SOME OBSERVATIONS UPON FOREST TREE BREEDING.

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It would perhaps be appropriate upon adding yet another general paper to the spate of literature on forest tree breeding to begin with an apology. Yet the echoes of this topical subject have reached New Zealand. The plant breeders have stated, after reviewing the area in exotic plantations, that "the economic prospects of forest tree breeding thus seem to dwarf those of any breeding scheme at present in progress in New Zealand." The forester on the other hand has, by and large, shown a marked apathy towards reaching out and grasping the plums which the breeder maintains are there for the picking. The reason for this gulf and the possibilities of bridging it have recently been ably dealt with by Smith (6). But it is also hoped that a few first-hand observations upon forest tree breeding work in progress in some overseas countries may assist New Zealand foresters in formulating their ideas as to what might and might not be done within their own sphere of activity.

One hastens to point out that what follows is not written as from the pen of a trained geneticist. The geneticist's case, that forest trees are just as capable of alteration as any other crop plant, must be obvious to any forester who has watched his trees growing and noted their great variation. The case is stated concisely in the opening sentence of the I.A.B. publication "Forest Tree Breeding and Genetics" (5), which reads: "It should be made clear at the outset that the possibility of improving forest trees by breeding methods is a matter beyond dispute." Moreover increasing knowledge of the manner in which forest trees vary and of the way in which this variation is distributed is placing a versatile tool in the hands of the tree breeder. The graded variation of forest tree characters as shown in the concept of a cline* gives the worker a wide range of material. Also the cross fertility of many tree species increases this still further. One result of this new knowledge has been the formulation of international provenance experiments using cline and other forest tree material. *Larix decidua* Mill., a tree natural to extensive areas of Europe and established artificially over wide areas, has been used for this purpose.

Granted that the geneticist's case is clear cut and that *improvements* to forest trees are beyond doubt. The word improvement has been emphasised because just what improvements the forester wishes and how these may be introduced into his management are matters quite apart from the new heaven described by the geneticist. In the old established forestry of the European continent the forester has his roots deeply embedded in a traditional past based upon centuries

* Cline: a pattern of genetical variation in which the difference of a character or characters are graded in a definite direction in space.

of trial and error. He can see little possibility of introducing tree improvements into his naturally regenerated forests. Moreover, he maintains that in the treatment of the forest leading to the final crops of mother seed trees he is effecting all the necessary improvements by thinning out undesirable types. This would appear to be so when one compares the fine naturally regenerated beech forests of the European continent with the poor planted beech forests of Britain. In his planted forests on the other hand it is a simple matter and he has in many cases adopted the practice of making use of the findings of tree provenance studies which commenced as far back as the beginning of the nineteenth century: in other words the application of improvements by simple selection, making use of the genetical cline, etc., as opposed to the geneticists improvements brought about by cross fertilisation and other refinement of breeding. Increased timber yield and improved tree form are in most cases welcome to the practising forester who has to make his forests pay. The tree breeder has scarcely had time to show that the improvements he claims he has got will be maintained over a complete rotation. Apparently desirable progenies of Douglas fir planted in Europe have in certain localities shown a disconcerting flattening of the growth curve early in the rotation. Fast growing races of spruce planted outside the species' natural range have had such disastrous effects on the forest soil as to nullify any benefits accruing from the faster growth.

The forester is dealing with a crop which affects his soil permanently, and he can do little other than change his species to correct any deleterious effect a crop may have. A forester's soil is therefore one of his first considerations. The plant breeder on the other hand is not so much concerned with the soil because his plants are mainly annuals and their commercial value allows artificial soil conditions, by cultivation, fertilising and crop-rotation, to be introduced.

The geneticist affirms that he is able to improve the fibre length of wood for pulp. But who could predict the requirements for pulpwood quality a rotation hence? On the east coast of the United States, a short space of time has seen some firms of the pulpwood industry do a major somersault from a raw material of long-fibred spruce to short-fibred hardwoods. On the same coast of Canada the use of very short-fibred American aspens (*Populus tremuloides* and *P. grandidentata*) is becoming more common because these species are partly taking the place of spruce as the forests are cut over. The raw material of industry is usually a matter of what happens to grow.

Countries outside the continent of Europe are by and large concerned with patching up the ravages caused by largely uncontrolled timber exploitation. The improvements which could be wrought by sound, elementary forest practice would be so great as to make the improvements of the tree breeders pale into insignificance. Yet even the forester, without these additional aspirations of tree-improvements, can make little headway.

Coming now to the breeding work performed in some of the countries practising it, we might well commence with Sweden. It is a country with 66% of its land covered in productive forests and it has a goodly part of its economy based upon forests. It has attained quite a high standard of forest practice and a very high standard of plant breeding.

Moreover many of the concepts of tree variation as well as of other plants, have been formulated by the Swedish botanists. The main centre of the work is the Forest Tree Breeding Institute at Ekebo with its five sub-stations in various parts of Sweden. This Institute was set up in 1938, the final incentive being the discovery of a vigorous triploid specimen of aspen (*Populus tremula* L.) in Swedish forests and the work of Turesson on the genetical and ecological make-up of species. As Lindquist, who had been working extensively on the races of *Pinus sylvestris* L., writes however: "Problems of the genecology of European forest trees have been occupying the minds of botanical investigators for more than a hundred years past." (3). Workers for the station were at first drawn from highly trained cytologists and geneticists of the Svalov co-operative breeding station for agricultural crops. The station was also modelled along the same co-operative lines as Svalov; forest companies and private forest owners contributing funds as well as the State. A significant development is that recently the State has provided most of the funds because forest owners cannot see results coming from the work of many decades.

For convenience of description the work of the station may be divided into three sections. Firstly, the collection of breeding material—vegetative and seed; secondly, analysis of the material for form, vigor of growth, photoperiodic response, frost resistance, progeny testing, etc., and lastly, hybridisation work. There are two primary aims: to improve growth rate and the form of the merchantable bole. The main species with which the work is concerned are: Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* Karst.), silver fir (*Abies alba* Mill.), *Fagus sylvatica* L., *Populus* spp., *Betula* spp., *Quercus* spp., *Larix* spp. and several introduced species.

Apart from the collection of material, activities have so far been directed mainly to overcoming difficulties in carrying out the actual process of cross fertilisation on such awkward subjects as trees. For instance, methods have been developed for inducing flowering on small grafted plants and on scions grafted on to the lower branches of old trees.

It has been found that young *Pinus montana* Mill., are suitable stocks for the grafting of spruce and Scots pine to induce early flowering. Where unions between stock and scion is particularly difficult the method of bottle grafting has been evolved. The flowering of some grafted subjects is controlled by glass-house technique so that a single line is induced to flower within a brief period and cross fertilisation can therefore be effected with a minimum effort and loss of time. With *Populus* and *Salix* seed-ripening can be hastened by placing branches in water cultures in a glass-house. Polyploids have been induced by colchicine, X-ray or heat treatment, and although these usually show adverse characteristics they are useful and unusual breeding material.

Cytological investigation proceeds hand in hand with breeding and is proving of great assistance in interpreting results obtained from cross fertilisation, and in studying polyploid plants produced by artificial treatment. For instance an extensive series of crosses have been carried out between *Betula verrucosa* Ehrh. and several other *Betula* spp. The fertility of these crosses has varied greatly and chromosome studies have shed light upon the results. Such a method of approach has also been successfully adopted for other hardwood species. It would appear that cytology might be able to assist the tree breeder to a greater extent than in many other crops.

Altogether the development of the laboratory side of forest tree breeding at Ekebo has been intensive, and the propagation equipment and results are such as would make a commercial horticultural firm envious. On the other hand it will be some time before any direct improvements through breeding work will be felt in the forest themselves, because new material must be tested over a complete rotation at least. Improvements from progeny testing and selection should however be obtained readily, although application of the work will be mainly confined to a small area of forests in the south of Sweden where silvicultural practice is in the form of clear felling and planting. In the remainder of Swedish forests, group felling with natural regeneration is the rule, and to all intents and purpose only three species are involved, Scots pine, Norway spruce and silver fir. A certain amount of planting up of gaps where regeneration has failed can be done with plants from selected seed.

In Denmark, another country where a considerable amount of forest tree breeding has been done, the work has developed along much the same lines as in Sweden. A free exchange of ideas takes place between the two countries. The investigations were commenced because of the interest and energy of one person, Syrac Larsen, but have recently been supported and extended by the Danish Forest Service. Danish forestry is based upon clear cutting and replanting so that any improvements effected in their species can readily be introduced. The foresters are interested in a number of species, more particularly North American, and the forest tree breeders have collected material extensively from both Canada and the United States.

In Germany breeding work, in the narrow sense of hybridisation, has been applied mainly to poplars. In the low lying silt country of north-west Germany along the Rhine the poplar is an important tree, as it also is in parts of Belgium and France. Poplar breeding however, is a simplified form of tree breeding. Improvements delected in the F_1 generation can be utilised because the tree is propagated vegetatively as a clone. Poplar breeding is by no means new, for hybrid black polars date back a long time.

Other work in Germany has been directed along the lines of studying the pattern of forest tree variations and their causes. Very detailed studies have been made of the genetical and ecological constitution of their forest species. Based upon these studies the area covered by a species has been divided into districts within which more or less natural races occur. For instance in the whole of Germany there are seven races of Scots pine recognised. Within these districts elite stands are selected for seed selection.

The manner in which forest law stipulates that seed may only be collected from these stands, and the manner in which seed so collected is in the main grown at centralised forest tree nurseries and the resultant stock redistributed to the same region whence the seed came, has already been briefly described in this journal (4). This work again is by no means new and had had time to show enough beneficial results for the Nazi regime to take the final plunge and introduce a law known as the law of "Forest Species." Under this forest owners or administrators were authorised to convert, within a period to be arranged, all unthrifty stands to stands derived from elite seed. From a date to be fixed, all afforestation thenceforth was to derive from elite seed. All extraordinary expenses involved in the changeover were to be indemnified and penalties were to be imposed on persons not complying with the law.

It has been maintained that German foresters are too conservative in the use of species and slow to adopt more modern methods of tree breeding. German forest practice is old, however, and there have in the past been some large scale attempts to establish exotics. These attempts are still proceeding but so far none has succeeded except in restricted areas. With these failures in mind, the German forester has placed his faith in obtaining improvements along the more obvious lines of making use of the variability within his indigenous species.

In Britain no tree breeding work has as yet been undertaken, though it is planned. By chance nature provided a sample of her own work, and a hybrid between *Larix decidua* Mill. and *L. kaempferi* Sar. originated in 1885 on the Dunkeld Estate in Scotland. Although somewhat variable, hybrid trees showed heterosis and the characteristic of Japanese larch in resistance to larch canker. According to European silviculturalists this hybrid is of considerable promise. It has been planted fairly widely in Scotland. Danish foresters are experimenting with methods of producing quantities of first cross seed, because the F_2 generation shows rather too much segregation.

An interesting feature of British woodlands and copses is the poor form of birch (*Betula pubescens* Ehrh. and *B. verrucosa* Ehrh.) seen as compared with these same trees in Germany and Sweden. In Britain they are regarded more as forest weeds and no doubt the best trees have been taken out long since without thought of replacement. A form of dysgenic forestry has unconsciously been taking place over the centuries. In Europe these same species are important forest trees and very good forms are to be seen in Sweden particularly.

In America the greatest wealth of commercial forest tree species on earth provides the breeder with a paradise of material of which he is beginning to make considerable use. In Canada, at the Harvard Forest of Harvard University and at the N.E. Forest Experiment Station, Philadelphia, work has been largely on poplars, and a number of new hybrid varieties have been produced. One breeder, evidently possessing the well-known American business acumen besides his ability to breed, has gone so far as to patent a particularly promising hybrid. It is hoped he has some distinguishing feature for this plant, for unless he is a good systematist too he will have difficulty in collecting his patent dues. The possibility of economically planting poplar stands in the east of Canada appears remote. Ecological conditions here are such that the American aspens, *Populus tremuloides* Michx. and *P. grandidentata* Michx., develop rapidly in logged spruce forests. So far there has been no attempt to introduce even simple silviculture into these vast areas. It will be much more profitable to treat areas of these aspens than to establish new stands with a notoriously difficult forest tree. In the United States some planting of hybrid poplars has been done by pulp and paper companies.

The southern pine forest belt covering as it does an area of several million acres, and possessing relatively fast growing trees, promises to become in time the largest timber producing area in the United States. It has been badly mutilated in utilisation and much silviculture is required before the belt can be brought into reasonable production. However, the aims of foresters are high and work has commenced on seed provenance studies.

The result of these has been to drive home to the American forester what has been known in Europe for a long time, the great importance of provenance and that local seed provenance is the safest. Preliminary study and crossing work is also being carried out on the two pine species which produce naval stores, *P. palustris* Mil. and *P. caribaea* Morelet, in an attempt to produce trees with increased resin production: there is a marked tree to tree variation in resin flow in natural stands. High yielding trees are selected with a view to establishing stands from clonal material and it is then hoped that the seed from these stands will give good progeny. So far extreme difficulty has been experienced in propagating cuttings, and elaborate equipment has been set up for this purpose. High temperatures, almost continuous overhead irrigation in the form of a spray, and the use of growth substances are required to ensure success.

One of the larger American stations is the Forest Service Institute of Forest Genetics at Placerville in California. This was originally the Eddy Tree Breeding Station founded and maintained by a private individual and taken over by the Forest Service in 1936. It has the advantage of having a well established arboretum. The investigations of this station are confined to the genus *Pinus* but there is ample scope in this field because western north America is the greatest natural stronghold of the genus. Some of the species have exceptional ranges in latitude and altitude. Here the tree breeder has a rich field of work in following the lines of Californian plant geneticists in a minute examination of species, genotypes, clines, etc., or in studying the effect of dysgenic logging practices camouflaged under the name "selective logging." Even Hawley in his most recent edition of "Practice of Silviculture" (2) has said, in describing the seed-tree method of regeneration : "Where the seed trees are going to be left and must be considered as a total loss, trees of lower commercial value may have to be chosen. They may be the deformed or limby trees or trees attacked by fungi or simply the smaller trees." One wonders if it was out of sheer desperation to get loggers to leave any seed trees that he wrote such a prescription.

In spite of the wide and profitable field at the disposal of investigators, work at the Placerville station has proceeded mainly along the lines of inter-specific hybridisation for the production of hybrid vigour. Tree breeders have no doubt had their imaginations fired by the outstanding successes of American plant breeders with hybrid maize. The production of hybrid vigour in maize, however, depends upon several factors, an essential one of which is that hybridisation is an easy process. When one witnesses the exertions of energetic Placerville workers in climbing, by rope, the subjects to be crossed, it is interesting to conjecture how easy this process could be made on a large scale. The Californian method of using trees *in situ* for cross fertilisation is in contrast to the Swedish and Danish methods of inducing flowering on small subjects and treating these. The Californians claim that success has been obtained with some crosses, though the measure of success is as yet only to be seen in advanced nursery beds. Early stages of crosses between *P. contorta* v. *latifolia* Engelm. and *P. banksiana* Lamb., and between *P. monticola* Dougl. and *P. strobus* L. show hybrid vigour. An interesting feature of the work is the number of species which will effectively cross.

In the foregoing account an attempt has been made to give a cross section as it were of forest tree breeding practices—using the term in the wide sense—carried out in countries which have reached very different degrees of forest practice. On the surface it would appear that Smith's summing up (6) is a fair statement of the results attained, that, "Prescriptions for areas to be artificially regenerated can take cognisance of certain trends of genetics research without going to the intensive, and at present impractical, extent to which laboratory tree-breeding has gone." Germany has already introduced the prescriptions on an elaborate scale and undoubtedly other countries would derive the greatest immediate benefit by an intensive study of their species with a view to formulating similar prescriptions.

In the long run, however, the more intensive breeding work is likely to be of benefit if it does no more than throw light, as it is bound to do, upon the genetic make-up of species.

The temptation is too great not to finish with some speculation as to what place, if any, forest tree breeding might find in New Zealand. In two or three decades from now, or possibly sooner, our major timber production will be from exotic species—mainly American—and in many areas the system of silviculture will be clear felling and replanting. This is a favourable type of forestry into which to introduce improvements. There is one peculiar feature we possess which is likely to cloud the issue : so far the tendency has been to cover a greater and greater area with exotic trees. This tendency is likely to grow rather than diminish with our increasing consciousness of soil erosion. We are faced with the problem of having an excess of land marginal to agriculture but suitable for forests, and the lay public, and indeed the majority of well informed people, see no reason why this area should not be planted in forests. The foresters problem will be to get sufficient breathing space to introduce management into existing forests.

If we examine the species which we are most likely to settle down to in exotic forestry, *Pinus radiata* stands out clearly as the most important. Secondary species are likely to be *Pinus ponderosa* Dougl., *P. nigra* Arnold, some of the southern American pines and *Pseudotsuga taxifolia* Brit., all of which are markedly variable species with wide natural ranges. There is therefore much ground to be covered in studying the units of variation and their adaptation in this country.

The exceptionally limited natural distribution of *Pinus radiata* does not allow the geneticist to discourse on its clines, its rassenkreis, etc. Nevertheless it too is a highly variable species and the forester would like to know much more about the nature of this variability (see frontispiece). The Californian tree geneticists have maintained that it is a species of recent hybrid origin and is still segregating ; hence the variation. But paleo-evidence, however, makes it appear that once the species was more widespread than now and is on the decline (1).* Populations in New Zealand show variation in form, branching, needle length, cone shape, seed and many other characteristics. Preliminary investigations have shown that these cannot be correlated in a simple manner. Variation is also considerably masked by the local factors of the habitat, and a plantation in Canterbury looks very different from a plantation in the pumice country of the North Island. A good case can be made for the intensive study of this variation, and for a study of the progeny from controlled fertilisation. The forester has already sorted out in his own mind some of the improvements for which he is looking in the species. Increased volume growth is required for small forests of defined limitations but

* See also "Note on *P. radiata* Relationships," on p. 324.—Ed.

is not so important for State forests where, as mentioned previously, extension of area is wanted. Moreover the management and utilisation methods being put into practice are such that as much growth is wasted as is utilised and increased volume growth has no great advantage. Quick initial growth will be required for some purposes: one company is already using a rotation as short as eleven years for the production of pulp wood. A small-branching habit is possibly the characteristic most wanted, because we cannot plant trees closely enough in New Zealand to suppress laterals, nor does it appear that rotations will be carried on long enough to obtain clear wood outside the knotty core.

Summary.

This topical subject is discussed briefly from eye-witness observations of some investigations proceeding in Sweden, Denmark, Germany, Canada and the United States of America, countries actively engaged in the work and vitally interested in the results. Two different lines are being followed: in all the countries named, except Germany, methods of cross fertilisation are being mainly relied upon to produce improvements either by the introduction of hybrid vigour or a recombination of desirable characters in new plants. At the present time the testing period required for such completely new material would appear to be excessively long and the possibility of introducing it into forest management, remote. German foresters making use of the natural variation within their indigenous species and following the lines of selection for improvement have successfully applied the results, though political foresters have probably gone too far in applying them.

In New Zealand we have a great range of introduced forest trees upon which our future forestry will be largely based, but about which we know comparatively little. A more intensive study of these would seem to be an essential preliminary to any tree breeding, accompanied perhaps or followed by simple progeny testing.

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