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Measuring Financial Gains from Genetically Superior Trees

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Additional keywords: Computer simulation, tree improvement, economic gains, *Pinus taeda.*

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SUMMARY

Planting genetically superior loblolly pines will probably yield high profits. Forest economists have made computer simulations that predict *financial* gains expected from a *tree improvement program under actual field conditions. Equations were derived from data on height, diameter, volume, and survival of unimproved loblolly plantations, and were then modified to show gains made by 8-year-old trees in actual tree improvement programs. Growth of genetically improved plantations was then analyzed, and financial gains were calculated for a 24-year* rotation for each of 472 genetic crosses. Before economists can predict specific dollar returns, *they must find out the growth patterns of superior trees during an entire rotation. The model also* needs *to be* refined to show impact of fusiform rust on growth and yield, to indicate *form classes of genetically improved trees, and to determine if large, small, or all trees make the gains.*

Additional keywords: Computer simulation, tree improvement, economic gains, *Pinus taeda.*

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Rising demands for wood products have stimulated land managers to initiate tree-improvement programs to increase per-acre yields. The success of such programs depends on how much can be spent on improved planting stock, what benefits can be expected at harvest, and how greatly revenues can be increased by the genetically superior trees. This paper describes a method for analyzing the economics of tree improvement.

Most economic analyses of tree improvement programs compute per-acre gains by extrapolating data from improved trees grown under special conditions rather than in the field (Lundgren and King 1966, Davis 1967, Porterfield 1974, Swofford and Smith 1972). The present analysis projects economic gains for improved loblolly pine plantations after actual field conditions were simulated. Our method was to derive growth equations incorporating data for unimproved loblolly plantations. After modifying these data to show gains obtained in an actual tree improvement program, we analyzed the growth of genetically improved plantations. We then estimated economic gains reflecting the influence of actual stand conditions on stumpage prices and harvesting costs, which have been shown to affect returns significantly (Row 1973).

DATA

A computer program (Row 1974) was developed to transform mathematical functions (Bailey and Clutter 1970, Lenhart and Clutter 1971) describing the growth of unimproved loblolly pine plantations. The data reflected 8-year gains in growth and volume of genetically improved planting stock with a geographic range extending from Virginia to Georgia and from the Coastal Plain to the Piedmont.[1] Although fusiform rust infection levels varied widely throughout the area, our simulation assumes that infection and mortality were randomly distributed throughout the data set. Our analysis combines data for the entire area though it would be possible to analyze each geographic province separately.

Average growth values were available for a total of 472 genetic crosses. There were 27 sets of tests for each genetic cross; each set included a check test and from 7 to 33 crosses averaging 27 surviving trees per cross. The descriptors measured were increases in height, diameter, volume, and survival.

[1] Gains were derived from data obtained from the North Carolina State Cooperative Tree Improvement Program.

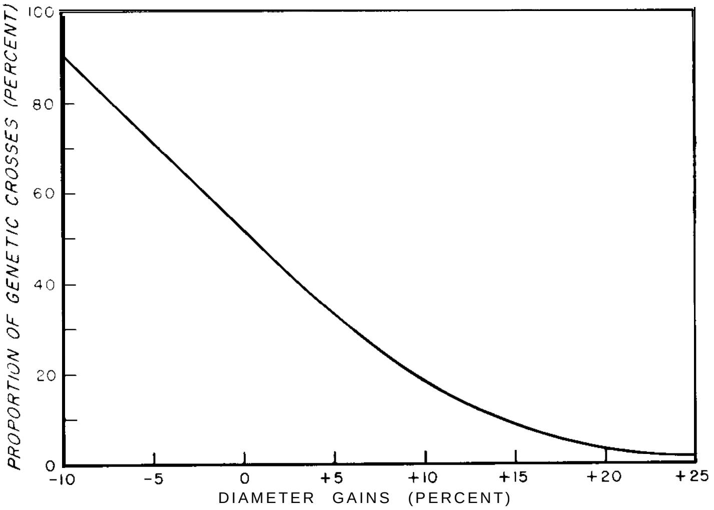

*Figure 2. Proportion of genetic **crosses** exceeding percentage **gains** in **diameter.***

by estimating diameters and heights at age 24 and inserting these values into volume equations developed by Goebel and Warner (1962).

Simulated harvest volumes of genetically improved trees showed substantial gains over volumes of unimproved trees (Figure 3). Average increase in volume per acre was about 12 percent; median gain was 7 percent. On large tracts of

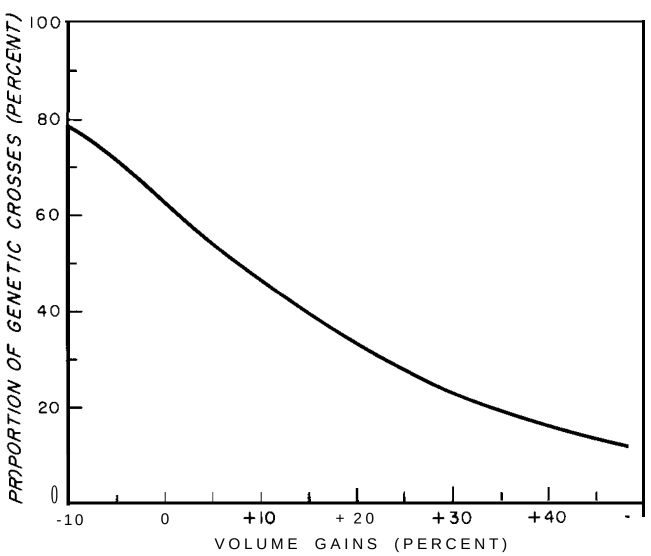

*Figure 3. Proportion of genetic **crosses exceeding** percentage gains in volume.*

Diameter.--Diameter-adjustment ratios were derived by dividing the average diameter of each genetic cross by the average diameter of unimproved trees. Tree gains were converted to stand gains by applying the diameter-adjustment ratios to anticipated minimum and maximum diameters; the relative frequency of basal area occurring for the enlarged diameters was also calculated. The techniques applied were developed for unimproved loblolly pine (Lenhart and Clutter 1971). With a beta distribution, the relative frequency of basal area occurring on trees of diameter D_i (expected basal area per interval) is:

$$f(D_i) = \frac{\Gamma(\alpha+\beta+2)}{(D_{max}-D_{min})\,\Gamma(\alpha+1)\,\Gamma(\beta+1)} \left(\frac{D_i-D_{min}}{D_{max}-D_{min}}\right)^{\alpha} \left(\frac{D_i-D_{min}}{D_{max}-D_{min}}\right)^{\beta}$$

where

$f(D_i)$ = relative frequency of basal area occurring on stems with diameter D,.

D_{min} = minimum diameter of trees in the stand.

D_{max} = maximum diameter of trees in the stand.

In the expression, alpha, beta, and gamma are distribution parameters defining the shape of the frequency curve and its values. The distribution parameters are functions of age and were not changed by calculating expected values of increased diameters. Our computer program divided the range of diameters into 20 equal intervals (smallest to largest) and converted the results into the expected number of genetically superior trees in each interval. The basal area and average diameter of a genetically improved stand was then computed from the final tabulation of diameters by intervals.

Our simulation showed notable gains in diameter (Figure 2). Fifty-four percent of the genetic crosses showed diameter growth that equaled or surpassed the unimproved trees. Average increases were about 2 percent; median gain was about 1.0 percent. Although average and median values for height increases of the genetic crosses exceeded those for diameter increases, a larger proportion of the crosses showed high gains in diameter. Nineteen percent or more of the genetic trials exceeded a 10 percent increase in diameter as compared to 17 percent for height.

Volume.--Since gains in merchantable volume harvested are not directly proportional to gains in juvenile volumes, we did not compute volume-gain ratios. Instead, we computed volume

Although the genetic tests did not include loblolly seed sources selected for increased survival, our data suggested that survival of progeny at age 8 exceeded that of controls (Figure 4). An average survival rate of 91.7 percent was recorded for genetically improved trees; the rate for checks was 86.3 percent. About 52 percent of the genetic crosses showed a higher survival rate than unimproved trees. Slightly more than 15 percent of the genetic selections demonstrated exceptional survival rates-more than 10 percent greater than survival of unimproved stock.

Financial Results of Planting Genetically Improved Trees

Management regime **.--*In*** the simulation, financial gains from genetically improved stock were calculated for a 24-year rotation for each of the 472 crosses. Management assumptions were: that the stands would be established on old-field sites or prepared cutover timber stands; that there would be 500 seedlings planted per acre; that site index would be 65 feet at age 25; and that the plantations would be harvested for pulpwood at age 24 without prior thinning.

Prices and costs.-The value of timber clearcut at age 24 was based on an equation developed for determining the stumpage price of National Forest pulpwood and sawtimber sales (Row 1973). The cubic foot price is derived from the following expression:

$$P\ g\text{-}5.35 + 2.253\,(D) - 0.024\,(D)^2 + 0.452\,(v),$$

where P is the price in cents per unit, D is average diameter, and v is the merchantable volume per acre. The discount rate was set at 7 percent, equivalent to a discount rate of 10 percent or more if the inflationary tendency of timber prices is introduced into the compound interest calculations. Plantation costs were disregarded, since the cost of establishing improved stock would be the same as that for unimproved with the exception of a premium for superior seedlings. The choice of whether or not to invest in a tree improvement program would then be based on returns from improved trees.

Returns .--Present net worth and annual equivalent income were the criteria chosen to evaluate financial implications. Only financial gains attributable to the use of genetically improved stock were considered. These gains were computed by dividing returns anticipated with improved trees by those expected from unimproved planting stock.

managed timber, 63 percent of the acres consisting of improved trees would exhibit growth rates higher than would acreage composed of unimproved trees. Furthermore, 20 percent of the acreage of improved trees would display volume gains of more than 30 percent.

Survival.—Survival gains were incorporated into the analysis as probability factors. The gains were compared to values obtained for unimproved plantations (Lenhart and Clutter 197 1). When the distribution did not prove normal, and when variations in survival appeared much higher than those obtained for height and diameter, differences in survival between improved and unimproved trees were accounted for by transforming the survival rates into probit form. Probits computed for survival of improved stock were then compared with those of unimproved trees. The Lenhart and Clutter (1971) expression of loblolly plantation survival distribution was:

$$\text{Probit}(S) = 9.3745 - .67637[\text{Log}_{10}(T)] - .96269[\text{Log}_{10}(N_O)],$$

where S is the surviving proportion, T is the plantation age, and N is the original number of seedlings planted per acre. The probits found in the Lenhart-Clutter study were normally distributed; standard error was .448. The range in probability (P) was from 0.0 to 1.0 (poorest to best); average survival probability was 0.5. Genetic improvement in survival was measured as the proportional increase in average P of the genetic crosses to P of controls.

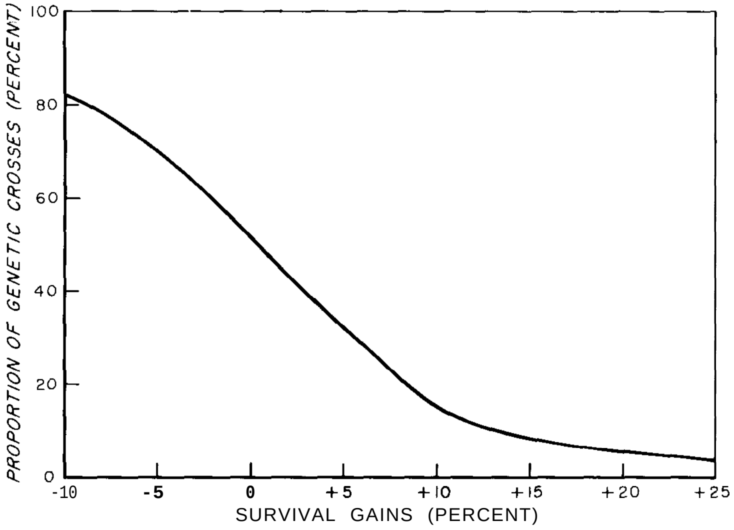

Figure 4.– Proportion of genetic crosses exceeding percentage gains in survival.

Previous economic analyses, particularly Porterfield's (1974), have shown that tree improvement investments are not only advisable but that returns would increase directly with the level of expenditure and effort. Our results indicate probable financial gains from genetic crosses that have not been rogued. In commercial operations, in which poor trees would be rogued, expected financial gains would be even higher than those shown here. These expectations would emanate from selecting from the upper segments of the initial distribution. An analysis of increased selection efforts, intensive roguing, and the resulting economies are contained in Porterfield's (1974) study. Since the present analytical technique is suitable for an entire tree-improvement program as well as for the portions remaining after roguing, this method can be used to predict gains after roguing and selection.

Improving the Method

Improvements in methodology for conducting economic analyses are limited by a lack of data for improved juvenile trees and by the lack of mathematical models of stand development. Future analyses of tree improvement would be improved by the following:

1. Improved knowledge of whether or not growth gains or specific gravity changes evident in the early years of the plantation will continue at the same or at increased or decreased rates throughout the rotation.

2. Volume equations reflecting improved form class of genetically improved trees and therefore requiring upper-stem diameter measurements.

3. Statistics about individual tree diameters and heights to determine if genetic gains are obtained primarily with large trees, small trees, or all trees proportionally.

4. Development of a dynamic model of fusiform rust infection to measure the impact of rust on both the entire stand and on individual tree diameters, heights, and volumes.

CONCLUSIONS

The results suggested here are subject to revision. Subsequent analyses will include additional data on growth patterns throughout the rotation. Ultimately, such information will

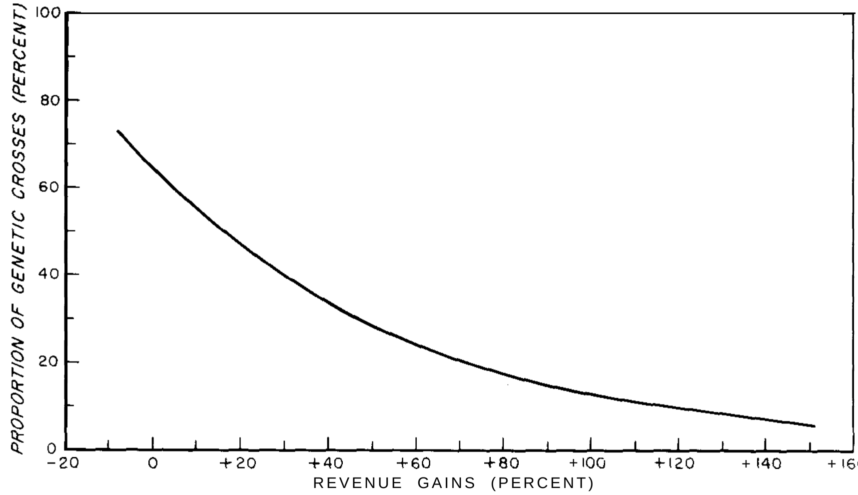

Figure 5. -- Proportion of genetic crosses exceeding percentage gains in revenue

About 6 percent of the genetic crosses showed financial gains of up to 150 percent (Figure 5). Average increase in present net worth was 29 percent, and median value was **16** percent. Very few of the genetic crosses indicated returns poorer than those of the controls.

The estimates can be transformed directly from percentage to dollar gains for private plantation managers. Industrial landowners can expect nearly a 30 percent increase in present net worth. For example, if a forest manager estimates a net worth of his loblolly plantations at $100 per acre, he can increase that estimate by about 30 percent or $30 if he changes to genetically superior stock. Or, stated differently, he can afford to pay up to $30 more per acre for genetically improved seedlings.

For large timber producing regions or ownerships with substantial acreages, gains from tree improvement justify large expenditures in nurseries, orchards, and research to assure even higher productivity. For example, in the three-state area of South Carolina, Georgia, and Florida, loblolly pine plantations occupy about **1,100,000** acres (Powers et al. **1975).** If, through conversion to genetically improved trees, financial productivity per acre could be increased by 30 percent, extremely large investments in tree improvement efforts, with associated economics of scale, would be justified. Since the forest land base is shrinking, publicly subsidized tree improvement efforts would enhance wood supplies on acreage retained for commercial production.

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reveal full-rotation performance when these trees compete with other superior trees in a plantation environment. Only after such comparisons will valid growth or wood fiber production equations be available. At the same time, economic research must provide accurate information about costs and future revenue possibilities. Achieving these objectives will enable each owner or planner to set goals suitable to his own situation and thus derive local estimates of financial gain. Investments in genetically superior planting stock will probably be highly profitable; yet, efforts to prescribe the investment levels necessary to achieve specific dollar returns remain clouded by uncertainty.

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