GREATER PULP YIELDS PER ACRE PER YEAR

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It is my understanding that advances in paper chemistry and engineering have improved pulp-making efficiency to the point where in some cases processing costs now represent not more than 30 to 40 percent of the value of a ton of pulp. Wood costs, on the other hand, have been steadily increasing due to scarcity of preferred species, high stumpage prices, increased labor costs, and higher transportation rates. It seems reasonable to believe, therefore, that research aimed at improving efficiency in the woods would pay dividends. In this paper I should like to call your attention to some possibilities for increasing the quantity and quality of pulpwood produced on an acre of forest land.

At recent meetings of the pulp and paper industry, this question has been asked: What is the average annual productive capacity of an acre of forest land, in terms of pounds of kraft pulp, and how can the yield be increased? There is, of course, no simple, all-inclusive answer to this question. It is well known that the volume increment of black spruce growing in a Lake States swamp is less than that of second-growth Douglas-fir on a good site in the Pacific Northwest or fast-growing slash pine in the piney woods of the Southeast. And wood quality, like growth rate, varies between species and is also affected by environmental factors and management practices. We do have, however, sufficient research and experience to arrive at some reasonable approximations for some of our major pulp-producing species.

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The volume, yield, and stand tables published by the U. S. Forest Service and other agencies show what to expect from fully stocked, unmanaged stands of our more important species. These tables indicate, for example, that unmanaged longleaf pine on an average site will produce 7 cords of pulpwood per acre in 15 years, 13 cords in 20 years, and so forth. Similar information is available on other important species. But such data are of limited value in predicting wood quality and yield potentials under intensive management, expecially over the longer rotations required to produce large wood products as well as pulpwood. For information of this kind, we must look largely to new research results published currently in trade and technical journals and the reports of the Forest Experiment Stations.

Both the quality and quantity of wood produced on a given acre of land can be modified to a considerable degree by cultural practices -- pruning, thinning, and poisoning or girdling to eliminate cull or inferior trees, and so forth. The value of pruning to increase the volume of clear, knot-free lumber in the butt log is well known. This is particularly important in managing species like Douglas-fir that do not prune well naturally.

The response of young stands to thinnings of different types and intensity is well illustrated by results from one of the oldest thinning studies in the South, recently reported on by Mann (3).[3] This study, known as the Maxwell thinning study, was established in 1915 by the Southern Forest Experiment Station in cooperation with the Urania Lumber Company in an 8-year-old natural loblolly pine stand growing on a good old-field site near Urania, La., There were four different thinning treatments plus an unthinned check plot. One plot (early light) was thinned lightly at age 8 and was thinned lightly, largely from below, at 5- to 10-year intervals thereafter. Two other thinning treatments (deferred light and deferred heavy) were first made when the stand was 18 years of age. These thinnings were mainly from above, removing rough and deformed dominants plus smaller merchantable-size trees apt to die from suppression. On these two plots, as on the first, subsequent thinnings of the same general kind were made at 5- to 10-year intervals. The fourth thinning plot (crop tree) was thinned very heavily at age 18, leaving only 100 of the largest and best trees per acre, and was not thinned thereafter.

The results are shown in part in figure 1, with average cordwood yields per acre per year for the 15-year period age 18 to 33 plotted over the average residual basal area. Basal area per acre, which is the total cross-sectional area in square feet of all trees at 4-1/2 feet above ground, is an excellent index to stand density. Note that maximum cordwood growth during this 15-year period occurred on the heavily stocked, unthinned plot. Growth on this plot was twice that on the plot thinned to only 100 trees

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[3] Underlined numbers in parentheses refer to the literature cited at the end of this report.

per acre. Up to age 33 total accumulative cordwood growth (that is, total on plot plus any removed in thinning) was also greatest on the unthinned plot -- 59.7 cords, an average of 1.8 cords per acre per year for the 33-year period. Diameter growth of the individual trees for this period, in contrast to volume growth of the stands, was greatest where the thinnings were heaviest.

After age 33, mortality was great on the check plot, due to trees dying from overcrowding, insects, storms, and other natural causes. Thus during the 11-year period, age 33 to age 44, the check plot lost an average of 0.34 cord per year, as compared to net gains (growth minus mortality) of 2.1, 1.7, and 1.7 cords per acre per year for, respectively, the light early, heavy deferred, and light deferred thinning plots.

On the basis of his analysis of these data, Mann (3) concludes that "maximum pulpwood production over a 33-year rotation is attained either without any intermediate thinning, or with only one or two light commercial salvage cuts to anticipate mortality." If, however, the management objective includes production of sawlogs as well as pulpwood over a longer rotation, light thinnings should be initiated at about age 23 to open up the stand just enough to forestall mortality, maintain diameter growth, and prevent excessive shortening of the live crown. Heavier thinnings would stimulate diameter growth, and thus shorten the period required to produce large wood products, but the loss in growing stock would reduce the total volume increment.

The application of these results to the management of young loblolly stands under different conditions of financing, marketing, and products objectives is beyond the scope of this paper, and the reader is referred to Mann's report (3) for such a discussion. The data were cited here largely to illustrate the extent to which volume growth of young stands can be modified by different types and intensities of thinning (fig. 1).

Now let us consider wood quality, which is also affected by management practices. When foresters talk about quality, they are thinking largely in terms of tree size, form, straightness, and freedom from knots and other visible defects. They are thinking of large trees with long, straight, clear boles that will bring premium prices as poles or pilings, veneer bolts, or sawlogs containing a large volume of clear lumber.

This concept of quality is all right as far as it goes, but in the interest of better and more profitable forest management it should be expanded to include the basic anatomical properties that determine the suitability of wood for various uses -- such things as high density for great strength and high pulp yields, and dimensional stability and attractive grain for cabinet woods. Of particular importance are such anatomical properties as the density of the wood, the proportion of summerwood to springwood in the annual rings, the number of rings per inch, the length and thickness of the wood fibers, the orientation of the fibrils with respect to the axis of the fibers, and the occurrence of compression wood or other abnormalities affecting strength, shrinkage, warpage, or pulp quality and yields.

Wood density, usually expressed as pounds per cubic foot or as specific gravity, is perhaps the best and most useful single index to wood quality from the standpoint of anatomical properties. Chidester (1) has shown the relationship between wood density and kraft pulp yields from southern yellow pines. His data are reproduced in figure 2. Note that every 2-pound increase in wood density produces about 1 pound more pulp. Stated another way, a cord of low-density southern pine wood will yield about 847 pounds of kraft pulp, whereas a cord of high-density wood of the same species will produce 1,477 pounds -- almost twice as much. The same general relationship between wood density and kraft yields is true of other species. This is perhaps the best reason for buying and selling wood on the basis of weight instead of volume.

Tree species differ considerably in specific gravity. For example, the wood of the southern pines is normally heavier than any of our other commercial softwoods, being about twice as heavy as the cedars, and is as heavy or heavier than many of the hardwoods. There is also much variation in specific gravity within a species. An idea of the variation found in nature can be obtained from the frequency distribution curves in figure 3 for four southern pines. These curves are based on data from hundreds of samples collected throughout the South by the Forest Products Laboratory (4). Here again I have drawn on southern pine data for purposes of illustration, partly because roughly half of the pulpwood produced in this country comes from southern pines, and partly because more is known about these species than any of our other softwoods.

Some of the variation in specific gravity noted in figure 3 is believed due to inherent differences in the individual trees within a racial strain or species. The remainder is accounted for by other factors that affect wood density. Of these, the more important are the percent of summerwood in the annual growth rings, rate of diameter increment, age, height in tree, size of crown, and environmental conditions affecting tree growth and development.

In many softwoods there is a high degree of correlation between specific gravity and the proportion of summerwood to springwood in the annual ring. This is shown, for southern pine pulpwood, by the data in figure 4, recently reported by Schafer (5). Under certain conditions there is a good correlation between growth rate and specific gravity. In southern pines, for example, small-crowned, slow-growing trees in dense stands normally have a higher percentage of summerwood and a higher specific gravity than large-crowned, widely spaced, fast-growing trees of the same species and age on the same site. New Forest Products Laboratory data show such a relationship for 20- to 30-year-old slash pine growing under different conditions of spacing and crown development on essentially similar sites. These data are presented in figure 5. Note that specific gravity decreases with increasing ring width, both at breast height and crown height. Also, that specific gravity is significantly higher at breast height than at crown height. These relationships apparently hold for all southern pines and, on the basis of present information, probably apply equally to Douglas-fir, and to other species of the yellow and red pine groups.

Research on the effect of silvicultural treatments on wood quality has not kept pace with advances in forest management. I know of no single study in this country in which managed stands treated in different ways and continued for all or a major portion of a rotation were sampled to determine the effects of treatment on both volume growth and the anatomical properties of the wood. One reason for this gap in our information is the objection to removing, for anatomical analysis, trees included in long-time studies planned with other objectives in mind. However, it is possible to arrive at some reasonable approximations, and to get an idea of trends, by combining data from various sources.

This has been done in figure 6, which shows the diameter, cordwood growth, density of the wood, and kraft pulp yields from young longleaf pine grown at various densities of stocking. The diameter and volume growth data are from the Loxley thinning study established in 1933-34 by the Southern Forest Experiment Station in cooperation with the Tennessee Coal, Iron & Railroad Company. A heavily stocked (up to 2,430 trees per acre 1.5 inches d.b.h. and over), even-aged, natural stand of longleaf pine growing on an average site near Loxley in southern Alabama was thinned to various densities of stocking at age 22. There were no subsequent thinnings during the 15-year period (age 22 to 37) with which we are concerned in this discussion. In all, there were 32 plots, including 8 unthinned check plots varying from 620 to 2,430 trees per acre. All plots were remeasured at 5-year intervals. Results have been reported from time to time by the Southern Station, most recently by Gaines (2).

As in the loblolly pine thinning study discussed earlier, the average diameter growth of merchantable trees was greatest on the heavily thinned plots. Greatest cordwood growth, however, for the 15-year period following thinning occurred on plots having about 800 trees per acre. At greater stand densities net volume growth decreased due to overcrowding, stagnation, and high mortality. Regression analysis of the data showed that cordwood increment was more closely related to number of trees per acre than to basal area. Basic data are not shown in figure 6, since our primary interest here is in trends. It should be mentioned, though, that the correlation between number of trees and volume growth is highly significant. The growth curve in figure 6 is the best that can be fitted to the data by statistical procedures.

Specific gravity determinations have not yet been made of trees on the Loxley thinning plots. However, we do have, from other studies, including the data in figure 5, good information on the relationship between diameter increment and the specific gravity of southern pine growing under essentially comparable conditions of age, site, spacing, and growth rate. By drawing on this information, and applying it to the Loxley data, we can estimate wood densities for the range of diameter increment rates found at the various stand densities in the Loxley study. Such a curve is shown in figure 6. The only assumption is that trees in the Loxley study behaved, with respect to effect of stand density on diameter increment and specific gravity, in about the same way as in essentially similar studies for which we have good information on specific gravity but not on volume growth.

Note that there is a significant increase in wood density up to about 1,200 trees per acre, the range of decreasing diameter growth, after which the density curve tends to flatten. From these data on wood density, and the kraft pulp yield data shown in figure 2, it is possible to calculate the kraft pulp equivalent of cordwood produced at the various densities of stocking. The relationship between density of stocking and kraft pulp yield, in tons per acre per year, is shown in the upper curve of figure 6. It is significant that this curve peaks at somewhat higher density of stocking than the cordwood growth curve. This is because increases in the weight of wood over this range of stand densities more than compensate for decreases in volume growth.

The importance of wood density is perhaps better illustrated by the two sets of curves shown in figure 7. The upper curve of the lower set is the same as the kraft pulp yield curve in figure 6. The lower curve shows what the kraft yields would be if wood density remained constant at 32.8 pounds per cubic foot -- specific gravity 0.525. The difference, about 340 pounds of pulp per acre per year, is indicative of the extent to which pulp yields may be influenced by the variations in specific gravity normally found over this range of stand densities and growth rates. Expressed in monetary terms, and assuming $90 as the value of a ton of kraft pulp, the difference amounts to about $15 per acre per year. Those of you who own and manage forest lands to supply pulpwood for your mills should be interested in that kind of money.

The examples cited above are intended to bring out the importance of wood structure, and to show that both the quantity and quality of wood produced on a given acre of forest land can be modified to a considerable extent by management practices. These findings, of course, are not specifically applicable to any and all species and conditions of site, age, and treatment. But they do point up the need for better information on the effects of silvicultural treatments on wood quality as here defined. They also suggest that forest managers might well benefit by paying more attention to wood quality. Some foresters tend to thin young southern pine stands too heavily even where pulpwood is a major objective of management. The result is decreased yields, in terms of wood pulp, due to lowered wood density and less than optimum growing stock for maximum possible volume increment. It should also be pointed out that low-density wood is weaker, shrinks more along the grain, warps more in drying, and is therefore less desirable for lumber and other uses as well as for pulp.

The laws of heredity may also be used to improve the yields, quality of product, and financial returns from our forests. Research in this country and in Europe has developed hybrid poplars having a phenomenal growth rate, blister-rust-resistant white pine, blight-resistant chestnut, naval stores pines that yield two and one-half times as much gum as run-of-the-woods trees, and other hybrids and strains having desirable characteristics. There is every reason to believe that selection and breeding work now under way, especially in the South and the California Forest Experiment Station's Institute of Forest Genetics, will result in trees that are greatly superior to anything we now have in regard to growth rate, form, pest resistance, drought resistance, density of wood produced, and possibly decay resistance and fiber length and thickness.

A simple example will serve to illustrate the possibilities of such research. We know that a well-stocked, well-managed stand of run-of-the-woods longleaf pine growing on a good site will produce an average of 1 cord of pulpwood per acre per year over a 40- to 50-year rotation. We know, too, that there are found in nature individual longleaf pines capable of much more rapid growth; that is, trees that produce merchantable pulpwood of a given size in a shorter period. At least part of their superiority is believed due to genetic factors as in the case of hybrid poplars. Assume that we can increase the inherent growth rate of longleaf pine by one-third through selection and breeding of superior trees. The result would be an equivalent increase in kraft pulp yield per acre per year; that is, from 550 up to 740 pounds per acre per year. A graphic comparison is made in figure 8.

Now assume that we can develop a strain of longleaf pine inherently capable, under average conditions of growth rate, stocking, site, and management, of producing wood with a specific gravity of 0.60, only 0.15 higher than the present average of about 0.45 for run-of-the woods, pulpwood-size trees of this species. If specific gravity is subject to genetic control, as seems probable, such an improvement in wood density should be readily attainable through selection and breeding. (We have already found longleaf pine with specific gravities ranging up to 0.75 and above -- see fig. 3.) The effect of such a modest (33 percent) increase in wood density upon kraft pulp yields is the same as an equivalent increase in growth rate (fig. 8); that is, increasing the weight of the wood by one-third has the same effect on kraft pulp yield per acre per year as increasing the volume of wood by one-third. This further illustrates the importance of wood density, a factor so often overlooked in forest management as well as in genetics research.

If, through selection and breeding, we can achieve the same modest increase in <u>both</u> growth rate and specific gravity, kraft pulp yields per acre per year from longleaf pine would be approximately doubled (fig. 8). This order of improvement should be well within the realm of possibility as individual trees having the desired characteristics are known to exist in nature.

It is believed, also, that tree improvement research can develop new strains or hybrids with either a higher or lower proportion of summerwood to springwood. This is one of the major objectives of Zobel (6) of the Texas Forest Service and other research foresters working in the South. The thick-walled summerwood tracheids make stiff fibers that produce relative rough sheets of paper of great tearing strength. The thin-walled springwood fibers, on the other hand, collapse and felt well and make smoother sheets of paper of higher bursting and tensile strength (1). The development of trees with fibers tailor-made for any particular use is not at all improbable.

The possibilities for greatly increasing the productive capacity of our forests and improving the quality of the product, thereby lowering the cost of the raw material used by the pulp and paper industry, are such as to merit the attention of top management in the industry. Foresters, especially those engaged in research, have the necessary technical skills, but they need the green light, some encouragement, and the wherewithal to do the job. This is still a largely unexplored field where a modest investment in research is certain to pay high dividends.

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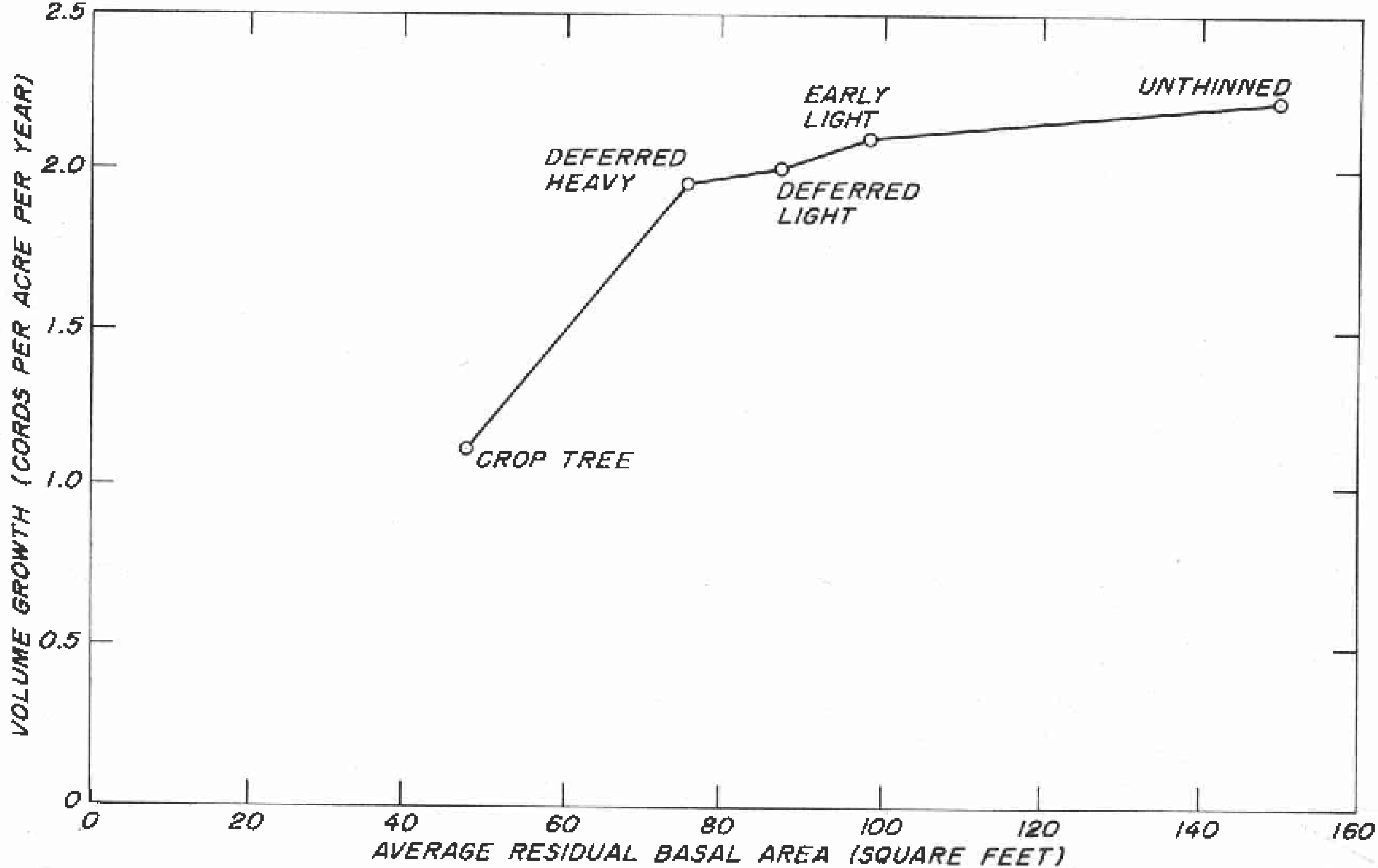

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Figure 1. --Relation of the volume growth to the basal area of loblolly pine treated with different types and intensities of thinning; based on Maxwell thinning plots, for 15-year period, age 18 to 33.

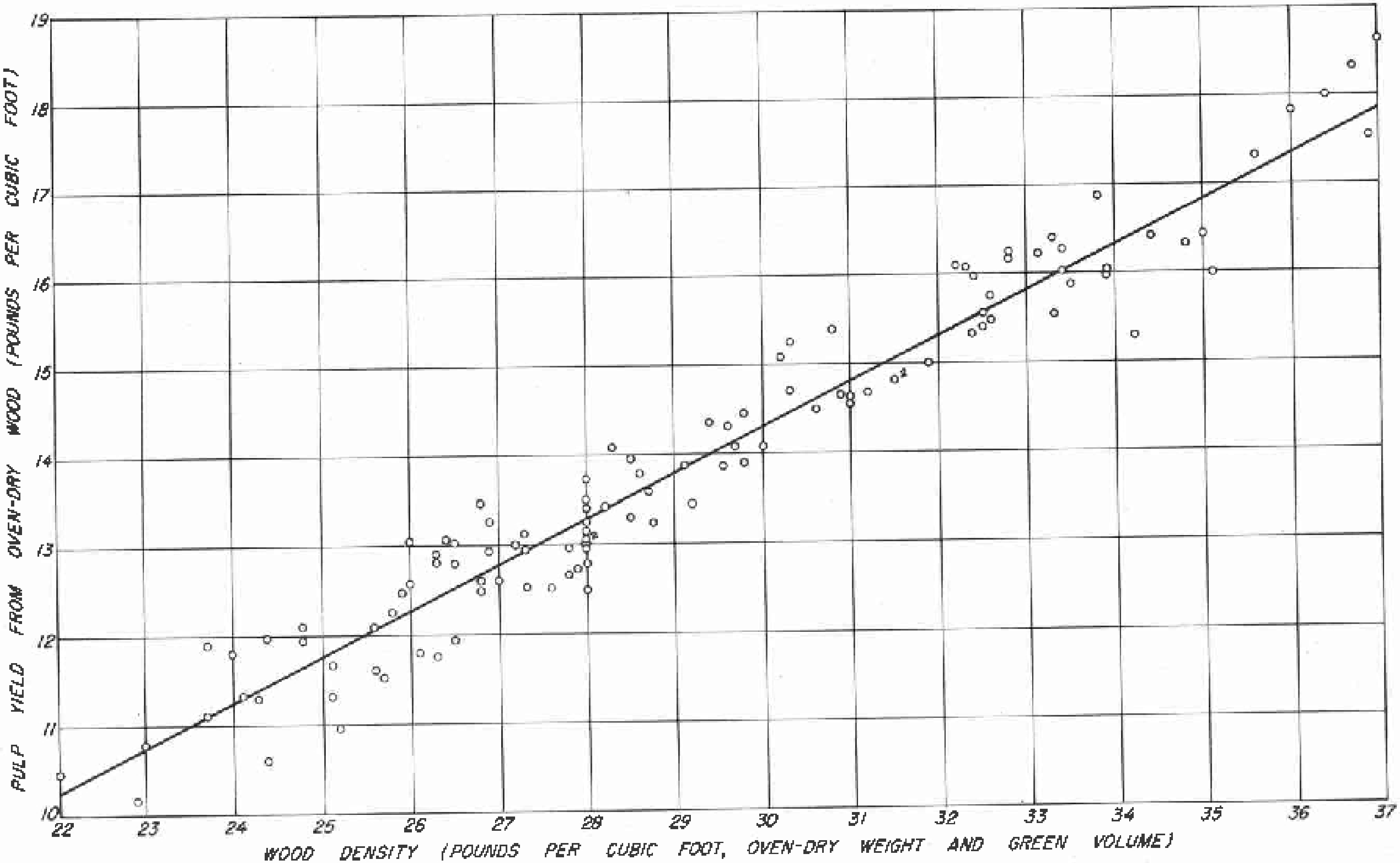

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Figure 2. --Relation between wood density and kraft pulp yields of southern yellow pine pulpwood.

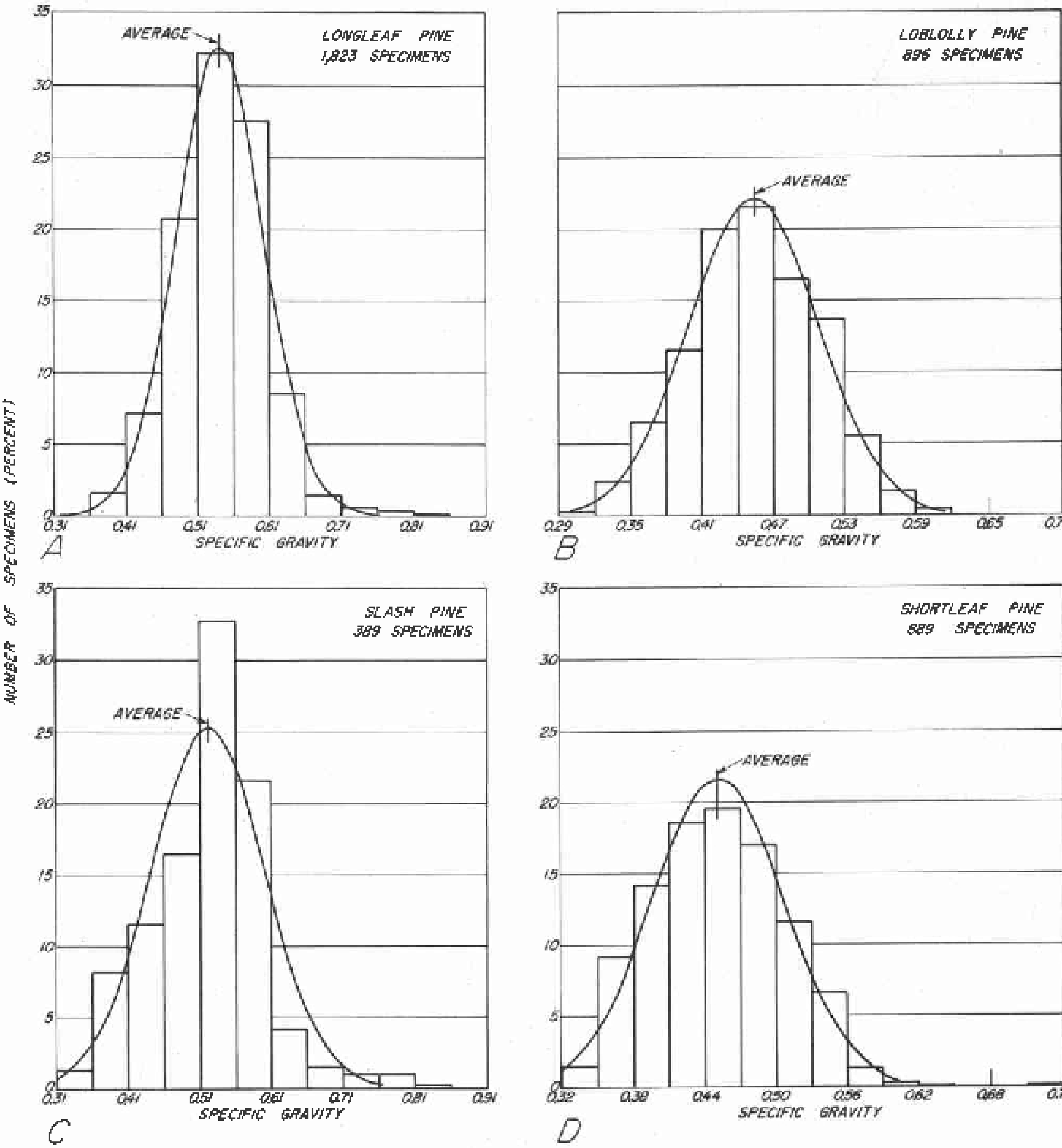

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Figure 3.--Frequency distribution of specific-gravity values for four species of southern yellow pine.

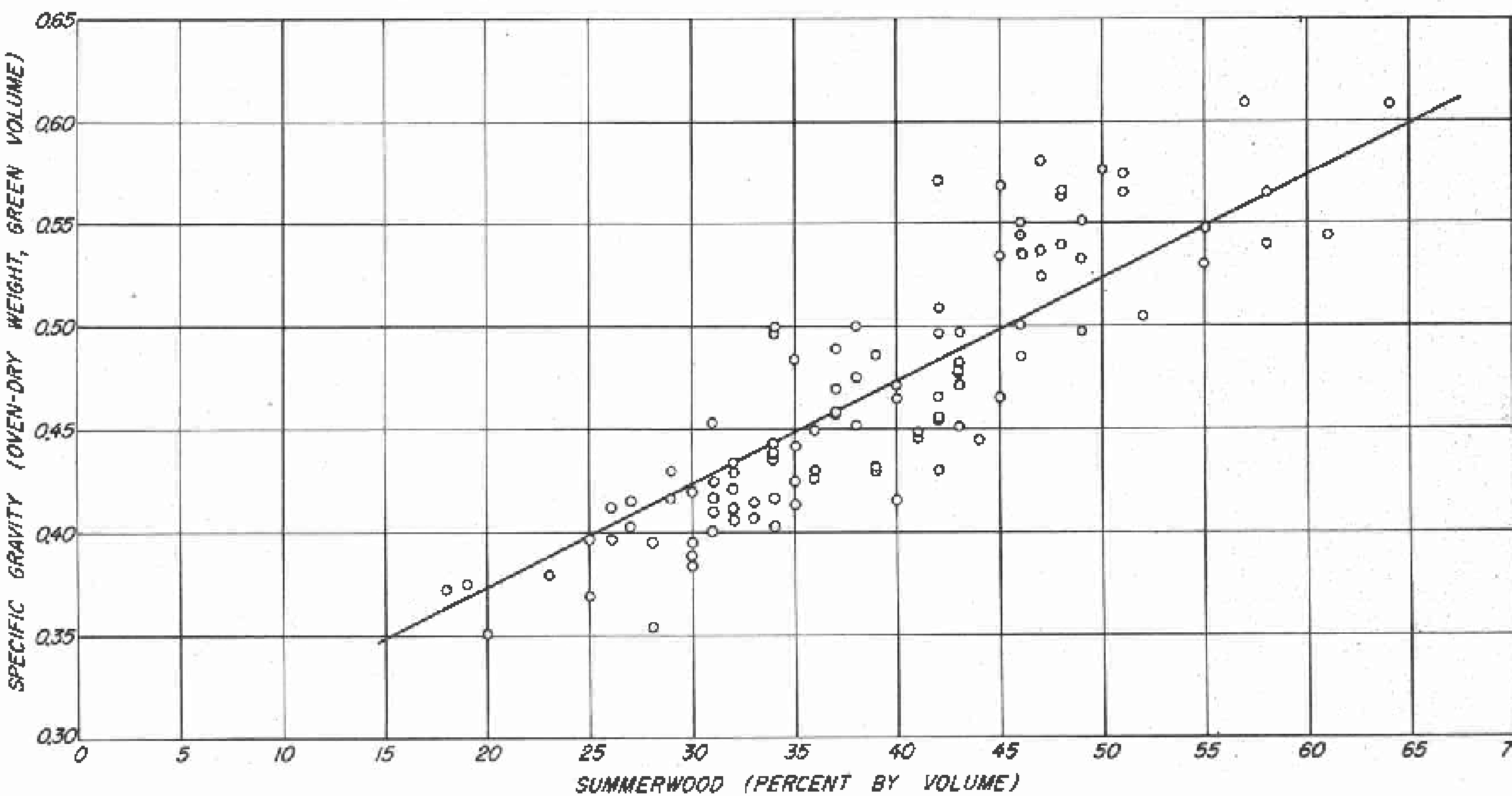

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Figure 4. --Relation between proportion of summerwood in the annual ring and the specific gravity of southern yellow pine.

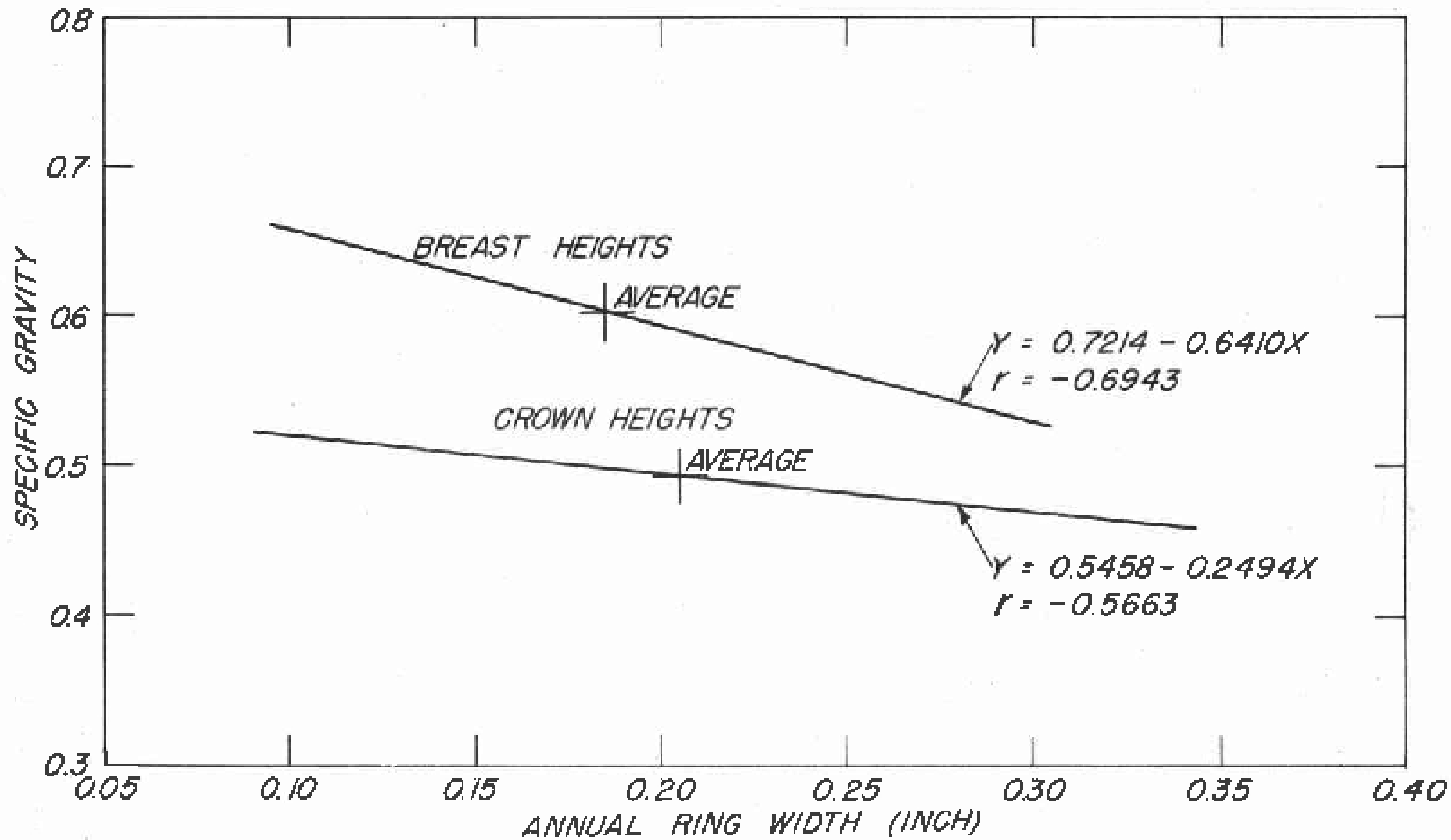

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Figure 5. --Relation of diameter increment to the specific gravity at breast and crown heights of 20- to 30-year-old slash pine growing at different spacings on essentially similar sites.

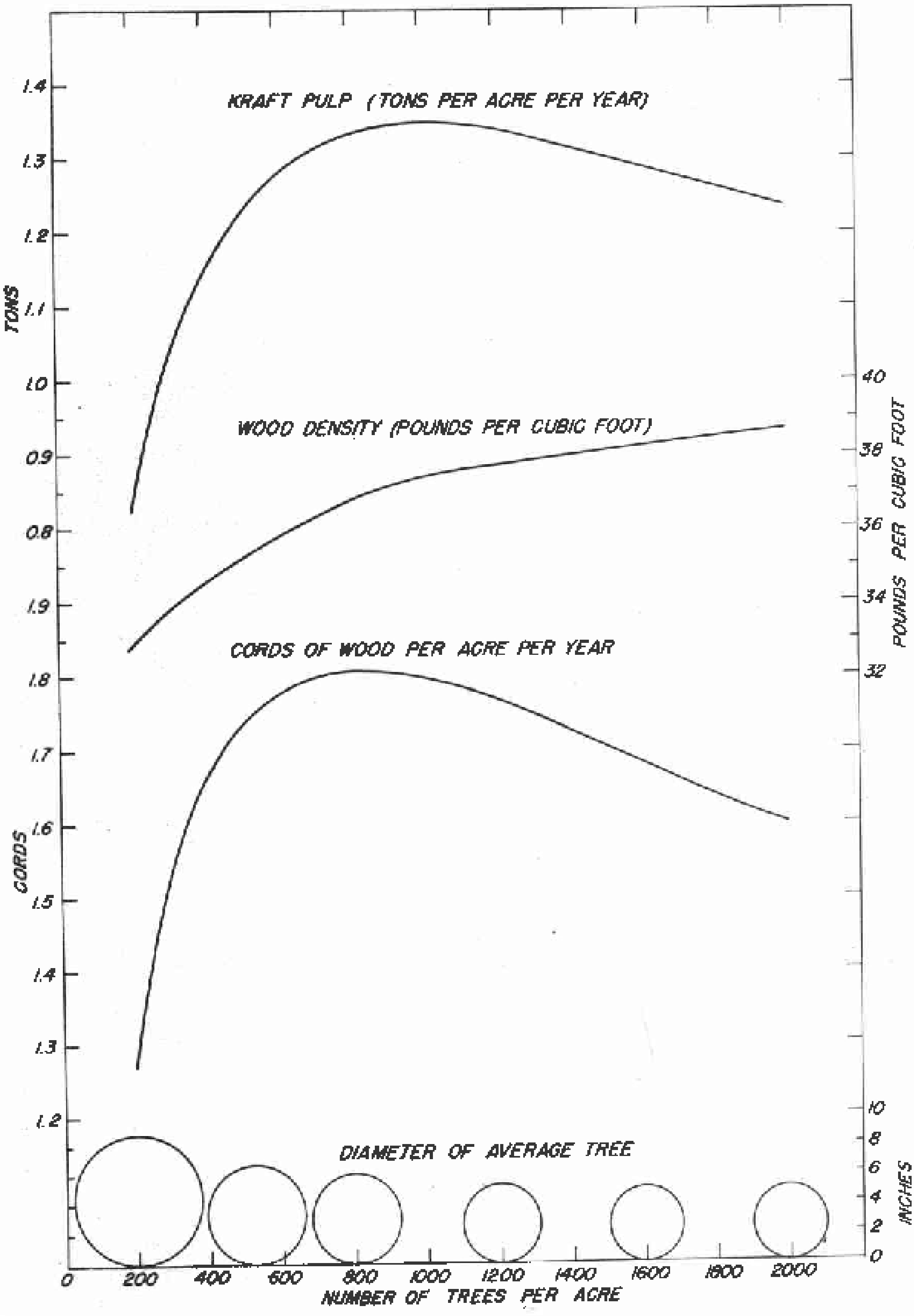

Figure 6.--Average diameter, cordwood growth, estimated density of wood, and kraft pulp yields from young longleaf pine grown at various densities of stocking.

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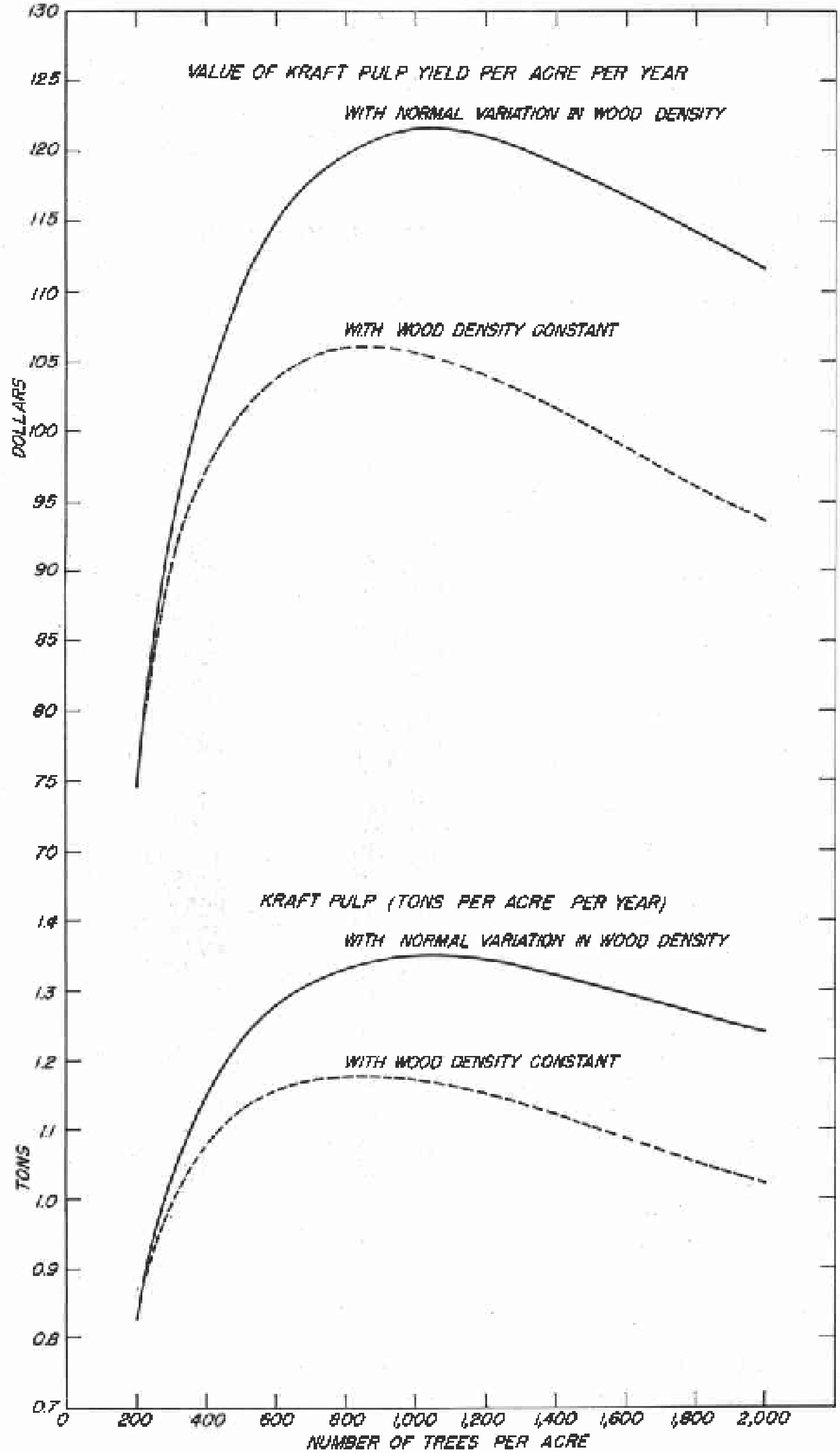

Figure 7. --Estimated kraft pulp yields per acre per year, and the monetary value thereof, from young longleaf pine stands of different densities of stocking with normal variation in wood density and with wood density constant.

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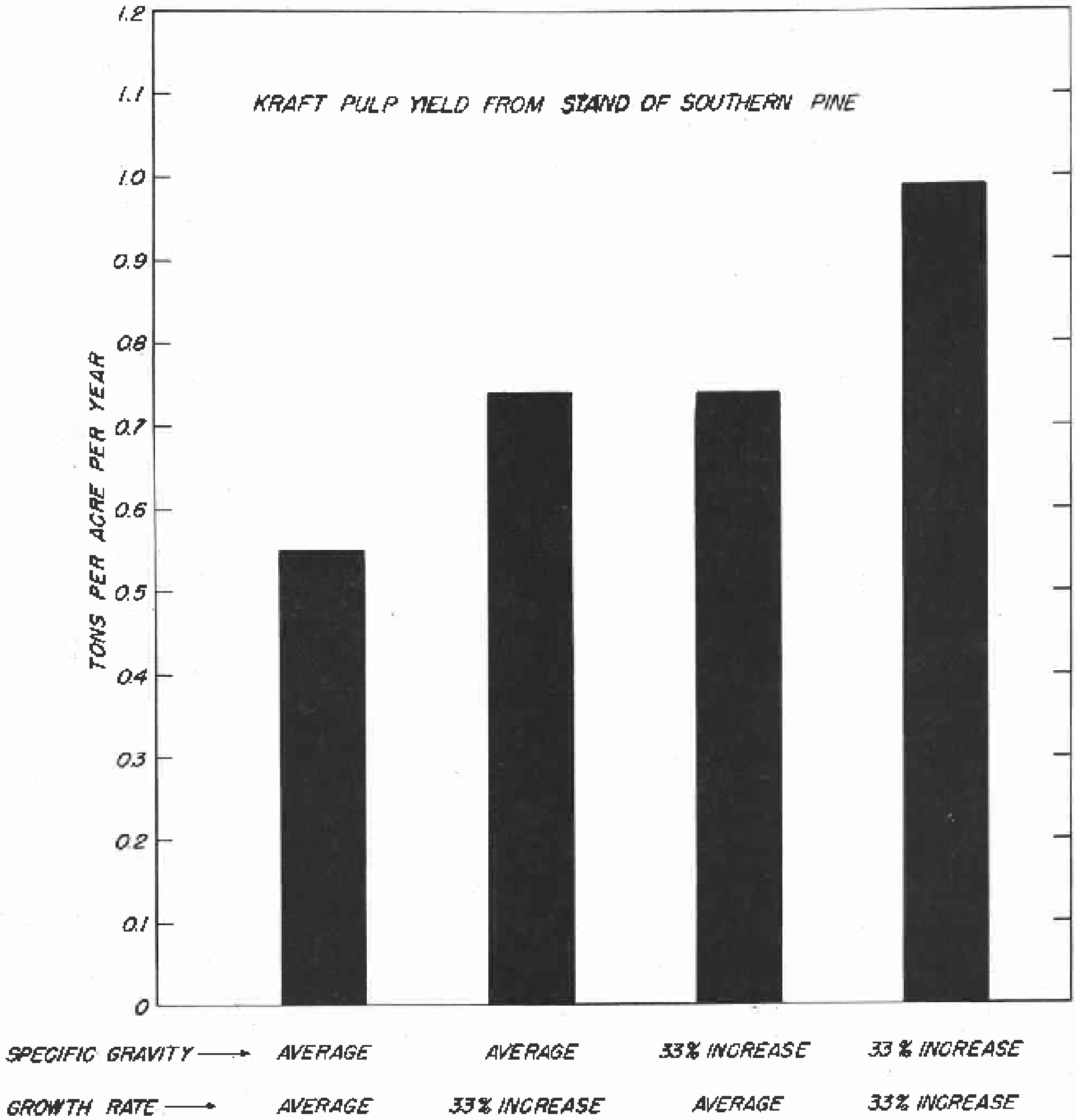

Figure 8.--The estimated effects of increases in specific gravity and growth rate on kraft pulp yields from longleaf pine.

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