REPORT OF TECHNICAL COMMITTEE I.

GENETICAL IMPROVEMENT OF NATURALLY REGENERATED STANDS

A. Selection of Superior Trees in the Northeast

At the 1953 winter meeting of the New England. Section of the Society of American Foresters, Charles L. Tebbe, in his talk, "Forestry in Transition", pointed out that the states east of the plains with 77% of the forest land area produce 35% of the sawtimber volume, while the west produces 65% on only 23% of the forest land area. At present, this is a reasonable situation considering the large amounts of old growth timber being cut in the west. In the not too distant future, however, the east must rely much more on homegrown timber if the increasing demand for sawtimber and cellulose is to be met.

To meet these growing requirements, we must not only increase our depleted growing stock, but we must improve our fully-stocked stands to obtain maximum production of high-quality timber. In our naturally regenerated stands, this can be done only if we leave the best possible seed trees to reproduce the stands. This means that we must select the seed trees on sound genetical principles. When artificial regeneration is necessary, the best possible planting stock mould be used. For years, agriculture has been using improved varieties and hybrids to insure maximum production. Forestry can obtain similar results by the use of improved planting stock. In the past decade, the field of tree breeding has expanded rapidly; geneticists all over the country are at work exploring the genetics of forest trees and developing new improved strains for planting. Essential for the tree breeding work is the discovery of superior or elite trees which will be the parents for the improved strains.

The Committee has prepared a general guide for the selection of such superior or elite trees. The requirements which must be met, in order for a tree to be classified as an elite tree, are of course much more exacting than those which ordinary seedtrees should meet. But rather than prepare two separate guides, the committee feels that one covering the requirements of the elite trees, or the ultimate in seed trees, will suffice. When using the guide for the selection of seed trees, it may be considered as a listing of the desirable characteristics which should be looked for in marking the stands for regeneration cutting.

Our present knowledge of the inheritance of tree characteristics is very limited. Both the form and vigor are strongly influenced by the environment and only through progeny testing can we determine the inherent abilities of a selected tree. However, as a general rule, a tree with good visible characters (a good phenotype) will give good progeny. Therefore, the more rigorous we are in our selection of seed trees, the more chance we have of improving the coming generations of trees.

Where to Look for Superior (Elite) Trees. A good site where trees are exposed to the best possible growing conditions will, in general, afford the most likely conditions under which elite trees can be recognized. Here selection pressure has favored trees which in all-round growth performance were the best. Selection has not been towards one particular characterstio, such as resistance to high temperatures during early life as on an exposed site, or drought resistance on a dry site. On a good site, a tree which is definitely superior to the surrounding trees of the same species in visible characters, more likely than not, will also be superior genetically in all-round performance.

Elite trees must generally be sought in stands near maturity or rotation age. At this age, the trees possessing undesirable characters have long since been eliminated from the stands through the influence of the environment and the competition with other better adapted trees. Young trees, although apparently most promising in the juvenile stage, may possess characteristics which, at an older age, render them entirely undesirable.

In order to make a reliable selection, the superior tree should grow in close competition with other individuals of its own kind and age. In such a situation where environmental variation is at a minimum, superiority in visible characteristics is most likely to be the result of genetical superiority. If selecting for a particular character, such as disease resistance, selection of isolated trees is of course in order as long as resistance due simply to escape from infection can be ruled out.

Stands vary in quality. Some are uniformly better than others; some are poorer, and some may be termed average. This may be due to site factors; it may also be due to some natural catastrophe in the early life of the stand, or perhaps to poor cutting practices in the past history of the stand. Often, it is the result of differences in the genetical qualities of the stands. The best stands to search for elite trees are the stands of uniformly good. quality. If a tree is definitely superior to the surrounding trees in a good stand, it is more likely to be truly superior than a comparable time in a stand of average quality.

Characteristics of Superior Trees in General. The following list of characteristics of superior trees applies to most species; in a later section of the report, some of the more important species will be considered. individually.

The characteristics have been listed in order of importance. A tree possessing all the desired characteristics is probably nonexistent. For the majority of species, the qualities most sought after are rapid growth in height and diameter, and resistance to injurious agents. A tree superior in these respects, but only average in other respects, would still be considered an elite, just as a tree with desirable crown and branching type, but only average or perhaps slightly above average in other respects, may well be considered an elite. It will be the geneticists job to bring the to types together in one new improved strain.

1. Rapid height and diameter growth. In order to qualify as an elite tree, a tree must exceed other trees of the same species and age growing in the immediate vicinity with 50% in volume growth. This is the requirement used as standard for Scotch pine in Sweden. For Norway spruce, the requirements are even more exacting. Until we have more information regarding the variation of growth in our northeastern species, this standard may be used.

2. Resistance to injurious agents. This includes:

a. parasitic fungi
b. insect pests
c. non-parasitic injuries, i.e., snow, ice, and wind

Trees showing injuries should be rejected unless the damage is correlated with old age, fire damage, and similar conditions. Where selection is being made with regard to resistance to a particular parasite, selection should be made in stands which are heavily infected.

3. Good seed producers. Trees vary considerably in the amount of seed they produce. The experience of European tree breeders has shown that trees which have been selected for superior vigor and good form sometimes had to be abandoned later because they were practically sterile. It is, therefore, extremely important to make certain that the selected trees are good seed producers.

4. The trunks must be perfectly straight and clean, and the taper should be at a minimum. A specific form-class classification would be desirable but until detailed studies have clarified the variation in this respect, the general statement that taper should be at a minimum must suffice.

5. Narrow crown. Particularly in the conifers, a narrow crown form is desirable. Here again, no exact crown-form classification will be available until studies of crown form variation have been undertaken.

6. Slender branches, desirable branch angle. Both factors strongly influence natural pruning. Branches at right angles to the trunk or ascending at a moderate angle are most desirable. It should be kept in mind that faster growing trees are apt to have heavier limbs., and growth vigor is more important than slender branches. Furthermore, quality can be controlled through proper silvicultural treatments provided branches are not excessively heavy.

7. Number of branches per whorl. An excessive number of branches per whorl must be avoided.

8. Bark characteristics. The bark often gives a good indication of the straightness of the grain in the wood and the general health and vigor of the tree. A relatively smooth, thin bark with straight; vertical grooves will generally be desirable.

9. Other desirable characteristics are minimum flare of the butt, apical dominance (strong central stem in the crown), and minimum sprouting from epicormic buds.

Characteristics of Superior Trees in Certain Species.

Eastern Hemlock. Rapid growth in hardwood competition and quick response to the removal of the hardwood overstory are of prime importance. So is good natural pruning. Large knots are one of the main objections to hemlock timber. Another serious objection is the occurrence of shake. It is not known at present if shake in hemlock is simply the result of environmental influences, such as wind or changes resulting in uneven growth rates, or if it to some extent is geneti- cally determined. In certain parts of New Hampshire, a par ticular ty- pe of hemlock, the "brown" hemlock, with wide plates and narrow grooves in the bark, is said to be very susceptible to shake. The most serious pest on hemlock is perhaps the hemlock looper; it is not known if resistance to this insect occurs.

White pine. Resistance to the blister rust and the white pine weevil override other considerations, and trees showing injuries from these pests should be discriminated against. Recent studies have shown a correlation be- tween bark thickness and the amount of weevil damage, the thinner the bark at breast height, the smaller the amount of weeviling. Selection towards thin bark may, therefore, be profitable. In heavily weeviled stands where natural regeneration is contemplated, trees showing good recovery should be favored.

Northern red oak. Rapid growth, good bole form, and good natural pruning are probably the qualities most sought for in elite specimens of northern red oak. Grown in forest stands, the boles of northern red oak should be tall, columnar, and straight. Trees developed in the open will normally have very broad massive crowns but in forest stands, the preferred crown is one which is relatively small and rounded. Although the susceptibility of northern red oak to infection by the Strumella canker is obscure, it seems that trees afflicted with this disease should be avoided. Resistance to other diseases, as for example the oak wilt, should also be borne in mind.

White ash. The general requirements for elite trees also applies to white ash. Frost damage in young plants and to some extent in mature trees is impor- tant, and resistance to injuries of this type should be searched for. Resis- tance to damage by browsing animals is desirable, but hard to get at; good recovery to such damage is probably the best that can be expected.

Sugar Maple. (selection for sugar production) Obvious points of impor tance are that the elite maple must produce large quantities of sap with a high sugar content. Good flow characteristics are also important but are closely related to the enviroirental conditions; studies on this point are still in the exploratory stage. The tree must have superior vigor in order to reach tapping size at an early age. Crown size has a. considerable influence on sugar percentage, p1ow, and syrup production per bucket. Studies at Cornell and Vemont indicate that selection of trees with deep, wide crowns may be worth- while; a good sugar tree is just about opposite in form from a good timber tree. Injurious agents seem to be of little importance, although Verticillium wilt may cause some damage.

Black cherry. The general requirements for elite trees apply directly to this species. Fast growth, small branches, apical dominance, and lack of epicoraic branches are particularly important. Resistance to cherry leaf spot or shot-hole disease (Coccomyces hiemalis), the black knot disease, the forest tent caterpillar, and to the gum spot insect defect are of importance. To what an extent resistance to these parasites occurs is not definitely known, but trees showing injuries of this type should be discriminated against.

Needed Research and Action Program. As indicated above, our knowledge reariing the variation within species is limited and needs to be studied on a sound statistical basis. Common forestry practice is to determine average values for growth rates for stands rather than variation. Distribution curves for the various important characteristics within a species will be a definite help in the selection work, and not until they have been worked out can the selection be considered anything but imperical.

Another aspect which will be of particular practical importance will be to determine through progeny testing the correlation between rigor of selection and the rate of improvement which can be obtained. Studies of this nature could be undertaken by the practicing foresters in naturally regenerated stands and should be encouraged by the Conference in every way.

The search for elite trees, their registration, and the determination of their inherent ability through progeny testing, is an undertaking which no man can undertake singlehanded. It requires the cooperation of foresters and geneticists throughout the region. The committee urges that the Conference take immediate steps to form an organization for this purpose. Such an organization should:

1. Make available to anyone interested standard forms for the recording of elite trees.

2. Keep a permanent file of selected trees.

3. Facilitate the distribution of material (seed as well as scions) from the trees.

4. Provide for the protection and preservation of elite trees.

5. Encourage testing of the trees both through clonal tests and through seed progeny tests.

In preparing this guide, the following references have been used freely:

Dorman, Keith W. : Hereditary variation as the basis for selecting superior forest trees. U.S.D.A. Forest Service. Southeastern Forest Expt. Sta., Station Paper No. 15; March 1952.

Forest Genetic Steering Committee: A guide for the selection of superior trees in the northern Rocky Mountains. U.S.D.A. Forest Service, Northern Rocky Mountain Forest and Range Experiment Station, Misc. Pub. No. 6. July 1952.

Lindquist, Bertil : Genetics in Swedish Forestry Practise. The Chronica Botanica Co., Waltham, Mass. U.S.A., 1948

B. Correlation Between Juvenile and Mature Characteristics

One of the most common objections against tree breeding is that it takes too long. That, of course, is no reason why tree improvement work on a genetical basis should not be undertaken; rather, it should be an incentive to get comprehensive breeding programs underway as soon as possible. The time element, however, is admittedly a handicap in tree breeding programs, and any shortcuts which may be developed would be of the utmost importance to the tree breeder.

The length of time between generations is often considered as the main obstacle, and it certainly is a real one. However, even more important is perhaps the fact that selection on the basis of juvenile characteristics, at least at present, is very unreliable. What, indeed, is the point of inducing early flowering in a tree in order to use it in a, breeding program if its inherent value-cannot be determined until long after it has started flowering under natural conditions? Trees grown under proper conditions without competition and with the proper application of commercial fertilizer produce flowers at a much earlier age than is generally believed. In a study of 55 different species of pine, it was found that on the average they forced both male and female flowers by the time they were 5 years old. On the other hand, it is impossible at present to make a clear-cut evaluation of the inherent vigor of the trees until they have reached a more advanced age, and resistance or susceptibility to injurious agents may not become apparent until even later. Here is a real challenge to the tree breeder. If methods can be developed through which selection for desirable characteristics could be made on the basis of juvenile traits, a definite speed-up of the breeding would result, and mass selection of desirable types in the commercial nursery might be possible.

Studies of the correlation between juvenile and mature characteristics of trees are usually long-term, and although studies are underway both here and abroad, only few results have been published. The following review of the literature is by no means complete but will give some idea of the way in which the problem has been approached.

Racial Variation of Seedling Material. Different provenances of the same species show definite variation with regard to the time of breaking and entering dormancy, growth vigor, growth form, and general morphological characteristics. Some of these traits can be recognized at a very early age. Seed of eastern hemlock from northern sources germinated at lower temperatures than southern sources (Olson and Nienstaedt, unpublished); similar results have been reported for Scotch pine by Schmidt (1951). Eastern hemlock seedlings of southern origin will, in their first season, continue growth under conditions of long day length, whereas northern sources will go into dormancy; after a short rest period they will, in some cases, resume growth when grown in more than 16 hours of light. Cuttings from 2-5 year old seedlings of P. deltoides showed a very definite correlation between the time of entering dormancy and the natural length of day in their native habitat. Thus, if moved to a, new location further south, they go into dormancy as soon as the day length of the new habitat equalled that of the native environment in the fall, even though the other environmental conditions were conducive to growth (Paisley and Perry, 1954).

Working on the hypothesis that the form of a tree is to a large extent determined by its phototropic responses, and further assuming that the relative response is already expressed in the germinating seedling, Schmidt (1951) exposed seedlings from many different seed sources of Scotch pine to a one-sided light source after they had been exposed to a period of darkness. Measur ing the resulting curvature of the hypocotyl, he found that the amount o vature followed a gradient from northeast to southwest Germany and from higher to lower elevations. Thus, seedlings from Polish and high-Alpine seed sources showed only a small amount of curvature, while seedlings from low elevations or southwest Germany showed more curvature. The total amount of snowfall in the regions involved follows an opposite gradient. Schmidt suggests that the heavy snow will tend to eliminate curved and crooked stems from the stands, and explains that the higher curvature in southwest German seed sources perhaps is a result of the lower snowfall in these areas.

It is clear from the above that where comparison is made between provenances, important information can be obtained during the first years of the plant life. With the conditions within the seed trade being what they are, it may be worthwhile to make it a general nursery practice always to plant some seed of a native source in small plots throughout the beds in which seed of unknown origin has been planted. By comparing the two sources, undesirable characteristics of the unknown seed source, such as too early a start of growth in the spring and late shoot ripening in the fall, may be discovered, and an unsuited seed source can be eliminated before it has reached the field.

Selection for Disease Resistance at the Juvenile Stage. Selection for resistance to injurious agents can, in may cases, be done at an early age either by exposing the plants to natural infection or by growing the plants under conditions favoring the development of disease symptoms and innoculating artificially. The accuracy of the test will depend on the effectiveness of the innoculation technique. In a study of disease resistance in chestnut to the chestnut blight fungus, seedling progenies from susceptible American chestnut and resistant Japanese and Chineses chestnut were innoculated with the fungus in their first growing season. Of the American seedlings, 90.6% showed disease symptoms, while only 65.1% and 67.1% of the Japanese and Chinese seedlings, respectively, showed positive innoculations. In studies of species populations, such values would be very satisfactory. A highly significant difference between the species is clearly expressed, and with our experience from observations in the field, we would consider the 9.4% of the American seedlings showing no disease symptoms the result of faulty innoculations. If, on the other hand, a segregating hybrid population was being studied, the results would have been questionable. Repeated innoculations would eventually have answered the question but had more plants been without positive infection, this would require a considerable amount of work (Nienstaedt, 1953).

In a study of the causes of resistance in chestnut to the chestnut blight fungus, it was found that the solubility and types of tannins in the bark of Asiatic chestnut are factors of resistance. Preliminary experiments indicate that differences in the type of tannins present in the three species of chest nut can be detected by means of paper chromatography, of crude water extracts of the bark of old trees. If differences in the type and quantity of tannins in the bark of the young hybrid seedlings could be detected by this method, it may prove to be an easy way of detecting resistant hybrids.

The determination of the causes of resistance to parasitic fungi and insect pests followed by attempts to design simple methods for the determination of the presence or absence of the factors involved, in the seedling or young plant, would, it seems, be a logical approach to the selection for disease resistance.

Selection for Special Characteristics. In a study of the inheritance of gum yield in longleaf pine, the yields were determined on 17-year-old saplings 3.1-6.2 inches in diameter. The study showed that progenies from mother trees with above-average gum yields produce significantly more gum than the progeny from below-average mother trees (Mergen, 1953). It will, of course, be neces sary to follow these trees until they reach normal gum-yielding age to determine if the correlation between mother trees and progenies still holds. Also, it will be necessary to determine if gum yields can be determined at an even, earlier age. It seems probable that it can.

Considering the forest products in the northeast, maple syrup immediately comes to mind. It would seem that it should be possible to estimate sugar concentration and yield at an early age and correlate it with the yield from mature trees. If this can be done, it may be a more accurate selection, as the younger plants can be grown under much more uniform conditions; many of the effects of the environment which so strongly affect sapflow could be eliminated.

Selection for Vigor on Basis of Early Growth. Studies of the correlation between early and mature growth vigor has been attempted but results have not been too promising. Barner (1952) makes the following general statement (translated):
Time and again it has been observed, both in practical forestry and in exporimental work, that a plant lot which showed superiority in growth in early years later would be surpassed by other lots growing under the same environmental con ditions.

This statement seems a fair summary of the situation. A pparently, the interaction between seed weight (especially in large seeded species), the influence of the environment and inherent vigor, is so complex and variable that a reliable estimate of growth vigor is difficult to obtain from this source.

However, it is possible that methods can be developed, which will enable us to estimate growth on the basis of juvenile development. The study of red pine reported by Hough (1953) shows this. He found a close correlation between the green weight of the 2/1 seedlings and height giwth during the first 10 years. Furthermore, the growth rate of the initially heavy seedlings increased during the second 5 years of growth and decreased for the lighter seedlings, thus widening the gap between the upper and lower weight classes. If this trend continues, the experiment will have demonstrated the possibilities of selection for vigor on the basis of juvenile behavior very nicely, at least for red pine.

Selection for Growth Form on the Basis of Juvenile Traits. There can be little doubt that some differences in crown form can be recognized at the transplant stage and that the most undesirable forms can be eliminated at that time on the basis of excessive and heavy branching. However, much more information is needed in this respect. We do not know how accurately crown types can be recognized, or to what extent bole form can be determined. Is it possible to determine the amount of taper early in the life of a tree?

Studies are underway along these lines, but they are still too young to yield results. Such studies are, of course, an integrated part of progeny testing and tests should be planned so that the best possible information on the correlation between juvenile and mature characteristics can be obtained. Schmidt (1943) has outlined the type of records to be kept in studies of this nature and has suggested that they should be accepted for international use in provenance testing. It seems unnecessary to set up similar rules for progeny testing in the Northeast. They will, to a large extent, depend on the species under observation and the general scope of the individual study.

Summary and Recommendations

The time element is a real handicap in tree-breeding programs. The length of time between generations is an important obstacle, and equally important is the fact that selection on the basis of juvenile characteristics at present is very unreliable. The studies which are underway indicate that progress can be made along the following lines:

1. Racial variations can be detected at a very early stage of development. Indoor studies under controlled light and temperature conditions should give information of fundamental, as well as practical, importance.

2. Through studies of the factors of disease resistance, it may be possible to design tests which will make selection for disease resistance at the juvenile stage more reliable.

3. Selection for high gum yield in longleaf pine can be done at an early age. It is suggested that studies of the correlation between sugar production characteristics in seedlings and mature trees may yield interesting results.

4. Much work is needed before selection for growth vigor can be done at the seedling stage.

5. Similarly, further studies of the correlation between the form of seedlings and mature trees are needed.

Studies such as have been mentioned above are to a large extent part of regular progeny testing. Whenever possible, the tests should be designed so that information along these lines can be obtained. In the past, many experiments have failed to yield the desired results, due to lack of proper planning; thus, for example, tests with wind-pollinated seed have been inconclusive (Minckler, 1942) and point towards the necessity of studying progenies of which both parents are known.

Bibliography

Barner, H. : Skovtraeforaecllingens muligheder. Dansk Skovforenings Tidsskrift 37: 62-79. 1952

Hough, A. F. : Relationships of red pine seed source, seed. weight, seedling weight, and height growth in Kane Test plantation. U.S.D.A. Forest Service, Fortheastern Forest Experiment Station. Station Paper 50. August, 1952.

Mergen, Francois : Gum yields in longleaf pine are inherited. U.S.D.A. Forest Service. Southeastern Forest Experiment Station. Research Notes No. 29. January, 1953.

Minckler, Leon S. : One-parent heredity tests with Loblolly pine. J. of Forestry 40: 505-506. 1942.

Nienstaedt, Hans : Factors in the resistance of chestnut, Castanea spp. to the chestnut blight, Endothia parasitica. Ph.D. Thesis, Yale University, 1951.

Factors in the resistance of chestnut, Castanea spp. to the chestnut blight fungus, Endothia prasitioa (Murr) A. and A. Phytonathology 43: 32-38. 1953.

Schmidt, Werner : Das ostwestgefalle der Kiefernrassen, neue Einblicke und. Methodenvorschage fur internationale Versuche. Intersylva. 3: 473 -494. 1943.

Kurzfristige Harkuftsteste bei der Kiefer. Forstarchiv. 22: 50-52. 1951.

Hans Nienstaedt, Chairman
H. J. Lutz
E. L. Giddings