Effects of Fertilization Upon Wood Properties of Loblolly Pine (Pinus taeda L.)[1/]

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Intensification of forest management practices has been accompanied by increasing interest in the use of commercial fertilizers to improve productivity of forest stands. Almost without exception, the field application of fertilizers has had 'volume production as its main objective with little concern being given to the effects of fertilizers on the quality of wood produced. Growth increase is unquestionably important, but fully as significant is the kind of wood produced by the fertilized trees and the possible effects of such wood upon products fabricated from it.

To achieve maximum gains through tree improvement, it is essential to determine whether individual trees respond differentially to fertilizers. Maximum improvement from new genetic "strains" is possible only by taking full advantage of individual tree response to fertilization.

Previous to this a comprehensive study of the effects of fertilization on wood properties of older trees growing under normal conditions had not been conducted in North America. One preliminary study, which led to the current more intensive research, was made by Zobel, et al. (1961) on wood of loblolly pine fertilized at age 16. Wood formed the seven years before fertilization was compared with wood formed the seven years after fertilization. Three consecutive annual applications of 160-80-80 pounds per acre of NPK produced wood with wider annual rings, lower density, and shorter tracheids. This same general pattern of response was reported by Erickson and Lambert (1958), Seibt (1963), Pechman and Wutz (1960), and Williams and Hamilton (1961).

The primary objectives of this investigation were:

1. To study individual tree response to fertilization, especially seeking trees that respond with increased growth rate but still maintain desirable wood characteristics.

2. To determine effect of fertilizers over time, i.e. how rapidly does a change in wood appear and how long do the added nutrients affect wood characteristics.

3. To determine the correlations among specific gravity, percent latewood, ring width, tracheid length, tangential tracheid width, and radial tracheid wall thickness.

MATERIALS AND METHODS

Two loblolly pine plantations on the Hill Experimental Forest of the School of Forestry, North Carolina State University, were selected for this investigation. The plantations, one established in 1935 and the other in 1939, are on a Georgeville silt loam, a typical well-drained Piedmont soil. They were established at a spacing of 6x6 feet following a broadcast burn. Both plantations are on sites above average for the Piedmont.

Two 10 mm. increment cores were taken in 1960 from 160 trees representing eight fertilizer treatments replicated twice ranging from no fertilizer to three consecutive annual applications of 160 pounds of ammonium nitrate (33 percent nitrogen), 80 pounds of treble super phosphate (47.7 percent P_2O_5) and 80 pounds of potassium chloride (62 percent K20) per acre.

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In order to determine the length of time the fertilizers were effective, each of the 320 increment cores were divided into the four following segments:

1. 1949-50 annual rings, representing the type of wood produced before fertilization.
2. 1952-53 annual rings, representing the wood formed during fertilization.
3. 1955-56 annual rings, representing wood formed after fertilization.
4. 1958-59 annual rings, representing the wood formed after fertilization.

The following measurements of each core segment were made after the removal of alcohol-benzene soluble extractives: annual ring width; proportion of latewood; specific gravity; length of 20 latewood tracheids; and tangential tracheid width and radial tracheid wall thickiness of 10 latewood tracheids. The tracheid measurements were made on macerated tissue after mounting on semi-permanent slides.

RESULTS AND DISCUSSION

In the treatment combinations tested in this experiment, level of potassium had no detectable effect upon any of the wood properties studied. The lack of a potassium effect is not unexpected, since all of the soils of the slate belt, in which the experimental area lies, are relatively high in potassium. Most of the changes reported are attributable to nitrogen, although nitrogen without phosphorus gave less response than a combination of nitrogen and phosphorus.

Growth Rate

Assuming a fully stocked stand for the 10 year period 1951-1961, trees that received 160 pounds of nitrogen, 80 pounds of phosphorus, and 80 pounds of potassium per acre produced approximately 1 cord of pulpwood per acre per year more than the unfertilized trees. The year following the first application of fertilizers trees that received 160 pounds of nitrogen in any combination with phosphorus and potassium showed a 50 percent increase in radial growth rate. They were still growing faster than the unfertilized trees eight years later.

Figure 1 is a graphic representation of the effects of fertilizers on radial growth rate. As one would expect, the radial growth rate decreases with increasing age in the check trees. Those trees receiving fertilizer treatment of at least 80 pounds of nitrogen show a significant increase in radial growth at the same age where radial growth decreased in the check trees. The maximum response to fertilizer appears to occur the year after the first of the three applications.

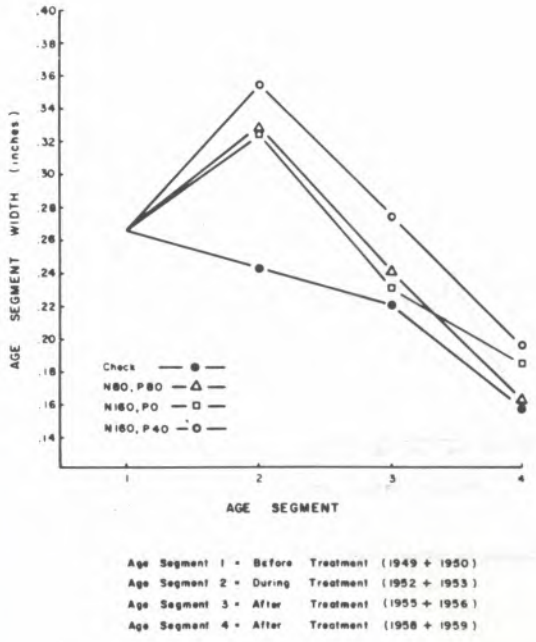

Figure 1 -- The effects of fertilizers on radial growth rate (age sgement width) in the 16-year-old plantation.

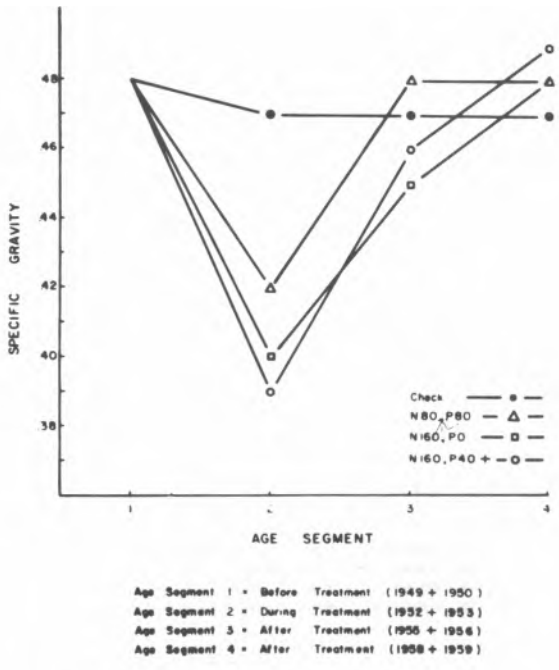

Figure 2 -- The effects of fertilizers on specific gravity in the 16-year-old plantation.

Specific Gravity and Percent Latewood

As has been pointed out by Schreiner (Zobel, 1956), specific gravity is a complex characteristic determined by several growth and physiological variables. It is affected by the percentage of latewood, tracheid wall thickness, tracheid diameter, and perhaps tracheid length.

Figure 2 shows the effect of fertilizers on wood specific gravity. The same pattern of response occurred for percent latewood. In general, wood specific gravity and percent latewood decreased as the amount of nitrogen applied increased. Treatment with 160 pounds of nitrogen, 80 pounds of phosphorus and 80 pounds of potassium caused average wood specific gravity to decrease from 0.48 to 0.39 and percent summerwood to decrease from 47 to 36. This represents a sizeable decrease in the amount of pulp obtainable from a cord of wood, but the increased rate of growth more than compensates for the decrease in density.

Without exception, the specific gravity and percent latewood of fertilized trees was greater the seventh and eighth years after the first treatment application than the check trees. This outcome was surprising, i.e., the specific gravity and proportion of latewood in the fertilized trees was expected to be equal to, or less than, the check trees. This discrepancy may possibly be explained by a study of Paul and Marts (1954). Their applications of complete fertilizer on longleaf pine (Pinus palustris) increased earlywood and decreased latewood, thus causing a reduction in specific gravity. However, when they irrigated the fertilized trees an increase in percent latewood occurred, thus probably increasing specific gravity. These trends would seem to explain the data of the current study where fertilization in dry years caused a decrease in percent latewood and specific gravity as contrasted 4 to fertilization in years of normal or above rainfall when an increase in percent latewood 1 and specific gravity occurred.

Tracheid Length, Radial Wall Thickness, and Tangential Tracheid Width

Without exception, in this study the average summerwood tracheid length and radial double wall thickness was less for all treatments at all periods during and after fertilization than were the tracheids of the check trees. This relationship for tracheid length is shown in Figure 3.

Trees that received 160 pounds of nitrogen with or without phosphorus and potassium showed a decrease in average summerwood tracheid length from 3.9 mm to 3.4 mm and a decrease in radial double wall thickness from 22 to 18U.

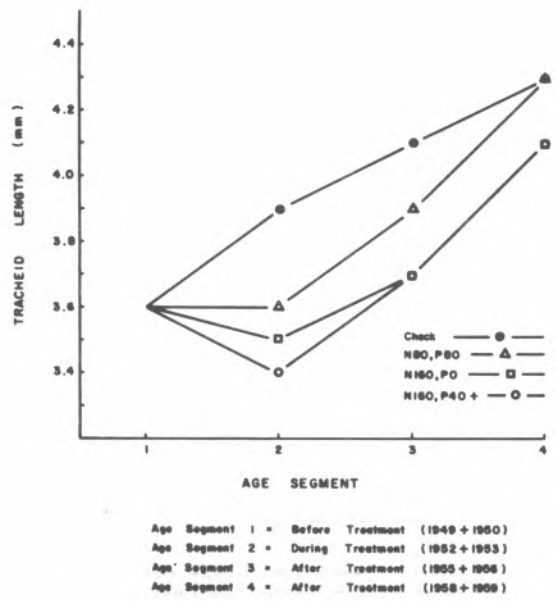

Figure 3 -- The effects of fertilizers on tracheid length in the 16-year-old plantation.

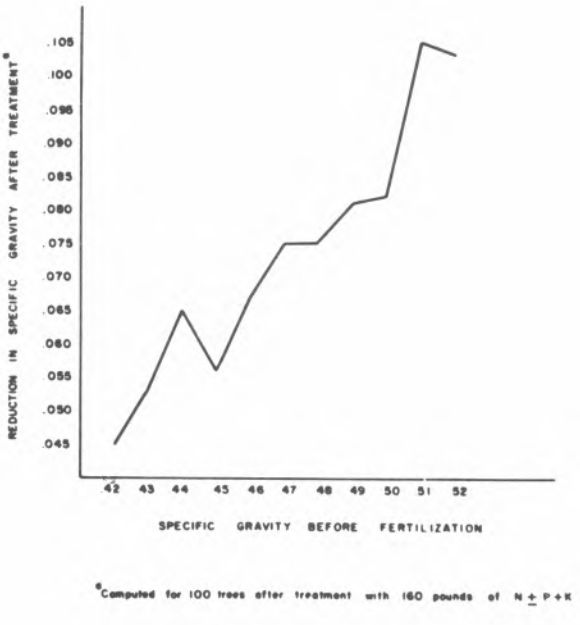

Figure 4 -- Relationship between specific gravity before fertilization and reduction in specific gravity after treatment with nitrogen fertilizers.

In contrast to all other growth and wood characteristics studied, the tangential width of summerwood tracheids failed to show any differences resulting from the several fertilizer treatments. There was a slight increase in tangential tracheid width, but this is attributable to the normal increase with age.

Individual Tree Response to Fertilizers

The possibility that individual trees within a species may react differently to a given fertilizer was discussed by York (1958) and by Maki (1959). As was shown in the previous section of this paper, the "average" tree receiving nitrogen without phosphorus or nitrogen and phosphorus responded with an increase in growth, decrease in specific gravity, decrease in tracheid length, and a decrease in radial double-wall thickness. However, of the 120 trees sampled from plots receiving at least 80 pounds of nitrogen, 30 trees failed to follow the "average" tree pattern of response.

The oft-challenged but now generally accepted concept that there is little or no correlation between specific gravity and tracheid length is supported by responses of the majority of "non-average" trees. Twenty-four of the 30 "non-average" trees showed an increase in growth rate, decrease in specific gravity, decrease in double-wall thickness, but an increase in tracheid length. Three trees showed a growth rate increase, decrease in specific gravity, decrease in tracheid length, but an increase in double-wall thickness. Such differences in response provide the basis for selection of trees to produce desired properties when fertilization is used in forest management.

In a preliminary study it appeared that the extent of changes brought about by fertilization might be somewhat associated with initial specific gravity (Zobel, et al., 1961). To test this indication, the 100 sample trees from the plots receiving at least 160 pounds of nitrogen were compared for response, using the specific gravity before fertilization as a base. Results are presented in Figure 4. An initially high specific gravity tree is much more affected by fertilization than a tree with initially low specific gravity. For example, trees with an initial specific gravity of 0.52 dropped an average of 0.10, whereas trees with initial specific gravity of 0.42 dropped an average of only 0.045. The magnitude of effect does not appear to be related to growth rate.

Since there is a direct relationship between initial specific gravity and amount of response to fertilizers, progeny of seed orchards established from high specific gravity superior trees would be affected through fertilizing more than progeny of seed orchards established from superior trees selected for low specific gravity. An organization interested in low density wood could expect to reap volume gains by fertilizing plus a desired further decrease in specific gravity.

The same relationship as described above for specific gravity is true for tracheid length and double-wall thickness, i.e., the longer the tracheids or the thicker the tracheid walls the greater the reduction from fertilization.

Relationship Among Wood Characteristics

In a breeding program involving wood properties, it is essential to have estimates of relationships among different wood and tracheid characteristics.

All possible correlations among the six wood and growth characteristics used in this study were calculated. Some significant correlations are shown in Table 1.

Table 1. Correlation coefficients of several wood characteristics.

Relationship of wood characteristics		Correlation Coefficients 1/
Radial growth rate	x Tracheid length	--.61**
Radial growth rate	x Radial double-wall thickness	--.48**
Specific gravity	x Percent summerwood	.72**
Specific gravity	x Radial double-wall thickness	.65**
Tracheid length	x Radial double-wall thickness	.64**
Tangential tracheid width	x Radial double-wall thickness	.39*

1/ Based on 24 df, $r_{.05}$=.388; $r_{.01}$=.496

All of the important relationships found among various wood characteristics are summarized in the following list:

1. As radial growth rate increases, tracheid length decreases, radial double wall thickness decreases, and tangential lumen width increases; there is no consistent change in specific gravity or tangential tracheid width.
2. As percent latewood increases, specific gravity increases, and there is a tendency for radial

double-wall thickness to increase; but there is no important relationship between percent latewood and radial growth rate.

3. As specific gravity increases, radial double-wall thickness increases and tangential lumen width decreases. There is no consistent relationship between specific gravity and tracheid length or tangential tracheid width.

4. As tracheid length increases, radial double-wall thickness increases, and there appears to be no relationship between tracheid length and tangential tracheid width.

5. As tangential tracheid width increases, radial double-wall thickness and tangential lumen width increase.

SUMMARY

An investigation was conducted to determine the effects of fertilizers on several wood properties of merchantable loblolly pine. The wood samples were taken from two plantations 10 years after a replicated experiment in forest fertilization had been established on the Hill Experimental Forest, Durham County, North Carolina. The plantations were 16 and 12 years old when first fertilized. Eight treatment combinations were tested ranging from (0-0-0) to (160-80-80). Two 10 mm increment cores were extracted from 10 trees in each treatment, a total of 160 trees. Each of the 320 increment cores was divided into four age segments composed of two annual rings each, representing the wood formed before treatment (1949-1950), during treatment (1952-1953), and two periods after treatment (1955-1956) and (1958-1959). The length of 20 tracheids and the double-wall thickness and tangential width of 10 tracheids were measured for each segment.

The experimental design used for analysis of variance and covariance for each variable was a split-plot, split over time.

Nitrogen caused greatest differences in wood properties and growth rate, although nitrogen with phosphorus gave slightly greater response than nitrogen without phosphorus. Fertilization caused an increase in growth rate, decrease in specific gravity, decrease in radial wall thickness, and a decrease in tracheid length. All trees did not respond to fertili zation in the same manner. For example, some trees decreased in specific gravity, but had increased tracheid lengths.

A comparison of the rate of change after fertilization with the initial value before fertilization showed that trees with either high initial specific gravity, or long tracheids or thick radial walls show more reduction than do those trees with initial low specific gravity or thin radial walls or short tracheids.

Meaningful correlations among several wood characteristics were also reported.

LITERATURE CITED

Erickson, H. D. and G. M. Lambert. 1958. Effects of fertilization and thinning on chemical composition, growth and specific gravity of young Douglas fir. For. Sci. 4:307-315.

Maki, T. E.,1959. The place of fertilizers in forest tree improvement. Proc. 5th South. Conf. on For. Tree Impr., School of Forestry, N. C. State, Raleigh, N. C.

Paul, B. H. and R. 0. Marts. 1954. Controlling the proportion of summerwood in longleaf pine. U.S.D.A. Rept. 1938, For. Prod. Lab., Madison, Wis.

Pechman, H. and A. Wutz. 1960. Haben Mineraldungung and Lupinenanbau einen Kiefernholz? (Do mineral fertilizers and the planting of lupines have any effect on the properties of the wood of spruce and pine?) Forstwissenschaftliches Centralblatt 79(3/4):99-105.

Seibt, G.,1963. The effect of fertilizers on wood density in Scots pine, Japanese larch, and Norway spruce. Aus dem Walde, Hannover 6:51-82.

Williams, R. F., and J. R. Hamilton. 1961. The effects of fertilization on four wood properties of slash pine. Jour. For. 59:662-665.

York, E. T., 1958. Are forest trees really different? Forest fertilization in a new era. A handbook presented by the American Potash Institute, Inc., Washington, D. C. pp. 48-53.

Zobel, B. J., 1956. Genetic, growth, and environmental factors affecting specific gravity of loblolly pine. For. Prod. Jour. 6:442-446.

_____,J. F. Goggans, T. E. Maki, and F. Henson. 1961. Some effects of fertilizers on wood properties of loblolly pine. Tappi 44:186-192.