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-173
1970

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THE AUTHORS

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MANUSCRIPT RECEIVED FOR PUBLICATION 19 JAN. 1970.

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What Effects from Thinnings?

THINNINGS ARE an integral part of even-aged management for efficient and profitable production of timber products. Thinnings started at an early age in hardwood stands increase value yields and reduce rotation age by concentrating growth on selected stems.

It is generally believed that thinnings stimulate diameter growth of the residual stems, but have little, if any, effect on height growth. Hebb (*1962*) and Ward (*1964*) stated that height growth and height are relatively unaffected by density. On the other hand, Larson (*1963*) and Smith (*1962*) reported that there is some evidence that density has a definite effect on height growth, especially at very low and possibly at very high densities.

Studying the response to thinning of a 7- to 9-year-old upland hardwood sapling stand, we found that height growth of yellow-poplar and oak trees was markedly reduced by heavy thinning. This suggests that stand density should be carefully controlled to achieve maximum benefit from thinnings in very young stands.

Study Area & Methods

THE EXPERIMENT

Our study was established in 7- to 9-year-old even-aged hardwood stands on the Vinton Furnace Experimental Forest in southeastern Ohio. These stands, which emerged after clearcutting, contain a wide variety of upland hardwood species.[1]

The study consisted of four blocks of plots having residual density levels of 10, 30, 50, 70, and 100 percent stocking[2] assigned at random to plots within blocks. No thinning was done in the 100-percent stocking plots; all other plots were thinned to the required density level. Data are based on 668 trees: 73 dominant or codominant oaks, 202 dominant or codominant yellow-poplars, 162 intermediate or suppressed oaks, and 231 intermediate or suppressed yellow-poplars.

THINNING METHOD

Initial thinnings were made in the winter of 1962-63, to achieve as uniform spacing between residual trees as possible. In general, the less desirable species[3] such as dogwood, sumac, sassafras, red maple, and blackgum—and the lower crown classes of all species—were removed first. However, many stems of less desirable species and lower crown classes had to be left to maintain uniform spacing. Thus the residual stand included stems of both desirable and undesirable species of all crown classes.

During the growing seasons of 1963 and 1964, sprouting from stumps of trees removed in the lower density plots was prolific, and these sprouts grew rapidly. This resulted in the 10-percent stocked plots increasing to almost 52 percent stocking, while the higher density plots increased proportionately less. So the plots were thinned again before the 1965 growing season to maintain

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[1] See appendix for stand composition.

[2] Percent stocking was calculated using Gingrich's (*1967*) formula (tree area in milacres $= -0.0507N + 0.1698\Sigma D + 0.0317\Sigma D^2$) modified to eliminate the negative intercept by forcing the curve through the origin, thus accommodating trees of small diameter.

[3] See appendix for listing of common and scientific names of all trees referred to in this study.

the prescribed density levels. In some of the lower density plots, sprouts from desirable species cut in the first thinning were retained to readjust stocking and spacing. These sprouts were used only to replace residual stems that had died. Although not as tall as the dead residuals, they were vigorous, free to grow, and were judged likely to become a permanent part of the stand.

MEASUREMENTS

Height was measured with a telescopic pole, to the nearest 1/10 foot, and diameter at breast height was measured to the nearest 1/100 inch with a diameter tape. Measurements on residual trees were made each fall after growth had stopped, over a 3-year period.

DATA ANALYSES

Differences among stocking levels in diameter and height growth were tested for significance, using the analysis of covariance, with original d.b.h. as the covariate so the effect of original d.b.h. could be removed. Analyses were performed on seedlings and seedling sprouts only, for all oak species combined, and for yellow-poplar. Separate analyses were made for the dominant and codominat trees as a group, and for the intermediate and suppressed trees as a group for each genus. Differences between the adjusted means were highly significant in each analysis. Multiple-regression equations were derived for predicting the growth rate from stocking level and initial diameter. The adjusted mean growth and the multiple-regression lines are shown in figures 1 and 2. Predicition equations and coefficients are listed in the appendix.

Figure 1.—Effect of stocking level on diameter growth of 7- to 9-year-old saplings. Values have been adjusted for the covariate initial diameter. See appendix for regression formulae.

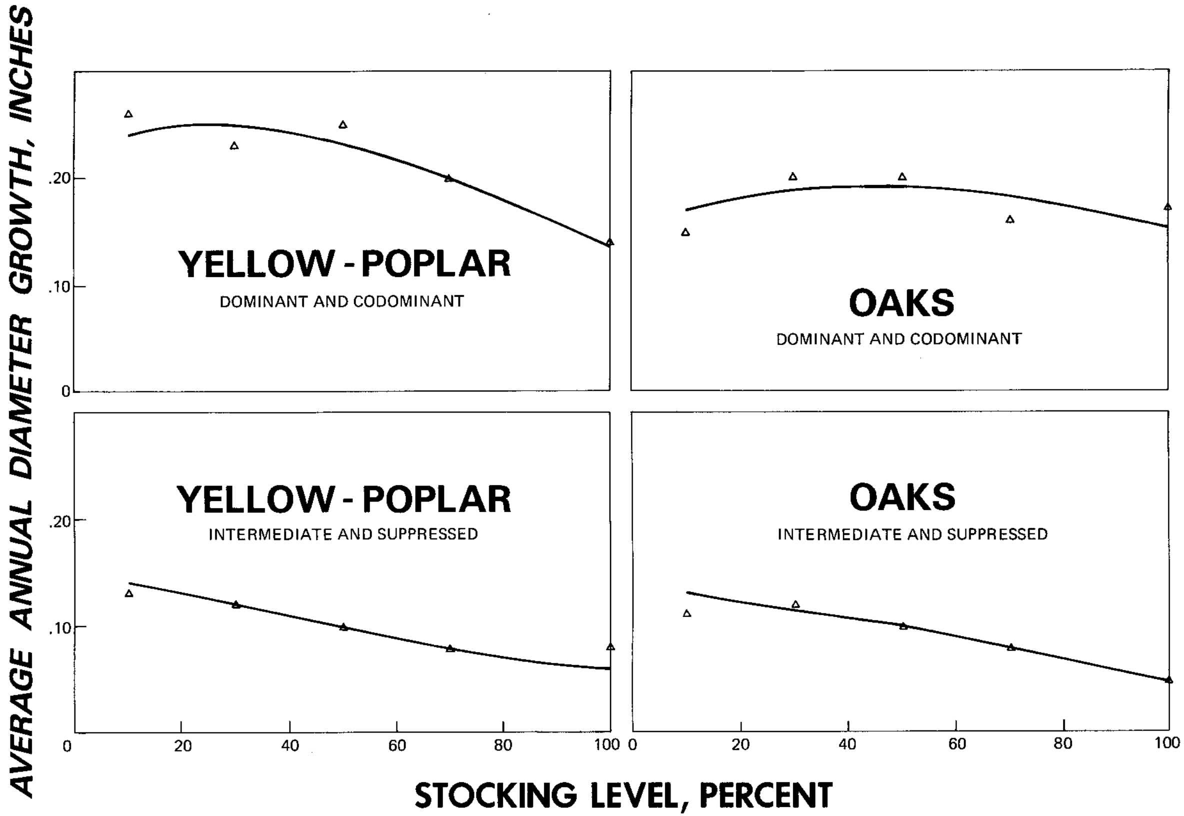
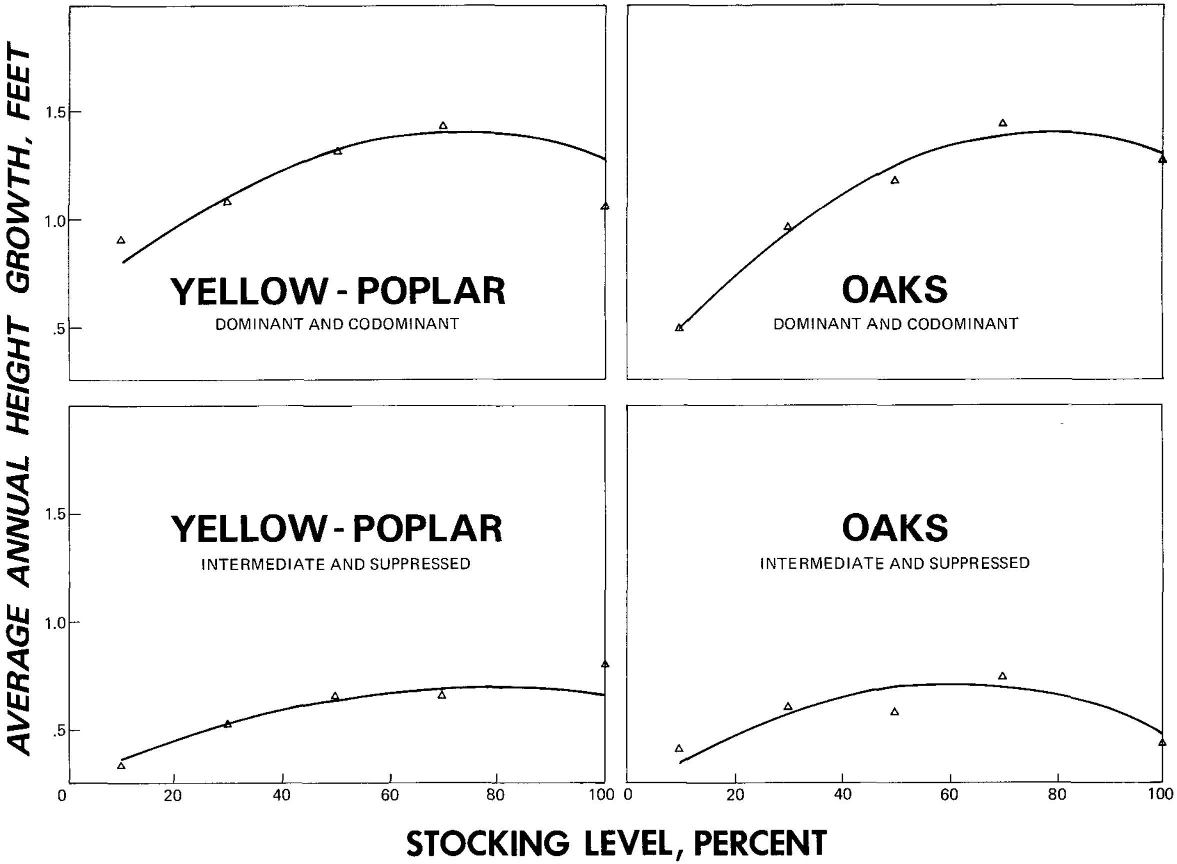


Figure 2.—Effect of stocking level on height growth of 7- to 9-year-old saplings. Values have been adjusted for the covariate initial diameter. See appendix for regression formulae.



Results & Discussion

Both diameter and height growth were significantly affected by initial diameter. The larger the initial tree diameter, the faster a tree grew.

Diameter growth of individual trees generally increased as stand density (stocking level) decreased. Greatest diameter growth occurred at the lowest density studied (10-percent stocking) for intermediate and suppressed trees of both yellow-poplar and the oaks. The dominant and codominant trees followed a similar pattern except that diameter growth dropped slightly at the 10-percent stocking level. Best diameter growth occurred at stocking levels of 50 percent or less for all species and crown classes (fig. 1).

We found that height growth of the individual trees of all crown classes and species was generally best at about 70-percent stocking. At higher stocking levels, height growth dropped slightly; but at lower stocking levels, height growth was markedly reduced. This reduction in height growth at lower densites was especially severe for the dominant and codominant stems (fig. 2). This variation in height growth due to density was made readily apparent by the extreme ranges in density studied. This effect may appear to be random or even non-existent when applied to the smaller range of densities appearing in unthinned or lightly thinned stands.

Although we have not included the data for red maple within the range of densities where it was present, it followed the same general growth patterns as yellow-poplar and the oaks.

Dominant and codominant trees grew faster in both height and diameter and showed greater absolute response to thinning than intermediate and suppressed trees. Nevertheless, the intermediate and suppressed trees did respond to thinning in essentially the same manner as their larger associates.

Conclusions

It is apparent from this study that maximum diameter growth and maximum height growth of young hardwood saplings occur at different levels of stand density. Thinnings that are too heavy will result in loss of height growth; thinnings that are too light will increase diameter growth little, if any.

Maximum height growth generally occurred at about 70 percent stocking; thinning to this density will stimulate both diameter and height growth as compared to unthinned trees. Thinning more heavily generally increases diameter growth further, but reduces height growth. Since very heavy thinnings also tend to increase stem taper, delay natural pruning, stimulate epicormic branching, and otherwise reduce overall tree quality, it is generally desirable to avoid thinnings that reduce density below about 50-percent stocking. As a general rule, we recommend 60-percent stocking as a useful compromise. Both height and diameter growth are acceptable at this level, and stem quality should not be adversely affected.

To minimize costs, some form of crop-tree thinning should be used when thinning sapling stands. In such thinnings, it is the density around the individual crop trees that is important, rather than overall stand density. Total release of crop trees (as in thinning to a specific radius) could reduce height growth even though density of the stand as a whole may be high.

In thinning sapling stands, the larger, dominant, and codominant trees of desirable species should be favored where possible. They respond better to thinning than do the smaller, intermediate, and suppressed trees.

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Literature Cited

Gingrich, Samuel F.
1967. MEASURING AND EVALUATING STOCKING AND STAND DENSITY IN UPLAND HARDWOOD FORESTS IN THE CENTRAL STATES. Forest Sci. 13:38-53.

Hebb, Edwin A.
1962. RELATION OF TREE GROWTH TO SITE FACTORS. Univ. Tenn. Agr. Exp. Sta. Bull. 349, 18 pp., illus.

Larson, Philip R.
1963. STEM FORM DEVELOPMENT OF FOREST TREES. Forest Sci. Monogr. 5, 42 pp.

Smith, David M.
1962. THE PRACTICE OF SILVICULTURE. 7th edition, John Wiley and Sons, New York, N. Y.

Ward, W. W.
1964. LIVE CROWN RATIO AND STAND DENSITY IN YOUNG, EVEN-AGED RED OAK STANDS. Forest Sci. 10:56-65.

Appendix A

Stand composition of sapling hardwood stands before thinning

Species	Stems per acre	Percent of total	Basal area per acre	Percent of total	Percent stocking
	Number	*Percent*	*Square feet*	*Percent*	*Percent*
Yellow-poplar	1,105	12.2	6.94	18.9	19.3
All oaks[1]	525	5.8	2.78	7.5	8.3
Red maple	1,200	13.2	6.90	18.8	18.9
Blackgum	425	4.7	2.39	6.5	6.8
Hickory	480	5.3	1.54	4.2	6.0
Cherry	125	1.4	1.79	4.8	3.2
Miscellaneous[2]	70	.8	1.11	3.0	1.9
Total, trees	3,930	43.4	23.45	63.7	64.4
Dogwood	3,510	38.8	9.02	24.5	34.9
Other brush[3]	1,615	17.8	4.32	11.8	17.4
Total, brush	5,125	56.6	13.34	36.3	52.3
All species	9,055	100.0	36.79	100.0	116.7

[1] White, chestnut, black, scarlet, and northern red oaks.
[2] Aspen, elm, ash, sugar maple, persimmon, and beech.
[3] Sumac, hazelnut, witchhazel, sassafras, sourwood, alder, and chestnut.

Appendix B

List of common and scientific names of species referred to in this study.

Alder, common	*Alnus serrulata* (Ait.) Willd.
Ash, white	*Fraxinus americana* L.
Aspen, bigtooth	*Populus grandidentata* Michx.
Beech, American	*Fagus grandifolia* Ehrh.
Blackgum	*Nyssa sylvatica* Marsh.
Cherry, black	*Prunus serotina* Ehrh.
Chestnut, American	*Castenea dentata* (Marsh.) Borkh.
Dogwood	*Cornus florida* L.
Elm, slippery	*Ulmus rubra* Muhl.
Hazelnut	*Corylus americana* Walt.
Hickory spp.	*Carya spp.* Nutt.
Maple, red	*Acer rubrum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, black	*Quercus velutina* Lam.
Oak, chestnut	*Quercus montana* Willd.
Oak, northern red	*Quercus rubra* L.
Oak, scarlet	*Quercus coccinea* Muenchh.
Oak, white	*Quercus alba* L.
Persimmon	*Diospyros virginiana* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Sourwood	*Oxydendrum arboreum* (L.) D. C.
Sumac, smooth	*Rhus glabra* L.
Sumac, staghorn	*Rhus typhina* L.
Witchhazel	*Hamamelis virginiana* L.
Yellow-poplar	*Liriodendron tulipifera* L.

Appendix C

Prediction equations for diameter and height growth.

DIAMETER GROWTH	$\bar{D}$	R^2
Yellow-poplar, dominant & codominant		
$d = 0.2299 + 0.2824\bar{D} + 0.0031S - 0.000063S^2$	1.668	36.5
Yellow-poplar, intermediate & suppressed		
$d = 0.2245 + 0.2819\bar{D} - 0.0029S + 0.000003S^2$	0.771	34.1
Oaks, dominant & codominant		
$d = 0.0541 + 0.324\bar{D} + 0.0034S - 0.000037S^2$	1.355	48.0
Oaks, intermediate & suppressed		
$d = 0.1848 + 0.2738\bar{D} - 0.0016S - 0.000009S^2$	0.774	42.7
HEIGHT GROWTH		
Yellow-poplar, dominant & codominant		
$h = 0.2561 + 0.9691\bar{D} + 0.0650S - 0.00045S^2$	1.668	27.3
Yellow-poplar, intermediate & suppressed		
$h = -0.2116 + 1.3697\bar{D} + 0.0314S - 0.0002S^2$	0.771	13.1
Oaks, dominant & codominant		
$h = 0.3172 + 0.2291\bar{D} + 0.0915S - 0.00058S^2$	1.355	29.7
Oaks, intermediate & suppressed		
$h = -0.7308 + 1.6792\bar{D} + 0.0522S - 0.00043S^2$	0.774	20.5

where d = 3-year diameter growth, h = 3-year height growth, $\bar{D}$ = average of the initial diameters as shown in the column at the right, and S = value of stocking level in percent. R^2 = Coefficient of determination (percent).

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