SOME PRESENT TRENDS IN TREE QUALITY IMPROVEMENT IN GERMANY

by Wolfgang Knigge 1/

It is with great pleasure that I accept your invitation to take part in the Sixth Lake States Forest Tree Improvement Conference. This gives me a welcome opportunity to renew contacts with American foresters and wood technologists in the field of tree and wood quality improvement. During the past 10 years, American progress in this special research field has been very rapid and successful and has received much attention in Germany. For this reason your leading researchers such as Philip Larson, Harold Mitchell, and Bruce Zobel, to mention only a few, enjoy an excellent reputation in my country.

I consider it a special distinction to fulfill your request for a summary of some present trends in tree quality improvement in Germany. I do this gladly because I believe that much can be learned by comparing experiences in this research area which has recently developed so rapidly.

In an attempt to give a short but pertinent survey of the present status and future goals of research work in my country, it will be necessary for me to limit my comments. I recognize that the major point of discussion at this meeting is primarily the improvement of wood quality through selection of genetically superior trees. This was also the central topic of the World Consultation on Forest Genetics and Tree Improvement held last month in Stockholm. Therefore I would like to limit my own remarks today to two different major working areas of German tree quality research. These two research questions are:

1. What standards can be used to judge wood quality in standing trees?

2. To what degree can wood properties be influenced and improved through forestry practices?

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CHOICE OF TREE SPECIES

We have to bear in mind that while the number of tree species on the North American Continent numbers several hundred, the number in Central Europe is limited to approximately 60 native species. This difference' results largely from the extinction of tree species during the ice age. Furthermore, of the 20 tree species which have practical importance in Germany, the four species--Scots pine, Norway spruce, beech, and oak--constitute 85 percent of our timber harvest. This relatively limited choice has been supplemented somewhat by the successful introduction of foreign tree species, especially those from North America. For example, Douglas-fir, Sitka spruce, grand fir, and white pine have been planted to a considerable extent in Germany.

In the past, German foresters have generally attempted to introduce the largest possible number of tree species which were appropriate for site conditions. It was believed that this procedure would assure in an optimal way many different types of wood for the unpredictable demands of future markets. However, in recent times, it has become quite clear that the continuation of this principle leads to the production of wood having undesirably great variation in quality and usefulness. It also appears that several of these tree species will have no satisfactory usefulness at all in the future. In regard to the increasing mechanization of our wood-using industries, it seemed advisable to limit our commercial tree species to those able to satisfy industries' demands for a uniform and high-quality raw material in quantity and quality. Therefore in the future, two major groups of tree species will be grown in Germany:

a) Those tree species having relatively uniform wood properties and a great number of possible uses, and which in addition, are able to produce rapidly a maximum wood volume and dry wood substance. This group of tree species is designated as the "quantity tree species" and includes mainly conifers, such as Norway spruce, Douglas-fir, and true firs. The most important deciduous tree species of this group are beech and poplar. The second general group includes

b) The so-called "quality tree species." These usually slower growing species produce a high proportion of knot-free wood, large diameter, and usually have favorable color and grain figure. Trees having these favorable wood properties command premium prices. To this group belong carefully raised Scots pine, larch, white (English) oak, and especially ash, maple, walnut, and several types of fruitwood, such as apple, cherry, and pear, which are desired by our furniture industry.

CRITERIA OF WOOD QUALITY

In searching for criteria for judging wood quality of a single tree, of a tree species, or of a forest stand, forest products research faces a difficult problem. It has to combine its own standards, which are usually absolute and biologically oriented, with those of the forest products industry, which can vary greatly in industrial purpose and changing utilization methods.

For example, the lumber industry is primarily concerned with the length, diameter, taper, and knottiness of logs. The veneer industry, in addition to diameter and knottiness, gives special emphasis to color and grain figure. The pulp and paper industry, however, is more concerned with fiber length, specific gravity, and the suitability of the wood for mechanical or chemical digestion. Other wood consumers have varying utilization requirements by which they judge their raw material. Forest products research has consequently found it necessary to seek theoretical standards which are a compromise attempting to satisfy the varying and changing requirements of the different forest industries.

After long deliberation, German research has placed particular importance on an optimal combination of the external tree characteristics as a useful measure of wood quality. For reasons which I shall discuss later, we prefer these standards to those which evaluate internal wood properties and which we believe are of secondary importance to our wood industries. Therefore, our evaluation of the standing tree is currently based mainly on the following characteristics in descending order of importance:

a) External dimensions of the stem, expressed in terms of diameter and length of the merchantable stem.

b) Branchiness, particularly the number, diameter, and angle of the branches and in addition the proportion of the stem having green, dead, or no branches. A third external standard is

c) Stem form, which is a comparison of the tree axis and cross-section with the ideal form of a geometric cylinder. After these follow internal wood characteristics such as

d) Physical wood properties, particularly specific gravity as an expression of dry weight production and as an indication for swelling and shrinking, and also the elasticity and strength properties. Now follows the

e) Anatomical and chemical composition, particularly fiber length, fiber angle, thickness of the cell wall, and proportion of spring and summer wood within the annual ring; and finally

f) Grain figure and color, which determine attractiveness of the wood in its natural form. It is clear, however, that the importance and practical effect of the standards just enumerated are of secondary importance when the tree is affected by

g) Wood defects: these can be deviations from the ideal stem form, disturbance of normal wood structure, or undesirable changes following tree felling. These wood defects can occur singly or combined. Their individual importance varies according to the special needs of the wood industry involved.

The major importance of tree growth, branching habit, and stem form as criteria for wood quality is due to the fact that these characteristics are easy to measure in standing trees and, when carefully evaluated, make possible a prediction of internal log quality. German foresters are highly interested in American attempts to supplement external measurements by increment borings as a standard inventory procedure, but this procedure is not common in Germany because our commercially important spruce and beech trees are highly inclined to secondary pathological decay following mechanical damage such as boring.

INFLUENCING WOOD CHARACTERISTICS THROUGH FOREST PRACTICES

With these general concepts for judging wood quality, German forest products research during the past decade has subsequently tried to establish how wood quality can be improved during wood production. These attempts are based on the observation that the characteristics of the individual stem are a product of the environment as well as of heredity. The conviction that variations in wood quality very often are a result of specific conditions has led to investigations to determine the degree to which wood properties can be influenced by intensive management practices during stand development. Researchers and many practicing foresters are also convinced that improvement of wood quality can be achieved more rapidly through proper forestry practices than through testing alone in which results become concrete only after a full rotation period. In summary, the conviction has been formulated that the final success of forestry practices should no longer be judged only from the standpoint of maximum forest yield, but equally from the standpoint of high-quality production.

We believe it worthwhile to consider new approaches in the following six areas of forest practices for an improvement of wood quality:

1. Tree species selection
2. Type of stand formation
3. Thinnings
4. Intelligent artificial pruning
5. Forest fertilization and
6. Rotation age

In the remainder of this paper, the results of recent German investigations will be briefly discussed in relation to their significance for the practicing German forester.

The remaining tree species which either have slower growth rate or do not possess especially favorable wood properties will be grown in the future only on sites unable to support "quantity" or "quality" tree species.

STAND ESTABLISHMENT

It is necessary to mention that in German forestry, artificial regeneration as a form of stand establishment is more common than natural stand regeneration. Furthermore, in most cases, planting is considered more practical than direct seeding. Therefore, in addition to selecting the most suitable tree species and a particular genetically superior provenance of this tree species, the practicing forester must specify the most favorable tree spacing in the stand. Generally the choice of tree spacing strongly influences:

a) The initial cost of founding the plantation.

b) The probable requirements for secondary planting and weeding the plantation.

c) The time of the first commercial thinning.

d) The growth trend of the stand, and in particular

e) The progress of natural pruning, which strongly influences the quality of the mature stand.

By selecting the proper spacing, the forester controls wood quality both through stimulating natural pruning and through modifying the natural growth rate of the tree. Under German silvicultural conditions it appears especially desirable to slow down the natural tendency of the stand for rapid growth in the early years of stand development. Rapid growth at this time, as everybody knows, usually produces loose and structurally weak juvenile wood surrounding the pith. To prevent this, and at the same time to accelerate natural pruning, German foresters have practiced fairly close planting. "Quality tree species"--those which will be used for knot-free lumber or veneer--are therefore usually planted 8,000 to 12,000 trees per acre. The "quantity tree species" of course are planted at a wider spacing; however, this generally does not exceed 5 by 5 feet.

These figures are also used as criteria in judging adequate stocking of natural regeneration. Natural regeneration which is spotty or which lacks a protective canopy or which is uneven-aged seldom produces satisfactory wood quality and therefore often requires premature harvest and replacement.

STAND TENDING

While the form of stand establishment determines the course of tree growth during the first two decades of the stand, the remaining development of individual tree quality until harvest depends greatly upon the methods of stand tending. These silvicultural methods include precommercial and commercial thinnings which are repeated at approximately 3- to 5-year intervals in my country. Under such an intensive management program, the German forester has the possibility to utilize the close correlation between wood quality and crown position of the individual tree. By intelligent use of thinning, the forester can influence tree form, the progress of natural pruning, the width of the annual ring and, within limits, the proportion of spring and summer wood within the annual ring and thus the specific gravity. To a certain degree, he can also modify the fiber length.

In earlier times forest yield researchers in Germany almost unanimously recommended relatively heavy thinning practices. Recently, however, investigations have shown that small- and medium-crowned trees have a relatively higher capacity for wood production and thus show a more efficient space economy than larger crowned trees. Although heavy thinning improves the production of remaining trees, it tends to remove so many of the space-efficient wood producers that the growth of the stand on a per-acre basis does not improve sufficiently over the rotation period. On the basis of recent yield studies, it is now recommended that initial thinnings, especially those during the decades of greater volume production, be relatively conservative.

This newer concept of light and moderate thinning in young stands has decided positive effects on wood quality. First by limiting the explosive juvenile growth rate of the stand, the forester is able to favorably influence the relation between ring width and specific gravity. Thus by increasing the specific gravity in addition to obtaining maximum volume production, the forester can increase the dry weight production of his juvenile stand. Second, light and moderate thinnings have an even more important effect on wood quality because they increase the rate of natural pruning. If one assumes that the optimum production goal for quality wood species should be about 50 percent knot-free wood volume, then white and black knots should be contained within the inner third of the bole diameter. Since the breast-height diameter of economically mature trees in Germany lies between 14 and 20 inches, natural pruning of the lower 12 to 18 feet of the trunk should be completed by the time the tree has a breast-height diameter of 5 to 7 inches or by the time the tree is approximately 30 years of age. It is usually possible for the practicing forester to inspect the progress of natural pruning and callus growth by carefully following the development of branch scars.

It is apparent that in implementing a program of light to moderate thinning in juvenile stands, as jointly advocated by German yield and forest product researchers, a heavier thinning program must occur in later stand development in order to obtain the desired diameter at harvest. By controlling the degree of thinning, we believe the forester can maintain a certain uniformity of annual ring width, even after the normal culmination of tree height and diameter growth. This uniformity of annual ring width is desirable to insure a certain uniformity of structure, spring and summer wood percentage, and wood density and strength properties, and thus to insure homogeneous wood properties.

ARTIFICIAL PRUNING

It is not always possible to obtain satisfactory natural pruning through spacing or thinning. This is especially true for most conifer stands. At least as long as "quality tree species" are to be produced, it is feasible to combine the first precommercial thinnings with artificial pruning.

During the past decades in Germany as well as the United States, there have been many thorough investigations attempting to find the most efficient artificial pruning methods. It is not necessary at this time to mention that the removal of dry branches, green branches, and lateral buds from the terminal leader through mechanical or, more recently, chemical means have all proved advantageous in one way or another.

In Germany, the removal of dry branches has proved to be of the highest practical significance. We found that certain tree species must be pruned in order to produce high-quality wood. For example, spruce and Douglas-fir must always be pruned and pine must often be pruned in order to obtain a reasonable amount of knot-free wood. Among deciduous tree species, pruning has proved necessary, especially for poplar and, to a lesser degree, for oak. According to our experience it is desirable to produce at least an 18- to 24-foot branch-free bole. The number of pruned stems per acre is determined chiefly by site quality. The higher the site quality, the greater the number of stems that should be pruned; and the older the stand, the fewer. As a general average, the number of crop trees to be pruned is about 80 to 160 trees per acre in hardwoods and 120 to 300 trees per acre in conifer stands. Thorough economic investigations have recently shown that under German economic conditions, the costs of artificial pruning are clearly covered by the increased value of higher quality wood.

FOREST FERTILIZATION

During the last 50 years, methods of soil improvement, especially the application of fertilizers, have been used to increase the growth of forest trees. The majority of German forest soils are less fertile than American forest soils due to more intensive land utilization and more generations of continuous cropping. It is, therefore, not surprising that many German investigations have shown a clear increase in forest yield of many tree species and forest types in response to carefully planned and executed fertilizer applications.

However, it still remains difficult to judge completely the effect of fertilization on wood quality. Past investigations attempting to answer this question do not agree. This inconclusiveness is due in part to the wide range of sites, silvicultural conditions, and soil improvement combinations which have been used. In general, a satisfactory increase in wood volume has been reported, providing the fertilizer application has corrected the nutrient deficiency of the site. In addition to significant increases in height growth, 2- to 3-fold increases in annual ring width have been reported. In conifers, this increase in annual ring width, however, is primarily an increase in the spring wood. This results in a decrease in specific gravity following fertilization and leads to the very important question: What is the net effect of forest fertilization on the dry weight production of the stand?

In the wide majority of investigations, the dry weight production appears to be increased. The evidence is particularly convincing in fertilizer application to low-quality sites, where sometimes a doubling of dry weight production occurs. Nevertheless the response of individual tree species, as well as that of investigated sites, has varied greatly in intensity and duration.

The economic benefits of carefully planned and executed soil improvement procedures are today widely accepted in Germany. From a forest product's standpoint, forest fertilization is recommended with certain reservations. Forest fertilization in juvenile stands--just as early heavy thinning--usually leads to increased annual ring width surrounding the pith and to a delay in natural pruning. In contrast, soil improvement measures which increase diameter growth after natural pruning has occurred are frequently very advantageous and counteract the natural decrease in annual ring width in the latter part of the rotation period. In the interest of higher wood quality, forest fertilization is therefore primarily recommended in stands of middle to old age.

MODIFICATION OF THE ROTATION PERIOD

In recent years, German forest research and practice have shown increasing interest in the relationship between wood quality and rotation period. In the past, the rotation periods of our commercial tree species have been strictly the result of maximum yield considerations. But from a wood products and forest economic standpoint, it is often desirable to increase the rotation period beyond the period set by maximum yield. Although with increasing rotation period the number of stems per acre decreases, particularly the proportion of small stems, the remaining stand of large individuals often returns a maximum monetary yield. This monetary yield is due not only to the premium prices often paid for trees of large dimension but also because increasing the rotation period diversifies the number of wood products harvested.

This tendency of increased wood quality through extended rotation period is, however, gradually weakened and finally reversed by greater production risks stemming from increased mortality, decay, and blowdown. Thus the upper limit of rotation age is determined by decline of stand vitality, the increased loss of volume through fungal decay and insect attack, the tendency for diffused-pore deciduous trees to form undesirable heartwood and discoloration, and finally the demands of the wood-using industries for logs and cordwood of small and medium diameters. Attempts to modify the rotation period in order to achieve maximum value have recently led to compromise proposals that the rotation period for valuable "quality tree species" should be somewhat lengthened, while that of the "quantity tree species" should be shortened.

OUTLOOK FOR THE FUTURE

Ideally the foregoing six considerations should lead to the following results in Germany:

a) Concentration of forest production in tree species which, because of their overall properties, are suitable for multiple use.

b) Increase in wood quality in the stand; and

c) Uniformity of wood properties within the individual tree.

If you come to my country today, you will find these ideas which I have just outlined in the initial stage of application in forestry practice. In spite of this, I believe that the broad practical use of these recommendations of forest products research will be increasingly apparent.

The very intensive forestry economy of Germany, as well as that of the other European countries, is presently in a phase of changing tasks and goals. The great technical problems of silviculture and forest protection, which demanded the greatest activity for one and one-half centuries, are now to the greatest extent solved. Now the problems of optimum utilization of our forest products are predominant. Since in Germany wood no longer plays a key role in supplying human needs and since the quantitative and qualitative requirements of the wood market have consequently changed considerably during the past decades, optimum utilization has become a definite production goal.

Therefore our forest economy has no other choice than to influence the quality of forest products as far as possible by producing logs with the highest degree of utilization. We also believe that in our present situation it is no longer only the wood working industry's business to transform low-quality logs into high-quality products.

In facing this problem, the German forest economy no longer relies solely on its own research findings, but increasingly seeks support from the successful and progressive North American forest science. But international progress in forestry necessitates international cooperation through regular exchange of scientific ideas and research findings. It is for this reason, that I am so grateful for the opportunity to attend this distinguished meeting and that I have attempted to make a small contribution to your proceedings. May I thank you once again for your interest and for the invitation to participate.

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