EFFECT OF NITROGEN FERTILIZER ON THE GROWTH RATE AND CERTAIN WOOD QUALITY CHARACTERISTICS OF SAWLOG SIZE RED OAK, YELLOW-POPLAR, AND WHITE ASH

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ABSTRACT

In the mid-1930's experimental plots established in even-aged, pole-sized stands of mixed hardwoods were fertilized in the early spring with varying amounts of nitrogen. Leaf samples, for chemical analysis, were taken the fall of the same year that the fertilizer was applied, and increment cores, for radial growth measurements, were taken the year following fertilization. All species studied showed a significant growth response to nitrogen fertilization, and in all cases there was a strong correlation between soil nitrogen supply and the nitrogen content of the leaves. Twenty-seven years later sample trees of three species were cut on the control and the variously fertilized plots and bolts and cross sections therefrom were shipped to the Forest Products Laboratory for wood quality evaluations. This material was checked for specific gravity and toughness, and subjected to machining tests that included planing, turning, and shaping. The fast-grown wood produced by the fertilized trees was found to be just as suitable for the uses and products--mainly furniture, millwork, paneling--normally made from these valuable hardwood species as wood produced by the slower growing control trees. Also, so far as could be determined from this study, such wood would be just as good or better for pulp and paper products.

ACKNOWLEDGMENTS

I wish to thank Harvard University for granting permission to remove 71 sample trees from the old Harvard Black Rock Forest nitrogen fertilizer plots. Special thanks are also due Jack Karnig, in charge of the Harvest Black Rock Forest, and Raymond F. Finn, formerly assistant director of the Forest, and now with the North Central Forest Experiment Station, for assistance in relocating the old plots and helping with arrangements for the selection and removal of sample trees. Several members of the Forest Products Laboratory staff participated in the study, and their contributions are hereby gratefully acknowledged. Kent McDonald had direct charge of logging operations and the transport of sample material, and also handled various phases of the laboratory analysis. M. Y. Pillow (now retired) assisted with the planning and the sampling and had overall supervision of the laboratory work. George Englerth (now retired) conducted the machining tests and prepared the comprehensive office report.

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In the mid-1930's when I was assistant director in charge of research at the then privately owned Black Rock Forest in New York, I initiated what has since proved to be the first large-scale fertilizer experiments with natural forest stands in the United States. The results of some of these experiments, which have been under observation now for about 35 years, will be the subject of this paper. Emphasis will be on the quality of wood produced by certain hardwood species whose growth was greatly stimulated with nitrogen fertilizer.

By way of background, I should point out that the 3,100-acre Black Rock Forest, now known as the Harvard Black Rock Forest, is located in the Hudson Highlands of New York, on the west side of the river, between the U.S. Military Academy to the south and the village of Cornwall-on-the-Hudson on the north. The topography of the area is mountainous, with numerous rock outcrops. Elevations range from 450 feet to 1,461 feet. Little of the land was suitable for cultivation at the time of settlement in 1694, although there is evidence of considerable clearing for pasture.

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[1] Maintained in Madison, Wis., in cooperation with the University of Wisconsin.

But mainly, the more rugged areas of the Highlands produced cordwood to make the charcoal required by the local iron industry, and later crossties for the railroads and fuel for the brick kilns that developed along the Hudson Valley.

During the 19th century, and perhaps earlier, the Highlands were clearcut on the average of every 40 years, and were frequently ravaged by wildfires. As a result, present stands are even-aged and mostly of sprout origin. The soils of the area--mostly stoney clay loam derived from glacial till--also show the effects of past abuse. They are generally low in organic material, low in nitrogen, and tend to be thin, especially at the higher elevations and on the steeper slopes. The soils of the area have been described in detail by Scholz (1931) and the geology by Denny (1938).

The objectives of the original experiments were: (1) To learn more about the nutritional needs of the local hardwood species so that we might improve our silviculture; and (2) to develop a foliar analysis technique that could be used as a management tool to estimate available nutrient levels of forest soils of unknown fertility with a relatively high degree of accuracy. At that point in time, when the country was just starting to recover from the Great Depression, no one seriously believed that the time would ever come when it would be economically feasible to use fertilizers to accelerate the growth of commercial forests.

In planning my research I most certainly did not anticipate the current surge of interest in what is now known as high-yield forestry. In fact, I am frequently embarrassed by being credited with foresight I didn't possess. However, this fact in no way detracts from the value of the results of this pioneering research in today's more favorable climate.

In any event, starting in 1935 and extending over a period of 5 years, varying amounts of nitrogen, phosphorus, and potassium fertilizer, singly and in different combinations, were applied to about thirty 1/4-acre plots established in even-aged pole-size stands of mixed hardwoods on several different sites on the Black Rock Forest. Adequate unfertilized control areas were reserved for each series of variously fertilized plots established on a relatively uniform site. Fertilizer was applied, broadcast, to the undisturbed forest floor early in the spring. There was only one application. Leaf samples, for chemical analysis, were taken in the fall of the same year during that 2- to 3-week period when nutrient content is maximum and relatively constant (Mitchell, 1936). Increment cores, for radial growth determination, were normally taken the year following fertilization.

Starting in 1936, cooperation was developed with Dr. Robert F. Chandler, Jr., then assistant professor of forest soils at Cornell University. He had similar interests, and by duplicating some of the studies at the Arnot Experimental Forest, near Ithaca, it was possible to include several important species, such as beech and basswood, that were infrequent in the Hudson Highlands.

Since results with phosphorous and potassium applications were negative, so far as growth response was concerned, only the nitrogen data are considered here. All data from the 20 combined Black Rock and Arnot Forest nitrogen fertilized plots are presented in detail in Black Rock Forest Bulletin No. 11 (Mitchell and Chandler, 1939).

All 24 species studied made a significant response to nitrogen applications in terms of increased radial growth. For certain species, such as yellow-poplar, basswood, and ash, the increase in radial growth was on the order of 300 percent. These species were classed as "nitrogen demanding." At the low end of the response scale, and classed as "nitrogen deficiency tolerant," were such species as the oaks, trembling aspen, and red maple. The other species--mainly hickory, sugar maple, beech, black-gum--were classed as intermediate in this respect. Fertilization with nitrogen did not result in an increase in epicormic branching immediately following treatment or later.

As shown in figures 1, 2, 3, and 4, a high degree of correlation was also found between available nitrogen supply and the nitrogen content of the leaves. Here, again, there were differences between species. From the experimentally established relationships between nitrogen supply and the nitrogen content of the leaves, it was possible to develop a standard of comparison, or rating scale, and a technique for using foliar analysis to estimate available nitrogen levels in forest soils of unknown fertility. Using this technique, 50 forest sites throughout the Northeast were rated according to nitrogen-supplying capacity. The results are shown in figure 5. It appears from the data obtained from this preliminary survey that the soils of the Black Rock and Arnot Forest study plots rank at the lower end of the distribution curve for relative nitrogen supply. This no doubt accounts for the significant response of all species to nitrogen fertilizer.

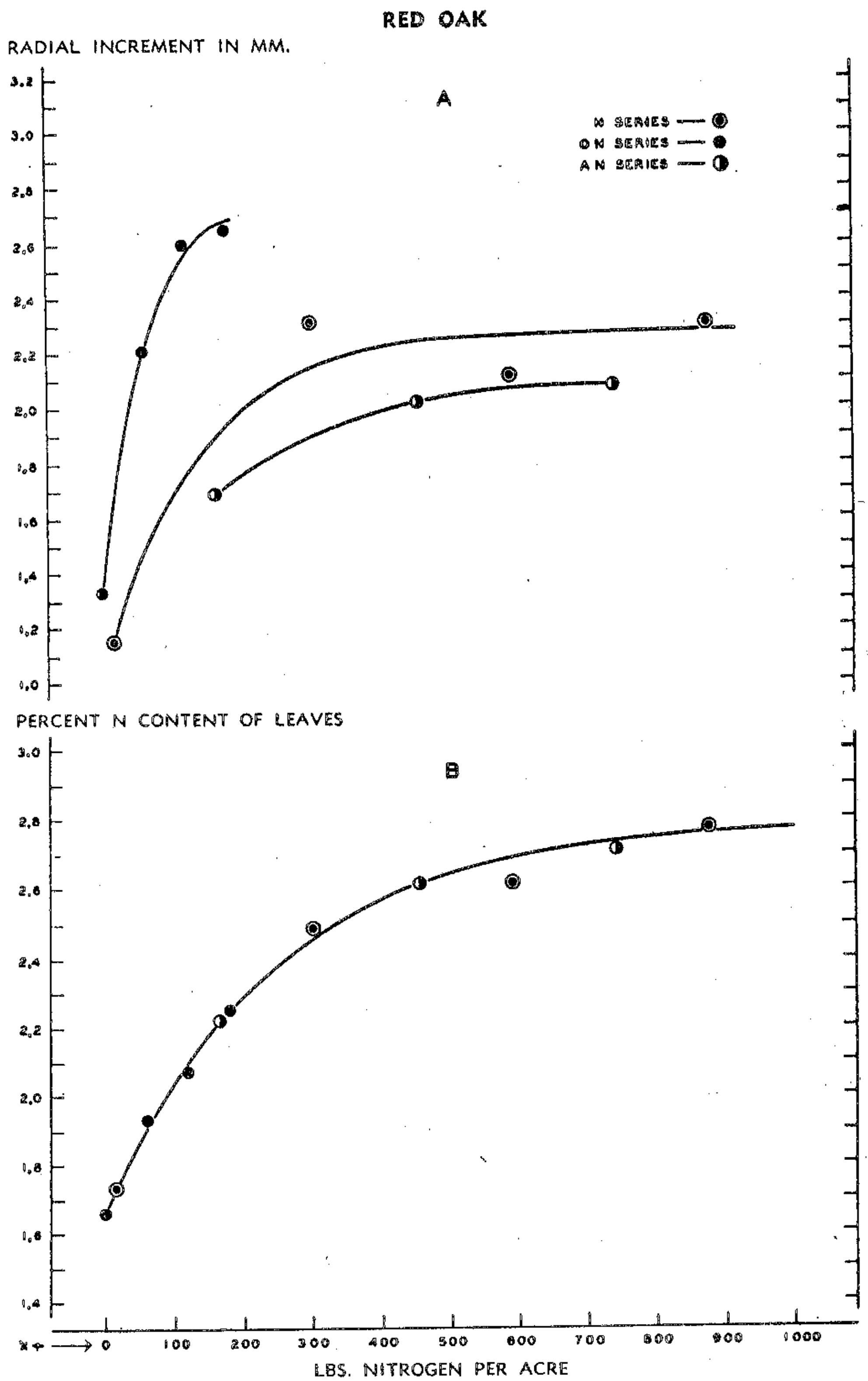

Figure 1.--The relationship between nitrogen supply and the annual radial increment and the nitrogen content of the leaves of red oak trees growing in even-aged stands of mixed hardwoods.

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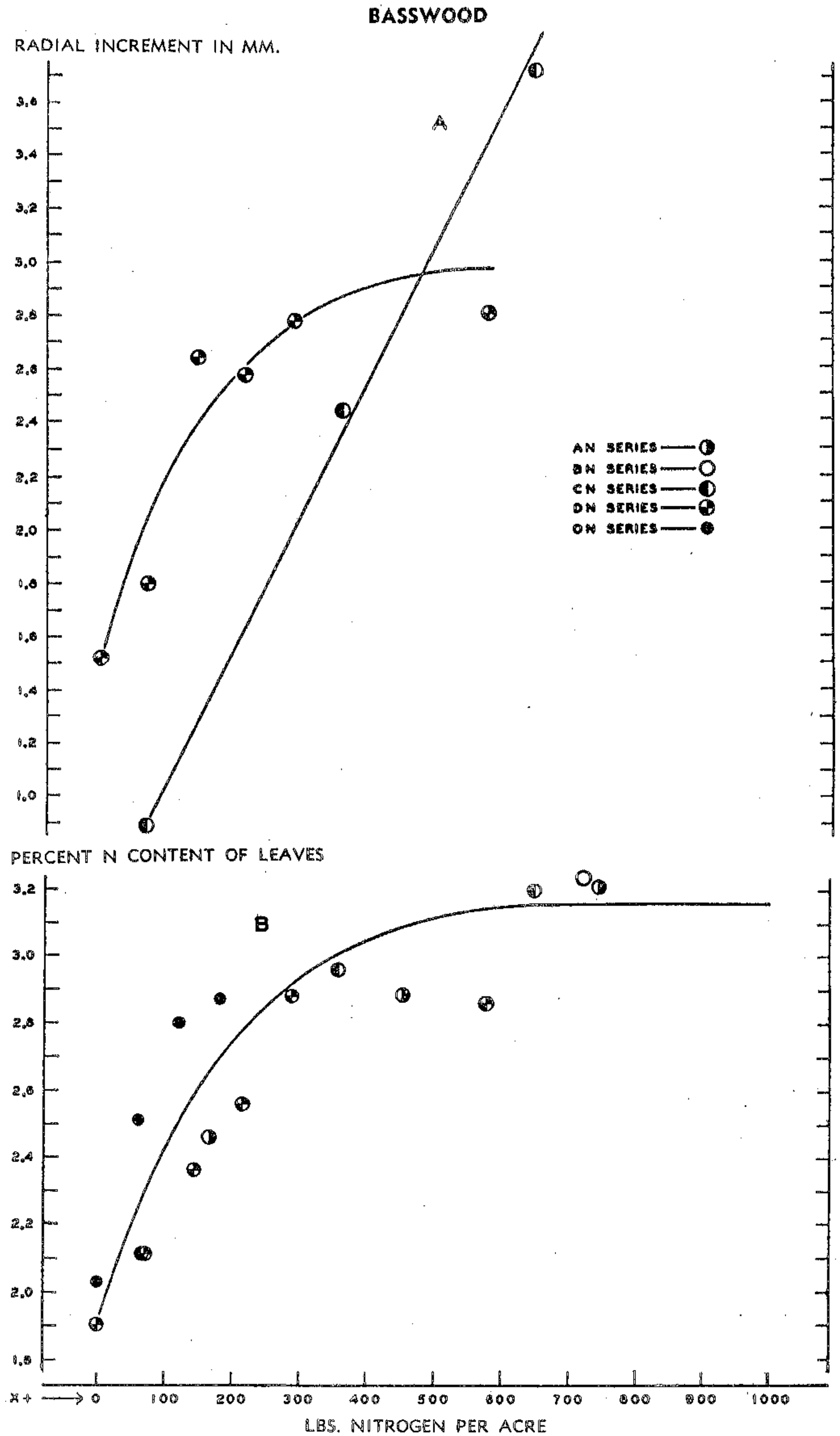

Figure 4.--The relationship between nitrogen supply and the annual radial increment and the nitrogen content of the leaves of basswood trees growing in even-aged stands of mixed hardwoods.

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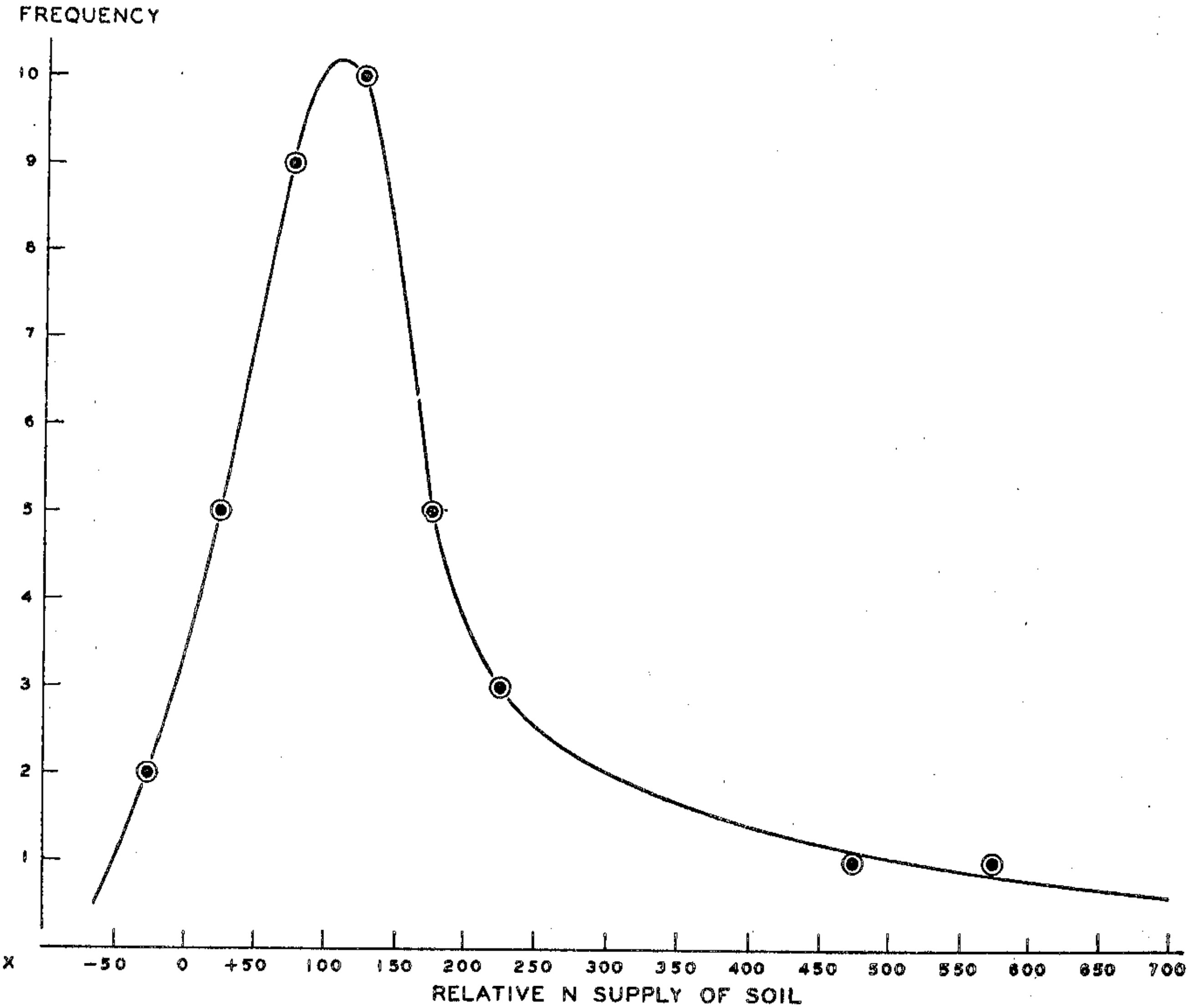

Figure 5.--The frequency distribution of 50 different forest sites throughout the Northeast classified according to relative nitrogen supply.

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It occurred to Dr. Chandler and I at the time that the wood produced by our faster growing trees might be abnormal in some respect or even unsuitable for traditional uses or products. We were not equipped to make such evaluations ourselves, so we quite naturally wrote to the Forest Products Laboratory in Madison to enlist their interest and cooperation. Certainly they would recognize the importance of our research and provide the needed help.

I'll never forget the reply we received soon thereafter. In extremely polite language it said, in effect, that they had more important matters to attend to, and that the answer was no. This reaction was typical of the times. There was very little interest or research in the whole area of forest soils, tree nutrition, wood quality, and the like, and such work was largely confined to a few of the older eastern universities. Industry at that time couldn't have cared less. Even the U.S. Forest Service, although mildly interested, had no program of consequence and didn't make a substantial committment until the mid-1950's. The odds against developing strong interest in and continued financing for further research in this area appeared to me to be insurmountable. So, with much regret, I tossed in the towel, abandoned my chosen field of specialization, and sought employment elsewhere. Dr. Chandler did likewise soon thereafter, probably for much the same reasons.

It was not until 27 years later, after I was well settled in my present job at the Forest Products Laboratory, that I was again in a position to follow up on, and in certain respects to complete, the research I had initiated so many years earlier. We contacted Harvard University and were granted permission to cut as many sample trees from the old nitrogen plots as we felt necessary to assess the long-term effects of accelerated growth on wood quality. In all, 71 sample trees were selected and felled, including 31 white ash, 28 red oak, and 12 yellow-poplar. Unfertilized control trees were of course included in the sample. All were in the dominant crown class and, for the same species within a variously fertilized series on the same site, an effort was made to sample trees of approximately the same age.

A 2-1/2-inch-thick disk was sawn from the bole of each sample tree 3 feet 8 inches above the ground level and another at 16 feet 2 inches above the ground level. In addition, a 5-foot-long bolt was cut immediately above the lower disk. Both disks and the bolts were shipped by truck to the Forest Products Laboratory for study (fig. 6).

At the Laboratory sawmill, four 4-foot-long boards, each 1-1/4 inches thick and 3 inches wide, were sawn from each sample bolt, one board from each face. Each flat-sawn board was so cut that the inner tangential surface included the first growth ring following the year of fertilization. The boards were dried and conditioned to 12 percent moisture content and rough surfaced to 27/32-inch thickness. Each board was then cut into four 12-inch-long pieces for machining and other tests.

Our primary objective was to determine whether or not wood produced by trees so stimulated with nitrogen was as suitable as average (untreated) wood for the products and uses normally made of these valuable hardwoods. This includes furniture, millwork, paneling, and the like.

Machining properties are probably the most useful and commonly used index to the suitability of wood for such products. Specific gravity,

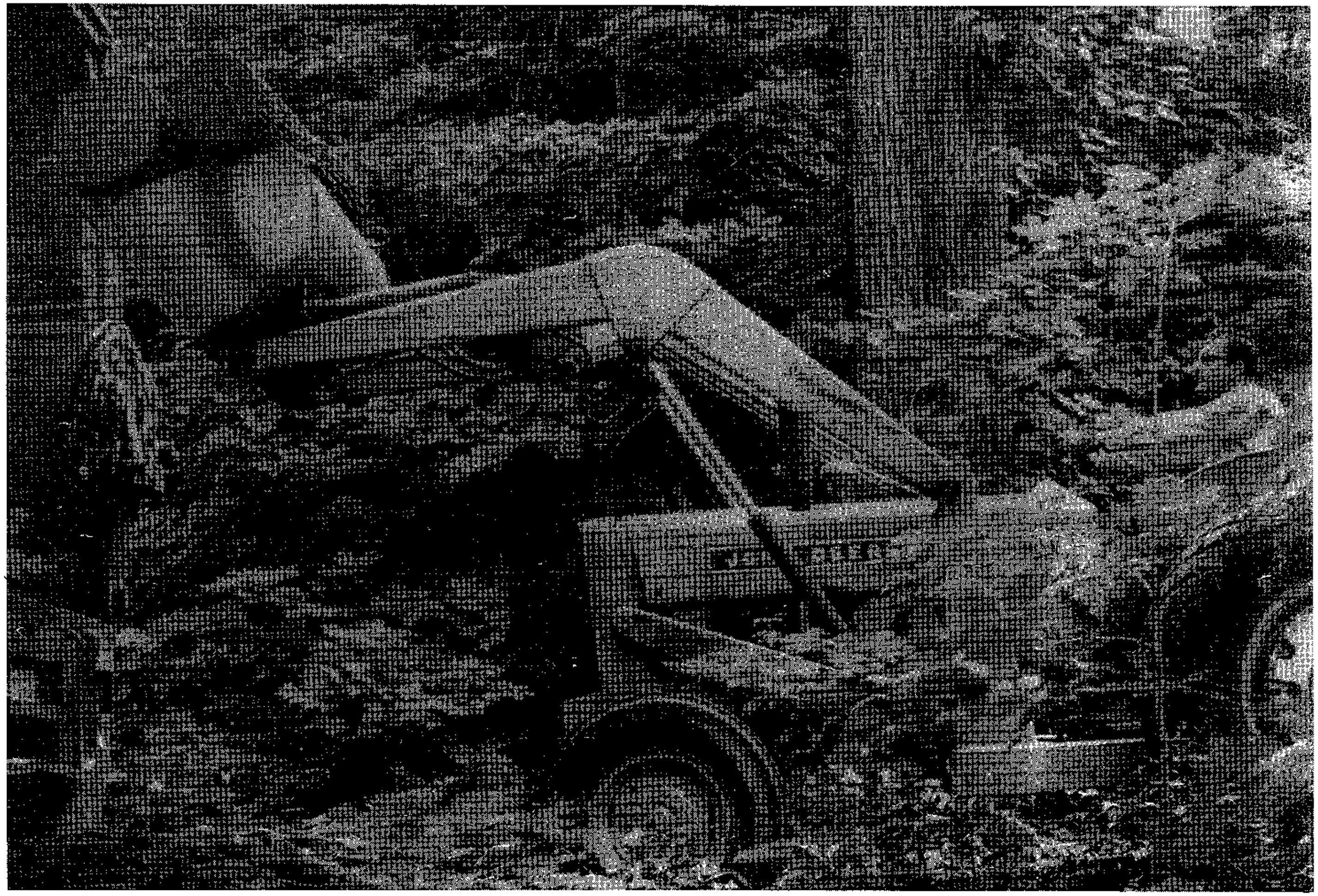

Figure 6.--Loading sample bolts into truck for transport to the Forest Products Laboratory.

which is related to strength, and toughness, the ability to absorb shock, are also important. Accordingly, all sample material was checked for specific gravity and toughness and subjected to machining tests. The latter were made according to standard methods developed by Davis (1958), and included planing, turning, and shaping (fig. 7).

The office report on this study contains numerous tables that summarize the thousands of observations made, and also the results of rigorous statistical analysis. This tabular material and the statistical data are not included in my paper because the essential findings resulting from all this work are rather meager and can be simply stated as follows:

1. No significant differences were found between the machining properties of wood produced by trees whose growth was greatly stimulated with nitrogen fertilizer and wood produced during the same period by slower growing control trees of the same species growing on the same site.

2. Where valid comparisons could be made, there was a trend toward increasing specific gravity with increasing growth rate.

3. There was a highly significant linear correlation between specific gravity and toughness.

4. One of the most interesting findings was that the growth response to the single application of nitrogen continued for 6 to 8 years (fig. 8). Had the stand been thinned 3 to 4 years following fertilization, the effects on growth acceleration might have continued even longer.

5. Examination of disks cut from fertilized trees at 3 feet 8 inches and 16 feet 2 inches above ground level showed the same general pattern

Figure 7.--Dr. George Englerth checking turning test specimens for defects.

(M 127 253)

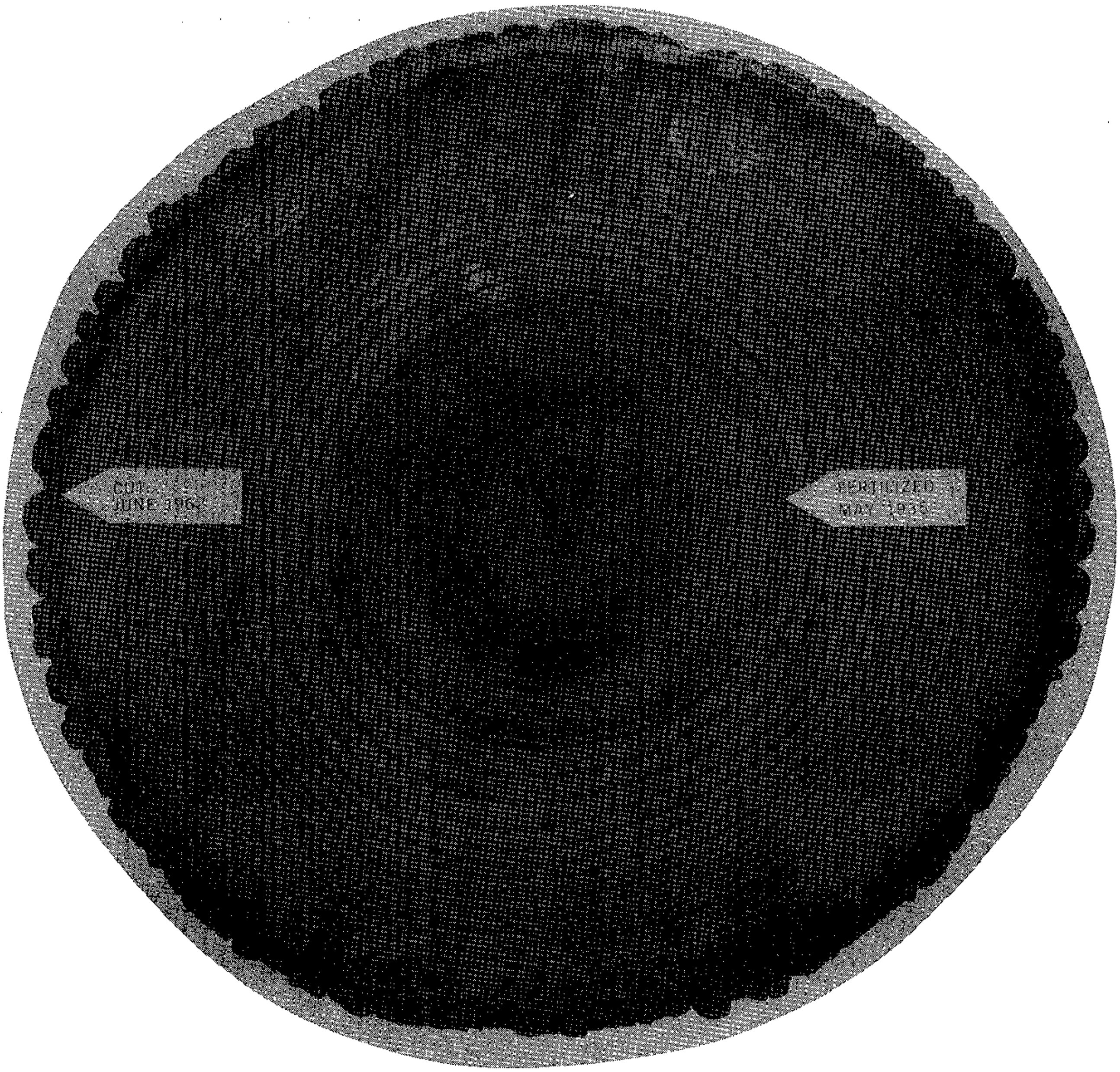

Figure 8.--Cross section (at breast height) from ash tree that was fertilized with nitrogen in May 1935 and cut in June 1962.

(M 130 132)

of growth response. The only difference was that the annual rings at the higher level were slightly narrower than the same year's growth nearer the ground level.

6. Only three of the 24 species studied were sampled for wood quality evaluation. It is probably unlikely that the response of the other species to growth acceleration would be greatly different. However, the original fertilizer plots are still intact, and if anyone is interested in pursuing the matter further, I am quite sure that satisfactory cooperative arrangements for so doing could be made with Harvard University.

7. As to utilization for pulp and paper products, assuming anyone would choose to so use prime sawlogs of such valuable hardwoods, the slight trend toward increasing wood density, due largely to thicker cell walls, should be an advantage. It would result in higher pulp yield per unit volume of wood.

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