MAINTAINING SITE PRODUCTIVITY BY THINNING AND TREE IMPROVEMENT[1/]

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Abstract.--Precommercial thinning of overly dense stands at about age 3 greatly increase yields of slash and loblolly pine. Several long term studies demonstrate that many options are available for commercial thinning. Genetically improved seedlings promise to increase overall productivity.

INTRODUCTION

The productive potential of forest land depends upon the availability of mineral nutrients and water coupled with the capacity of the trees to synthesize wood. Tree capacity is a function of leaf surface area and net rate of carbon fixation of the species. For maximum production, the leaf area per unit of ground area--the Leaf Area Index (LAI)--must be near the maximum for the species and stage of development (Cannell 1978). Maximum LAI's for southern pine stands have not been determined, but a reasonable assumption is that a closed forest canopy will have an LAI at or approaching the maximum.

The forester controls the LAI by regulating tree numbers and spacing at the time of stand establishment and by thinning during the rotation. However, once the LAI is at the maximum, and environmental factors are not limiting, further increase in dry matter production must come by other means such as site improvement by fertilization and water control, or by genetic improvements in the capacity of the species to synthesize wood.

In this paper I discuss the significance of thinning in maintaining stand productivity, and briefly consider tree improvement as a means for increasing stand yields.

Thinning

Thinning, whether by natural or artificial means, is inescapable in all but the most open stands simply because large trees occupy more space than small trees. Stands thin themselves naturally through competition-induced mortality. Silvicultural thinnings are planned to anticipate and harvest this mortality.

1/Paper presented at the 62nd Annual Meeting of the Appalachian Society of American Foresters, Myrtle Beach, SC, January 27-28, 1983.

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From
Maintaining Forest Site Productivity;
1983 Myrtle Beach, SC. SAF 83-09.
Bethesda, MD: Society of Am. Foresters.

Silvicultural thinnings are defined as cuttings made in immature stands to stimulate the growth of the trees that remain and to increase the total yield of useful material (Smith 1962). Growth is stimulated by the increased supplies of nutrients and water and by the increased exposure of the residual crowns to sunlight after trees are removed. Growth rates of the trees usually increase following a thinning until the crowns and root systems expand to occupy the newly created space. When the canopy is once more closed and competition again becomes an important growth retarding factor, growth rates of individual trees decline. Evidence from innumerable studies of stand growth of many species shows that although individual tree growth is increased by thinning, gross production of wood per unit of area is affected very little unless stocking is very much reduced or the stand becomes exceedingly dense (Smith 1962).

Figure 1 shows the influence of thinning on total merchantable volume yields of loblolly (*Pinus taeda* L.) and slash pine (*P. elliottii* Engelm. var. *elliottii*) for a number of study plots that have been subjected to an array of thinning treatments for periods of 10 to 40 years. The basal area after the last thinning and the total volume production are expressed as percentages of the respective values for the unthinned plots. Volumes include only green wood--thinnings plus standing volume--not the wood lost to mortality. Each point represents a single treatment; lines connect thinning treatments within a study.

The figure shows that, except for very heavy crown thinnings, a reduction of basal area down to about 40 to 50 percent of the maximum only reduced merchantable yields by about 10 percent; while reduction of basal area down to about 65 to 70 percent in light thinning resulted in increased yields of up to 10 percent.

Light thinnings from below that take out the suppressed and intermediate trees generally anticipate mortality, increasing the total volume harvested. As thinning gets heavier and codominants are removed, total yield declines. Even though diameter growth of the remaining trees is stimulated, the added volume is not sufficient to make up for the loss in growing stock. The value gained by increasing tree size or reducing the rotation, must outweigh the loss in total yield to justify such thinning (Bassett 1969).

It is probably safe to assume that, as a general rule, maximum merchantable volume yield can be obtained for these species by maintaining a basal area of at least 60 percent of normal. This conclusion is also reached by Morriss (1958), who surveyed southern pine thinning practices by experienced foresters.

The effects of a number of common thinning methods and some thinning extremes on stand productivity of loblolly pine are illustrated in Figures 2 and 3. The data in Figure 2 were taken from a long term study reported by Mann (1952). In addition to an unthinned check, treatments were: (1) A series of light thinnings from below at 5- to 10-year intervals beginning at age 8 and ending at age 39, with residual basal areas that averaged 99 square feet per acre. (2) A series of heavy crown thinnings starting at age 18 in which rough and deformed dominants and codominants were removed. Later thinnings removed mostly codominant and intermediate trees leaving average residual basal areas of 81 square feet per acre. (3) A crop-tree thinning at age 18 which left the 100 largest and best dominants and codominants per acre. Total cordwood yields, exclusive of mortality, are summarized through ages 38 and 44 and mean stand diameters and basal areas at the end of each period are indicated (fig. 2).

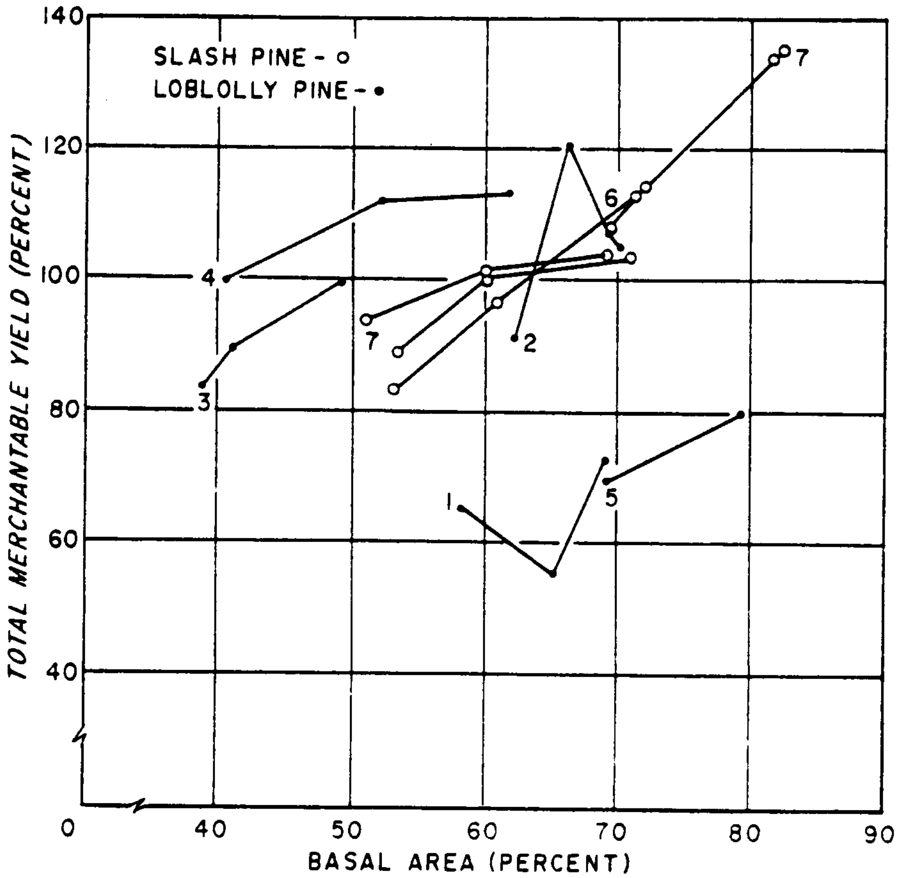

Figure 1.--Relative values of total merchantable volumes, exclusive of mortality, from different thinning regimes in relation to basal area. Unthinned stands = 100%. (See text). 1-Bassett (1969), 2-Mann (1952), 3,4-Goebel et al. (1974), 5-Sprinz et al. (1979), 6-Keister et al. (1968), 7-Mann and Enghardt (1972).

For rotations up to about 30 years, it is evident that unthinned loblolly stands produce more pulpwood than thinned stands. Bennett (1971) and Keister et al. (1968) have found that early thinning in slash pine plantations has little effect on total cubic yields. These data suggest that the objective of increasing yields over a pulpwood rotation by thinning is probably not possible; early thinning should be used to increase tree size rather than volume production.

Over a longer rotation, however, the data in Figure 2 indicate that both low and crown thinnings can increase both tree size and yield of pulpwood and sawtimber over that produced by unthinned stands. Light thinnings produced the greatest yields and because thinning was started earlier they also produced larger trees than all but the crop-tree thinning. The crop-tree thinning produced larger trees but because of the reduction in basal area it produced less sawtimber volume than the unthinned stands: 16.6 MBF versus 17.5 MBF per acre.

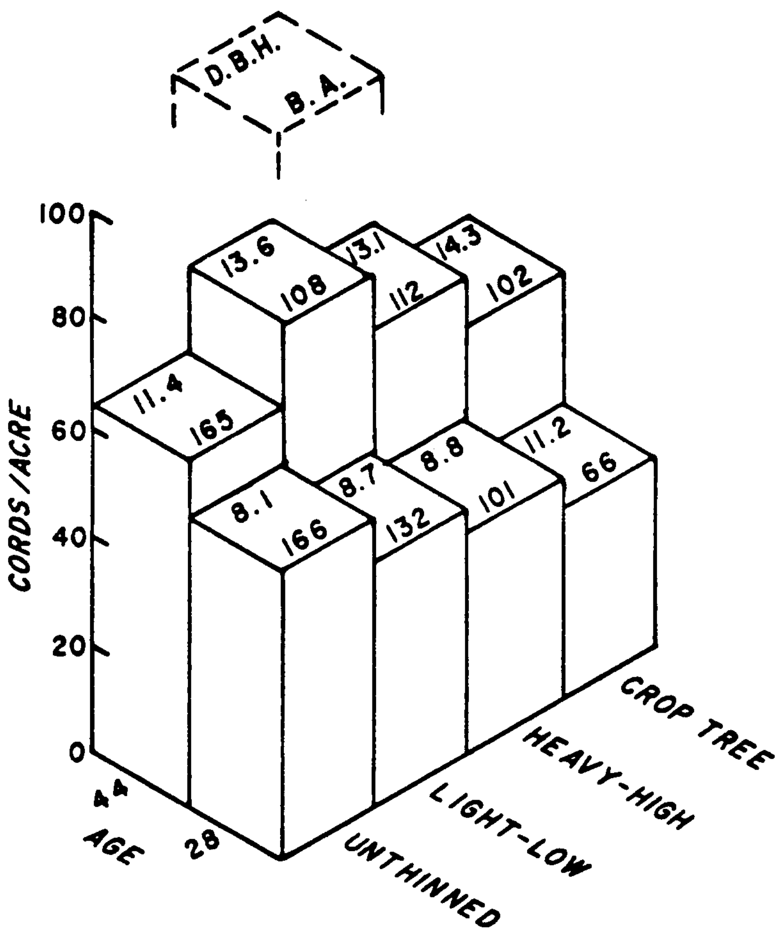

Figure 2.--Yield response of loblolly pine to different types and intensities of thinning. Shown is total cordwood yield: standing plus cut volume for age 8 to 28 and 8 to 44 years (Mann 1952).

Figure 3 shows the effects of thinning designed to promote rapid growth of trees to maximize the production of sawtimber and minimize the length of rotation (Bassett 1969). In a loblolly pine plantation spaced 6x6 feet, 100 crop-trees per acre were selected at age 9, and four thinning treatments were begun: (1) Low thinning at 3-year intervals to a basal area of 85 square feet per acre. (2) Sawtimber-pulpwood, in which trees within 5 feet of the crowns of the crop-trees were periodically cut and crop-trees were pruned. (3) Delayed sawtimber, in which the cut was delayed until the trees to be cut reached merchantable size, crop trees pruned. (4) Sawtimber only, in which all but the crop-trees were cut and crop-trees were pruned.

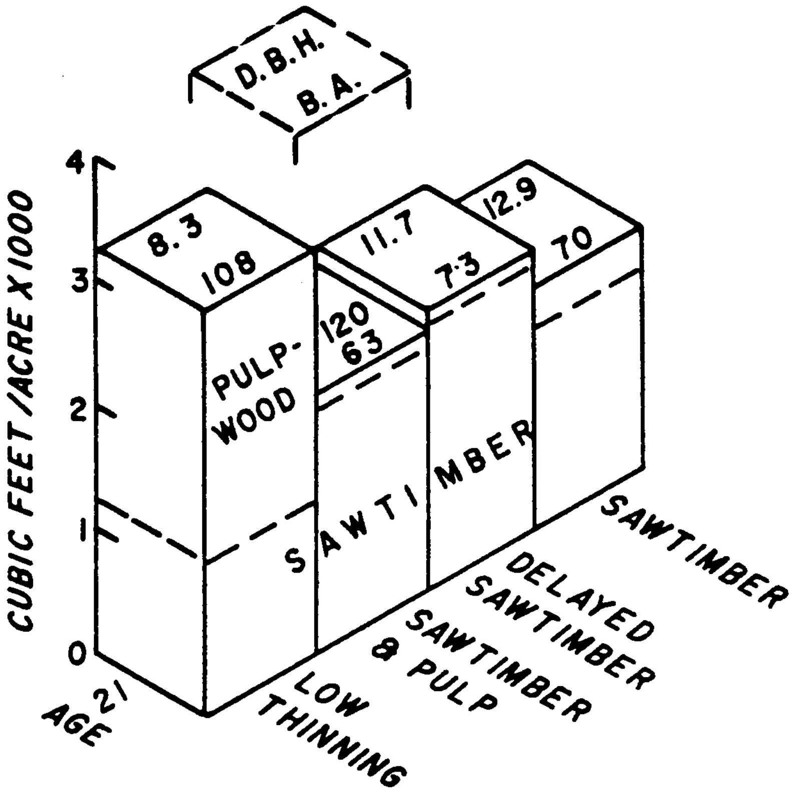

Figure 3.--Yield response of loblolly pine to crop-tree thinning. Total cubic foot yield in sawtimber and pulpwood at age 21 years (Bassett 1969).

At age 21 the lightly thinned plots yielded almost twice as much cubic volume as the sawtimber only plots, and considerably more than the other treatments. In terms of sawtimber, however, almost all of the volume per acre on all plots except those lightly thinned was in sawtimber-size trees (fig. 3).

Heavy thinning obviously removes much of the growing stock and severely reduces cubic volume production. The justification for such a practice must come from the size and value of the trees produced and from a shortened rotation.

Commercial thinning, as these studies have shown, increases total merchantable yields only in long rotations and only when thinning is primarily from below. The amount of the increase will depend on age, site, and type of thinning. In short- to medium-length rotations, thinning should play a secondary role--mostly as a sanitation and salvage measure (Bennett and Langdon 1976).

There is one common stand condition however, where early thinning can bring about a dramatic increase in production. In some years, both loblolly and slash pine produce such an abundance of seed, that regeneration cuts often result in seedling stands of 50,000 or more plants per acre. Similar conditions are common in direct-seeded stands when conditions for germination and early survival are ideal, and in young plantations invaded by seed, from neighboring stands. Dense seedling stands may stagnate or grow slowly for many years (Grano 1969). Dominant trees in such stands may be 10 or more feet shorter than trees of comparable age in more open stands (Collins 1967). Such overstocked stands must be thinned early if they are to produce a merchantable yield within a reasonable time.

Figures 4 and 5 show the response of overcrowded stands of slash and loblolly pine to precommercial thinning. Both stands were established by natural regeneration. The slash pine seeded on old fields to densities of 50,000 stems per acre (Jones 1977): the loblolly pine stand became established following a wildfire, with densities of 250,000 seedlings per acre (Grano 1969). Quarter-acre study plots were thinned in the slash pine stand at age 3 to single trees spaced at 10x10 feet, and to clumps of 6 to 8 trees each, with clumps spaced 10 feet apart. Unthinned plots were established as checks (Jones 1977). In the loblolly pine stand three treatments were tested on 1/10th acre plots: (1) Thinning at age 7 in 8-foot wide strips leaving 3-foot wide strips of trees. (2) Thinning at age 7 in 8-foot wide strips followed 3 years later with a hand thinning in the uncut strips to a spacing between trees of about 8 feet. (3) An unthinned check (Grano 1969).

At age 17 the single-tree plots in the slash pine stand contained trees averaging 4.2 inches larger in diameter and 10 feet taller in height than the check plots. They also contained 16.8 cords of pulpwood per acre while unthinned plots had only 1.5 cords (fig. 4). At age 23 the single-tree plots have produced 28 cords, the clump plots 19 cords, and the check plots less than 5 cords. Trees on unthinned plots were 39 feet tall, while those in clumps were 48 feet and those on single-tree plots were 54 feet tall. Effects on diameter growth were correspondingly great (fig. 4). On the average, single-tree plots grew six times the merchantable volume of check plots, and clump plots four times the volume.

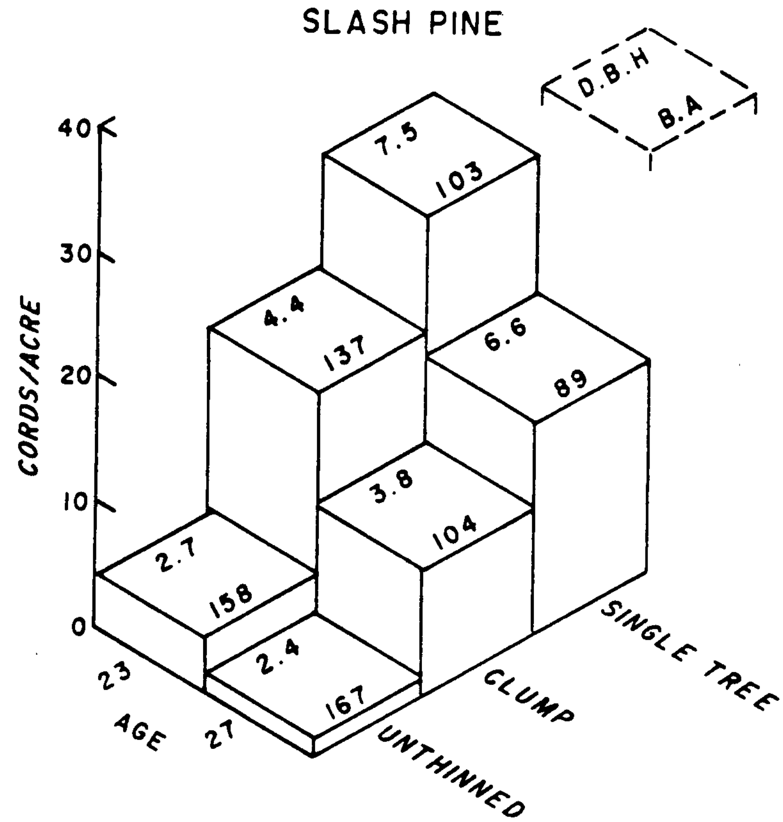

Figure 4.--Yield response of slash pine to precommercial thinning. Residual trees per acre at age 3 = 20,000 unthinned, 3000 clump, 436 single tree (Jones 1974, 1977).

The loblolly pine responses were also large but less dramatic (fig. 5). At age 19, 12 years after thinning, trees on strip + hand thinned plots averaged about 3 inches larger in diameter than those on check plots and trees on strip-only plots averaged less than 1 inch larger. Tree heights averaged 44 feet on unthinned plots, 48 feet on strip-only, and 52 feet on strip + hand plots. The strip + hand plots produced almost four times the merchantable volume of the check plots, and the strip-only plots twice the volume (fig. 5).

These two studies demonstrate that precommercial thinning is necessary if young, overcrowded stands are to produce acceptable quantities of merchantable wood. Threshold densities at which thinning should be done have not been fixed, but suggestions range from 1500 to 5000 stems per acre (Jones 1974). There is general agreement that residual stocking should be 500 to 750 pine stems per acre, depending on the product objective, and that thinning should be accomplished at about age 3 (Balmer and Williston 1973, Mann and Lohrey 1974).

The economics of precommercial thinning will not be considered here, but most foresters will want to view such treatments as an economic investment. In most cases the cost of treatment in overcrowded stands less than 3 years old will be easily justified by the improvement in yield of merchantable products and in the reduction in rotation length.

It is evident that within the broad range of densities which foresters normally face, gross production is pretty much set once maximum LAI has been achieved. The challenge is to bring the stand to the maximum LAI then fine tune its development to maximize output of the desired products at least cost and in the shortest time. The fine tuning can be accomplished by traditional silvicultural methods such as thinning. To increase production beyond that point requires site improvement through such treatments as fertilization or species improvement through selection and breeding.

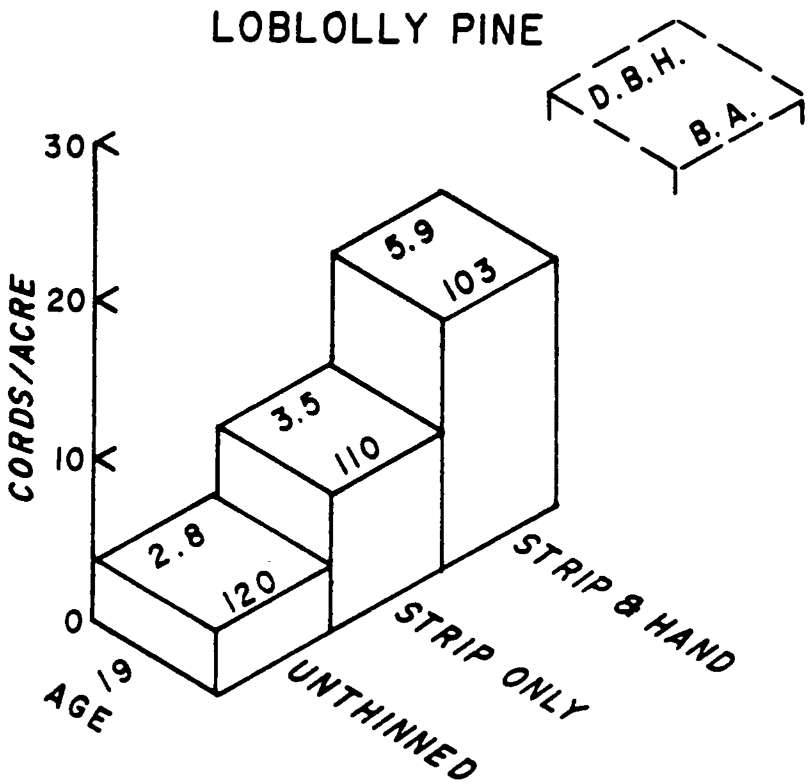

Figure 5.--Yield response of loblolly pine to pre-commercial thinning. Residual trees per acre at age 7 = 30,520 unthinned, 5400 strip thinned, 1850 strip + hand thinned (Grano 1969).

Tree Improvement

The central problem of maintaining or increasing useable yield per acre whether by thinning, tree improvement, or site amelioration, is related to the competition-driven density-regulating mechanism that controls stand growth and development (fig. 6). During the period from stand establishment to crown closure growth is unrestricted and growing space is underutilized (A→B, fig. 6). Following crown closure, growing space becomes completely occupied and competition begins for light, moisture and soil nutrients, leading to a gradual reduction in growth of the individual trees. Eventually, as competition becomes more intense, the suppressed and weaker trees begin to die and the stand begins to thin itself (B→C, fig. 6). With continued growth and mortality, a point is reached where self-thinning proceeds in a regular manner so as to maintain the stand at a maximum or limiting density as conditioned by current mean tree size (C→D, fig. 6).

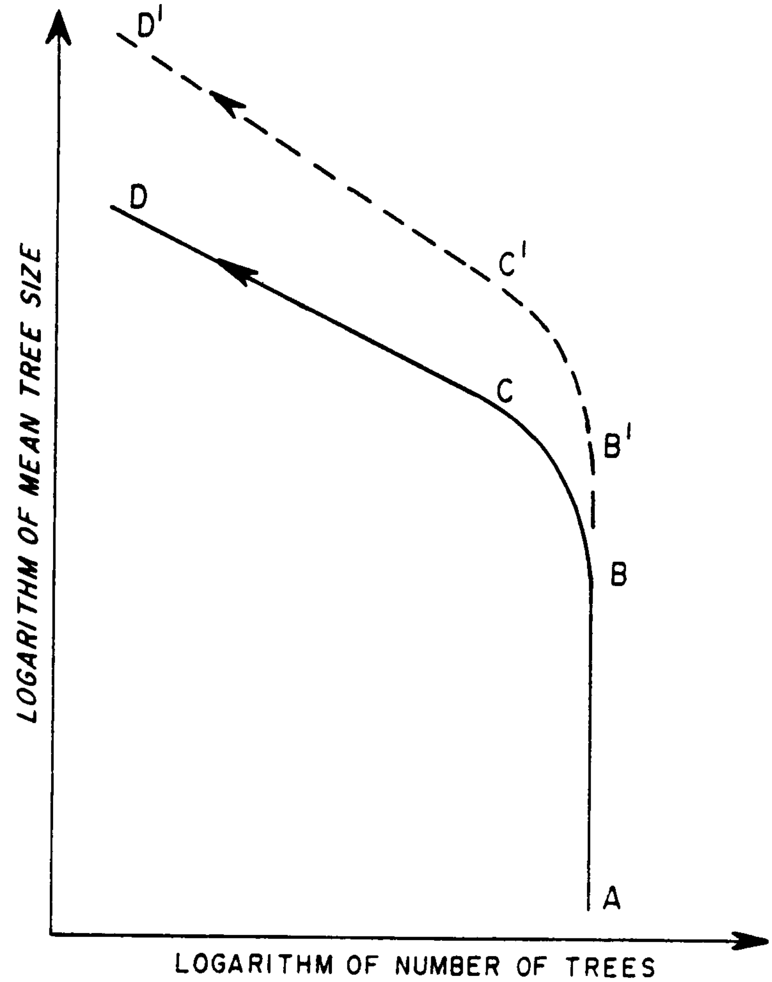

Figure 6.--Development trajectory of a hypothetical stand showing the relationship between mean tree size and number of trees per unit of area from establishment (point A) through self-thinning (points B→C→D)(after Ford 1976).

The gradient of the self-thinning line between points C and D (fig. 6) has been found to be close to -3/2 for self-thinning populations of all pure, even-aged species so far studied (White and Harper 1970). The only apparent difference among species is the height of the line above the horizontal axis. Neither gradient nor height of the self-thinning line are affected by site quality (Yoda et al. 1963). Site and density only affect the rate at which a stand approaches the self-thinning line. The closer together the trees are, or the better the site and the faster the growth, the sooner the stand will start to self-thin.

As the self-thinning line defines the maximum density for a stand of given mean tree size so it also defines the maximum standing yield for the same combination of number and size. It is, therefore, within the constraints imposed by the self-thinning stage of stand development that yield increases through genetic improvement must be sought.

Some modes by which yield increases can be obtained are: (1) Faster growth rates to permit stands to reach the self-thinning stage earlier (A→B→C, fig. 6). (2) Attaining a larger size before self-thinning begins (A→B', fig. 6). (3) Increasing the unit increment in mean tree size per unit of increase in mortality so as to increase the gradient of the self-thinning line (C'→D', fig. 6)(Ford 1976). Both (2) and (3) imply an increase in the standing biomass of a certain density over that of natural populations and will require fundamental improvements in the physiological processes governing the growth of trees in stands. A long history of genetic research and tree improvement programs have adequately demonstrated the existence of inherently rapid growing strains implied by item (1). For example, results of progeny test plantings of first generation selection of slash and loblolly pine families from Georgia Forestry Commission seed orchards show average volume gains of from 7 percent for loblolly to 22 percent for slash pine (Kraus and LaFarge 1983).

It is uncertain how much of the superior growth per tree will be realized on a per-acre basis, because few test plantings have yet reached the age or developmental stage to express the effects of competition and self-thinning. The inadequacies of small plot size and wide spacing of many of the test plantings make it difficult to evaluate them silviculturally. However, one report cites 9- and 10-year-old operational plantations of improved slash pine having 15 percent gains in volume (Zoerb 1977). As more such data are published, it will become possible to evaluate genetic gains in ways that are useful to the forest manager for planning purposes.

Increased yields resulting from the inherently faster growing stock now being planted can probably be assumed to come in the form of faster growth rates prior to the self-thinning stage of stand development (A→B, fig. 6). Although it is possible that some of the improved families will produce gains over and above the limits imposed on natural populations by self-thinning, it will be difficult to show without long-term tests whether the height or gradient of the self-thinning line has been improved.

Intensive energy-dependent management practices will be required to take advantage of the fast growing strains (Schultz 1975). Site preparation and weed control will be required, and fertilizer will be needed on nutrient deficient sites.

Yield increases from improved strains will also come about from reduced losses from fusiform rust because of a greater resistance to the disease. Kraus and LaFarge (1983) report a 27 percent improvement in resistance to rust in slash pine and an 8 percent improvement in loblolly pine seedlings produced by the Georgia Forestry Commission seed orchards. Yield increases will also come in the form of improved straightness and quality of the boles of the trees.

It is generally assumed that the inherently fast growing stock will be grown in plantations for maximum yields. Natural stands, however, make up over 70 percent of the commercial pine forests in the South. Some method for improving the genetic makeup of these stands, therefore, would be quite valuable.

In conclusion, thinning, thoughtfully applied, is a proven practice for maintaining stand productivity while increasing the yield of useable products. Growing stands of genetically improved strains of trees has the potential to increase yields substantially, but to obtain full benefit from the improved stock will require intensive management, and high inputs of energy. Ultimately, however, securing increased yields, whether by thinning or by growing genetically improved stock, will depend on the ability of the forester to use new techniques and knowledge to manipulate and fine tune the species-site-product system with which he works.

LITERATURE CITED

Balmer, W. E., and Williston, H. L. 1973. The need for precommercial thinning. USDA For. Serv. For. Manage. Bull. 6. USDA For. Serv., Southeast. Area State and Private For., Atlanta, GA.

Bassett, J. R. 1969. Growth of widely spaced loblolly pine. J. For. 67: 634-636.

Bennett, F. A., and Langdon, O. G. 1976. Management of natural stands of slash pine. USDA For. Serv. Res. Pap. SE-147, 12 p. Southeast. For. Exp. Stn., Asheville, NC.

Cannell, M. G. R. 1968. Improving per hectare forest productivity. In Proc. Fifth North Amer. For. Biol. Workshop. School For. Resour. and Conserv., Univ. Florida, Gainesville, FL. pp. 120-148.

Collins, A. B., III. 1967. Density and height growth in natural slash pine. USDA For. Serv. Res. Pap. SE-27, 8 p. Southeast. For. Exp. Stn., Asheville, NC.

Ford, E. D. 1976. Competition, genetic systems and improvement of forest yield. In Tree physiology and yield improvement, M. G. R. Cannell and F. T. Last (eds.). Academic Press, NY. pp. 463-472.

Goebel, N. B., Warner, J. R., and VanLear, D. H. 1974. Periodic thinnings in loblolly pine stands: Growth, yield, and economic analyses. Clemson Univ., Coll. For. & Rec. Resour., Dept. For., For. Res. Series No. 28, 11 p.

Grano, C. X. 1969. Precommercial thinning of loblolly pine. J. For. 67: 825-827.

Jones, E. P., Jr. 1974. Precommercial thinning for slash and loblolly pines. In Proc. Symp. on Management of Young Pines. USDA For. Serv., Southeast. Area State and Private For., Atlanta, GA. pp. 229-233.

_____. 1977. Precommercial thinning of naturally seeded slash pine increases volume and monetary returns. USDA For. Serv. Res. Pap. SE-164, 12 p. Southeast. For. Exp. Stn., Asheville, NC.

Keister, T. D., Crow, A. B., and Burns, P. Y. 1968. Results of a test of classical thinning methods in a slash pine plantation. J. For. 66: 409-441.

Kraus, J. F., and LaFarge, T. L. 1983. Georgia's seed orchard trees. A report on the first-generation selections. Ga. For. Comm. Rpt.-- in press.

Mann, W. F., Jr. 1952. Response of loblolly pine to thinning. J. For. 50: 443-446.

_____, and Enghardt, H. G. 1972. Growth of planted slash pine under several thinning regimes. USDA For. Serv. Res. Pap. SO-76, 10 p. South. For. Exp. Stn., New Orleans, LA.

_____, and Lohrey, R. E. 1974. Precommercial thinning of southern pines. J. For. 72: 557-560.

Morriss, D. J. 1958. Basal area thinning guides for thinning in the south. J. For. 56: 903-905.

Schultz, R. P. 1975. Managing genetically improved southern pines. In Forest tree improvement--the third decade. 24th Ann. For. Symp., La. State Univ., Baton Rouge, LA. pp. 209-237.

Sprinz, P., Clason, T., and Bower, D. 1979. Spacing and thinning effects on the growth and development of a loblolly pine plantation. For. Res. Rpt. 1979. North Louisiana Hill Farm Exp. Stn., Homer, LA. La. State Univ. and Agric. and Mech. Coll. Center for Agric. Sci. and Rural Devel. 90 p.

White, J., and Harper, J. L. 1970. Correlated changes in plant size and number in plant populations. J. Ecol. 58: 467-485.

Yoda, K., Kira, T., Ogawa, H., and Hozumi, K. 1963. Intraspecific competition among higher plants. XI. Self-thinning in overcrowded pure stands under cultivated and natural conditions. J. Biol. Osaka City Univ. 14: 107-129.

Zoerb, M. H., Jr. 1977. A second look at operational plantations of improved slash pine. Union Camp Corp., Woodlands Res. Dep. Woodlands Res. Notes 33, 3 p.