TREE BREEDING PROGRAM AT THE PETAWAWA FOREST EXPERIMENT STATION

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The objective of the work in forest genetics and tree breeding is to produce strains of trees which, in a defined environment, possess the ability for maximum utilization of the productive capacity of the forest soils and thus increase the return in wood and money from the forest.

The degree of success in obtaining this objective is based entirely on the tree breeder's knowledge of the genetic composition and the local and regional variations of the species concerned. If such knowledge is not available or is incomplete, the tree breeder must work for solution of the problems involved and join and promote cooperative investigations closely related to his main line of investigation.

It is obvious that the yield from the forest could be increased considerably by proper fire protection, intensive silvicultural methods, close utilization, and intelligent management. While these means are mostly concerned with protection and improvement of a system already in existence, tree breeding is concerned with selection of the best types found and with creation of something new and better.

Having defined the objective for tree breeding and its place in the general forest research program, we may turn to the Petawawa breeding program and give the reasons for the line of investigation we have chosen. The wood—using industries are of considerable importance in the Canadian economic system. Of these, the pulp industries and the sawmills are the most important and almost exclusively based on a supply of coniferous wood. With the facilities available for tree breeding, it has been of importance to limit our efforts and concentrate on the most important species. The spruces and the hard pines are therefore our main fields of investigation.

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In the following are listed some of our main problems.

GENETIC COMPOSITION, NATURAL AND CLINAL VARIATION

It is of tremendous importance for the tree breeder to have a clear picture of the variation found within the species with which he is working.

While the genetic composition and the natural variation can be studied in the field, the clinal variation must be investigated in various experiments. Botanical notes, herbarium material, range maps, and handbooks of dendrology may furnish a preliminary framework for the investigations. The study of local yield tables compared with meteorological data serves also as a valuable guide, especially where a species has a north-south distribution.

Very little work has been done along these lines in North America, but from the available material we may obtain the following information:

The White Spruce Problem

The white spruce now found in the eastern and middle part of the North American continent is descended from a spruce that, during an interglacial period, came south and east from the gene ceutrum around the Bering Sea. White spruce seems closely related to the spruces of Japan and eastern China. It is difficult exactly to picture what distribution white spruce had during the Wisconsin glaciation. It has certainly been in the east and may have gone south along the emerged continental shelf. But how far west was it found? Bog pollen analyses indicate that it, together with black spruce, may have *been* found in the upper Mississippi region. The climate along the east coast was very wet and foggy during the glaciation, while the climate in the middle of the continent was quite dry. This fact has some influence on the white spruce types of twiny. The eastern types seem more sensitive to a change in moisture than to a change in temperature, while the opposite seems to be the case with the western types. The provenance experiments at Petawawa indicate that there are two different thermoclines, one pointing east and one pointing west. This is peculiar, but may in part be explained by the influence of day length. When the day length cline is investigated we find a good correlation for all types from the continental part of the Province of Quebec and westward, while the coastal types from extreme eastern Quebec and New Brunswick behave quite differently. We have, then, an indication of a tree race formation which does not follow the general clinal variation.

This is an important fact to keep in mind and it strongly supports the importance of keeping the selection program inside one well defined climatic region.

Experiments designed for the study of clinal variations serve the following theoretical and practical purposes:

1. To establish what clines are in existence.

2. To define more exactly what influence the clines have on wood production.

3. To work in the above information with the general forest classification for preparation of limits for seed distribution.

4. To set out races of both positive and negative value.

With a tendency to oversimplification we may say that selection work in a specified area may prove useless if a race from another area can outgrow the "native race" on home ground. Several such cases have been reported in the European provenance literature; the most impressive is the case of the German races of Norway spruce being superior to the native Norway spruces in southern Sweden and producing 20-50 percent more volume.

The Red Spruce, Black Spruce Problem

An interesting problem is found in the relation between red spruce and black spruce. Both species survived glaciation in eastern North America. Red spruce was apparently only found in the Appalachian Mountains, where it developed into a very tolerant, relatively slow growing "stayer type" able to compete with the hardwoods. Black spruce survived in a much longer east-west fringe south of the glacier and developed into an intolerant pioneer species capable of invading raw soils, etc.

This indicates that we have, right under our noses, two species which behave physiologically like the European and the Japanese larch, and therefore might prove as valuable in producing an heterotic hybrid.

Red spruce types from the southern Appalachians have been collected for further investigation of this possibility, and hybrids made about 10 years ago give promise that a fast growing hybrid can be produced.

The Norway Spruce Problem

Norway spruce has been widely planted both in Canada and the United States. In a study conducted over many years it has been possible to find types well adapted to the climate. An investigation, furthermore, revealed that breeding for weevil resistance might be possible and the best types have been combined by controlled pollination to obtain material for further investigation of this possibility.

The Problem of Hard Pines

Red pine is peculiar in being an inland shore pine and growing mainly on sandy soils. All through the range there is but little variation in form and botanical features, and it seems very close to being a pure line. The reported provenance experiments indicated clinal variation, even though the material has not been analyzed from this point of view,

and a closer study might reveal the distribution of certain physiological races. Only in one case reported from New York is there a strain which is somewhat different from the rest, and which might show promise of being a plastic type, i.e., a type capable of adapting itself to miry environments. Such types are very useful in forestry and important to the tree breeders.

Very little is known about jack pine but our general impression is that there is quite a variation both within the stands and between different climatic regions.

We have here listed some of the problems in the most important conifers. For further study, provenance experiments are under way in red, white, black, and Norway spruces, and in red pine and jack pine. These experiments are in various stages of progress but it is planned to have the test plantations established in various important climatic regions within the next five years. To that end, a seed bank has been established at Petawawa to take care of the seed until the collections are complete.

DETERMINATION OF SELECTION VALUE IN SMALL POPULATIONS

Progress in tree breeding is based on selection of good stand material and it is expected that the selection is only of value within one general climatic region, at least as far as growth is concerned.

To secure progress, a large number of trees must be tested and, as the rating of the selected trees must be based on the progenies, various methods can be applied.

1. Open pollinated seed is collected from each selected tree and kept separate in the trials. This method is relatively simple and a large number of trees can be tasted.,

2. Controlled pollination with either one father or a standard pollen mixture. This method is much more laborious and relatively few trees can be tested.

3. Self-pollination, a somewhat faster method than No. 2 especially if larger bags, in which male and female flowers can be isolated, are used.

Method No. 1 has its limitations especially because we do not know the male parent. The tree might have been pollinated by a pollen mixture, which might express the average genotype of the stand, or it might be pollinated by some trees one year and by other trees the next year. We believe though, that the dominant growth genes of the female tree should emerge in the progeny test. The ease with which a large number of trees can be tested makes this method very important.

Methods No. 2 and No. 3 are much slower to work with and only a limited amount of seed can be obtained and only relatively few trees can be tested. These methods are well suited for detailed study of the variations in small populations. The self-pollination technique, especially, looks promising and valuable to the tree breeder, as it might be possible to determine the breeding value of single trees by the behaviour of their self-pollinated progenies.

Single trees of the previously mentioned conifers have been selected for phenotypical appearance, and a large number of open-pollinate, one-parent progenies are now under trial.

A fairly large number of artificial hybrids and self-pollinations have been established both in white and Norway spruces and in red and jack pines for determining the breeding value of single trees.

INTERSPECIFIC AND INTRASPECIFIC HYBRIDS

Through cooperation it has been possible to cross the Petawawa types of red pine and jack pine with eastern and western races in the hope that we might be able to produce a plastic type or even be able to combine frost-hardiness with high yield. This work is still in progress, and other species will be taken up for these investigations. Several spruce hybrids have been attempted but results are still uncertain and not ready for publication.

VEGETATIVE AND GENERATIVE PROPAGATION

Multiplication of selected material is an important part of tree breeding work. We have evidence that the techniques used in the mild climate of western Europe are not too successful in the continental climate at Petawawa. any improvements, aiming at an average survival of SO percent or over, have been made on the grafting technique and on the handling of grafted plants. Both greenhouse grafting and outside grafting are done and materials suitable for vegetative propagation by cuttings have been produced on a scale large enough to establish seed orchards.

We have furthermore put a great deal of work into producing root stocks suitable for the inducement of early and abundant flowering. In hard pines and in spruces we have found suitable material and intend eventually to produce our own seed for root stocks.

Another important problem is that of inducing trees in the forest to flower abundantly, Various methods of girdling and fertilizing are used to increase seed production. Some of the methods investigated seem quite promising and might eventually be applied in practical silviculture.

Good facilities for propagation are found at Petawawa. A greenhouse with attached work room has been built. Our nursery has been enlarged considerably and an irrigation system installed. Labor supply is quite satisfactory, as we can draw laborers from the station crew in the busy spring period.

OTHER STUDIES

In the material at hand at the station several studies have been undertaken for the investigation of resistance to fungi, insects, and low temperatures. The physiological response of plants to climate is constantly recorded in our phonological observations, mainly in the provenance experiments.

Timber yield and wood quality studies have barely been started but preparation of yield tables for various local areas have been made by our Branch and may, when the work is completed, serve as a useful framework for investigations of timber yield. We have also had under study the possibilities of improving the fiber length in important pulpwood species, but we are still lacking a good sampling technique. In this respect, a study of wood-density seems promising. The wood producers are more interested in an increased production in tons of cellulose per acre than in a small increase in fiber length.

This short survey of the tree breeding activities carried out by the Forestry Branch of the Department of Resources and Development in Canada may reveal to you that special stress is laid on basic problems of fundamental value to a future, more detailed, locally conducted breeding program. In this way we make full use of this large research organization which is represented by many field stations from the Rocky Mountains and eastward. At the same time a more local improvement program is in progress. This latter program is intended to show the range of improvement that can be made and how those improvements can be adapted to the general field of forestry.