TREE IMPROVEMENT IN AUSTRALIA AND NEW ZEALAND IN RELATION TO WORK IN THE UNITES STATES

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Tree improvement work, in common with biological research in general, depends heavily on international cooperation. In the account which follows, I will attempt to give a picture of the present status and potentialities of tree improvement work in Australia and New Zealand2/, with particular emphasis on the recent increase in interest in the southern pines. I believe that one of the clearest features of this picture is the advantage to be gained, by all parties, from a broad cooperative effort in tree improvement, involving workers in these countries and the United States.

Australia

As background for a discussion of tree improvement in Australia, some data on climate, forest resources, and industrial demand may be of interest. A recent estimate (2) places Australia's annual con sumption of sawn timber at 150 million cubic feet, based on a popu lation increase from the present 8 million to 12 million in the next 20 years. This volume, which does not include uses other than sawn timber, is more than twice the productive capacity of the existing State Forests, and is moreover largely in hardwoods, principally eucalypts. World industrial demand averages 85% for coniferous timbers (2), and although Australia has shown ingenuity in utilizing her eucalypts for purposes for which softwoods are better suited, she has been forced to import large volumes of coniferous timber. This situation has stimulated an active program of conifer planting, dating back to 1888 (10). Coniferous plantations now cover roughly 310,000 acres in Australia (11). This figure is to be compared with the million acres of coniferous plantations which it is estimated will be required (11). Against this figure should be set the estimated 44 million acres of saw-timber forest (largely eucalypts) at present in productive condition (2).

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2/ The author visited Australia during the months of September and October, 1952, as a participant in the Eucalyptus Study Tour, sponsored jointly by the Food and Agriculture Organization of the United Nations and the Commonwealth of Australia. Further travel in Queensland and New Zealand was sponsored by the U. S. Forest Service.

The commercial forests are largely restricted to costal fringes, and in these areas, temperature extremes do not exert a limiting effect on forest growth. Rainfall amount and distribution appear to be the critical factors, with commercial forests restricted to areas with 20 inches or more of annual precipitation, which falls either predominantly in the winter or uniformly throughout the year (8). The summer rainfall regions of the north carry few forests of value under present conditions. Within the forest regions of Australia, conifers have been planted largely on lands unfit for agriculture and previously covered with low-grade eucalypt forest, generally in the drier parts of the commercial forest area.

More than one half of the roughly 310,000 acres of conifer plantations are of Monterey pine, (Pinus radiata D. Don.). In general this species has been concentrated in the regions of winter rainfall in Western Australia and South Australia, and to some extent in the cooler portions of the region of uniform rainfall in Victoria, New South Wales and Tasmania. This species has not been notably successful in Queensland, nor on some of the less fertile coastal plain soils of Western Australia (12).

Monterey pine presents problems and opportunities alike to the silviculturist and to the tree breeder. The silviculturists have been delighted with the rapid growth and high yields attainable with this pine. In the southeast of South Australia, where this pine has staged its best performances, mean annual increments of 500 cubic, feet per acre, and yields of 8,000 cubic feet per acre at 26 to 30 years have been achieved. In view of the scarcity of conifer timber, some of Monterey pine's silvicultural and technical shortcomings have been overlooked, at least for the present. Although clear, straight-grained wood of this pine compares very favorably with that of many of the leading commercial pines of the world, many of the plantations of Australia are producing a much lower proportion of such wood than would be obtainable with the aid of more intensive silviculture and the application of some elementary plant breeding. The need for improvement in the form of Monterey pine may be gauged by Jacobs' (7) estimate that only about 150 good stems may be found in the 680 which are normally planted per acre. This is a severe handicap to the silviculturist, who is thereby forced to compromise between even spacing and the selection of the best stems as crop trees when he marks plantations for thinnings.

To date, only one improvement program with this species is well under way, although several others are in their initial stages. The start of this work in Australia is recorded by Jacobs (7) who gives credit to Field (3), in New Zealand, for suggesting in 1934, that Monterey pines of desirable type might be propagated by the method of rooting of cuttings which he had devised.

Jacobs proceeded to select parent or "stud" trees on the basis of variation in number of whorls produced each year, regularity of whorls, branch angle, abundance of cones, spiral grain, growth rate, and other features. Cuttings from a number of these stud trees were rooted and outplanted in blocks to test the persistance in clones, of the phenotypic expressions for which the stud trees were originally selected. In general, these phenotypes have persisted, and Fielding (5) has started a program of controlled pollinations designed to determine their mode of inheritance. In cooperation with the Division of Forest Products of the Commonwealth Scientific and Industrial Research Organization, he has laid down a series of tests of inheritance of fiber length which promise to be of great value to Australia's expanding pulp and paper industry. These studies are based on the finding by the Division of Forest Products that tracheid length in a small twig may be used to estimate tracheid length in the stem of the same tree. Thus a tree with an initial tracheid length of 2mm., as determined from examination of the twigs, may produce wood with an average tracheid length of 4mm. (1).

Another important character, peculiar to Monterey pine and some of the related closed-cone pines, is the persistance of closed, cones on the main stem. Fielding (4) has called attention to the fact that these stein cones produce a defect in lumber which is more serious than knots of a comparable diameter. He has shown that individual trees differ in the proportion of their total cone production which is found on the rain stem, and that this proportion is rather constant in clones.

Since the work of Jacobs (7) in rooting of Monterey pine, there have been important changes in outlook and method. Whereas Jacobs suggested that despite their higher cost, rooted cuttings might be used to establish commercial plantations of selected types. Fielding and other workers are now thinking of clonal plantations primarily as seed orchards and only incidentally as sources of timber. Moreover, Fielding has reduced the cost of establishing clonal plantations by rooting cuttings in re-usable metal tubes. This adaptation of a technique developed in Queensland for propagating seedlings of the Araucarias saves the cost of transplanting and insures a high rate of plantation survival.

Whereas the ease of rooting cuttings facilitates genetical improvement of Monterey pine, seed production of this species is somewhat less favorable. As is the case with many other pines, it is common for the trees which the silviculturist prefers on the basis of growth rate and form to be rather scanty seed producers. Moreover, unless Monterey pine is grown at very wide spacings, it takes at least 10 years to produce trees which bear appreciable numbers of cones, and these are likely to be concentrated near the tip of the main stem. This fact, coupled with the rapid height growth of this pine, makes controlled pollination and seed collection difficult, and emphasizes the urgency of developing dwarfing rootstocks and techniques for hastening and increasing flowering.

Fielding's work at Canberra in the Capital Territory is supplemented by some selection and pollination at Mount Burr, South Australia, where the State and the Commonwealth conduct a cooperative program. Some propagation of cuttings from selected good phenotypes of Monterey pine is under way in Tasmania and in Victoria.

A number of promising phenotypes of Monterey pine have been marked in the State Forests of New South Wales, and open-pollinated seed from these is being grown in experimental plantations. Some of this material is being grown at the Institute of Forest Genetics at Placerville.

Cluster pine, (Pinus pinaster Sol.), is second in importance in Australia's conifer plantations. About 3,000 acres of this species have been planted in South Australia, but the greatest plantings have been in Western Australia. Here cluster pine has been planted on the infertile sands of the coastal plain, where certain mineral deficiencies, principally of phosphorus and zinc, must generally be made good by application of superphosphate fertilizers and zinc foliage sprays (12). Little in the way of tree improvement work has been started with this species beyond the establishment, by experimental plantations, of the well-known superiority in growth rate of the race originating in the vicinity of Leiria, Portugal. The series of provenance test plantings at Gnangara, north of Perth, indicate that the Corsican race, although inferior to the Leiria race in growth rate, is superior in form, lacking the basal sweep characteristic of the Leiria pines. To date, the attempt to combine the good qualities of these two races in a hybrid has not been made. Tree improvement work in Western Australia is contemplated, but when it is undertaken, the workers will be faced with an obstacle characteristic of Australia - cone and seed destruction by the black cockatoo, which seems to favor particularly the large seeds of cluster pine despite the fact that they are enclosed in extremely resistant cones.

The southern pines are represented in Australia principally by loblolly pine, (Pinus taeda L.), and slash pine, (Pinus elliotti Engelm.), the latter being generally the more favored species. These species are planted largely in the uniform rainfall areas of New South Wales and Queensland, but there are some rather good slash pine plantations in the winter rainfall area, near Perth in Western Australia.

Queensland has been the most active state in planting and improvement work with the southern pines. More than 10 years ago a program of inbreeding and controlled intraspecies cross pollinations with slash and loblolly pines was started by Dr. Harold Young of the Queensland Department of Agriculture and Stock. A number of trees were found which were self-fertile to varying degrees, and by a certain amount of culling of inbred progenies in the nursery, it was possible to establish rather large plots of inbreds in the field. Some of these plots are quite uniform in appearance, and, as might be expected, reproduce some of the more conspicuous characteristics of the parent trees. Second generation inbreeding has already been started. Meanwhile, the results of first generation inbreeding and crossing are being used to evaluate the genotypes of selected seed trees.

The procedure for selecting and progeny-testing seed trees has been worked out by Alan Trist, Cecil Haley, and James McWilliam of the Queensland Forestry Department. Pruning is done in two stages; and an initial low pruning of 230 stems per acre, followed a few years later by pruning up to 20 feet of 160 trees per acre. At the time of selecting these trees for high pruning, any which seem to the foreman to be of exceptionally good vigor or form are specially marked and called to the attention of the forester in charge of the area. If the forester judges these trees to be of sufficiently high standard, they are marked with two bands to designate them as trees for collection of seed, and among this class of trees, a few which are outstanding are marked with three bands and reserved for controlled pollination work and propagation as clones. This procedure illustrates a typical feature of forest research work both in Australia and New Zealand, namely the close integration of routine management and investigative activities.

Evaluation of progenies - inbred, control-pollinated or wind pollinated - is done according to a generalized score method. Vigor and form of each progeny tree are rated on a 5-point scale. Form rating take into account straightness and taper of stem, branch size and angle, tendency to fork or produce occasional large ascending branches and crown balance. These individual components of the form ratings are not recorded, emphasis being placed on the same investigator covering a large number of progeny trees in a short period. Progenies, which usually consist of at least 100 individuals, are then rated according to the percentage of acceptable trees they contain. Acceptable trees are those which rate in the highest class on the vigor and form rating scales. The rating of a given progeny is then compared with that made by a comparable adjacent plot of trees raised from routine seed - the stock used for general planting operations. This general method is not designed to elucidate the mode of inheritance of specific genes, but seems to offer promise of effecting marked improvement over stock raised form the unselected seed normally used. In fact, even the open-pollinated progenies of selected good phenotypes are strikingly better in average form than comparable progenies from un-selected seed trees. Some of the progenies resulting from controlled crosses between good phenotypes are quite outstanding.

In general, slash pine has been more successful in the Queensland plantations than loblolly pine. Phosphorus nutrition may play a part in the difference, as it has been established that in some of the Queensland plantation areas phosphorus is deficient and the requirements of loblolly are higher than those of slash pine. However, it should be noted that information on geographic origin of these species in Queensland plantations is rather scanty, and it seems possible that geographic races of both species exist which would give better performance than those now in use. In procuring seed of slash pine, the Queensland Department of Forestry has consistently specified that the seed should not originate south of Ocala, Florida. This specification would serve principally to eliminate the South Florida type of slash pine, but still leaves considerable uncertainty as to exact geographic origin. In the case of loblolly pine the uncertainty is even greater due to the wider distribution of this species.

Aside from the problem of geographic origin, the principal difficulty confronting the Queensland tree breeders is the difficulty of rooting cuttings of slash pine. Attempts are being continued, with a low percentage of success, but an increasing emphasis is being placed on grafting as a means of producing clones of superior types for establishment of seed orchards.

Hoop pine, (Araucaria cunninghamii Ait.), one of Queensland's native conifers, produces, in old growth stands, a soft, easily worked, uniform timber of high value. Clear logs are used to produce peeled veneers of very high quality. For more than 30 years, the Queensland Department of Forestry has been planting hoop pine, with a high degree of success, using tubed stock. These plantations which now total more than 29,000 acres (6), promise to be much more productive than the indigenous mixed forests from which hoop pine has been extracted in the past. Pruning and thinning prescriptions are much the same as those set up for slash pine, and included provision for the selection of superior phenotypes for seed collection and controlled pollination. Hoop pine, like Monterey pine, exhibits a degree of morphological diversity in plantations which is most stimulating to the plant breeder. Unfortunately, the vegetative propagation of hoop pine is not particularly easy, and rooted cuttings and grafts made from any but leading shoots are very slow to develop into upright trees. Hoop pine has the further disadvantage, as compared with slash and loblolly pines, that it is relatively late to flower, and then flowers rather sparsely and, irregularly. In spite of these handicaps, a small but vigorous program of genetical improvement work with hoop pine is under way in Queensland.

A fairly new program in southern pine planting is being undertaken by the Forestry Commission of New South Wales in the northern part of the state. An example is the Barcoongere State Forest on the coast near Coff's Harbour, where it is planned to replace 22,000 acres of low quality Eucalypt forest with pines. Preliminary acre plots were planted in 1945, and after several years' observations, large scale planting was commenced. At present, 3000 acres have been planted with slash and loblolly pines, but since 1950, only slash pine has been used as a consequence of the relatively poor showing made by the loblolly pine in the preliminary plots. Little is known of the geographic origin of the loblolly, and the slash has been raised from seed of Queensland origin. No improvement work has been undertaken, but there seems to be a great opportunity for increasing productivity by determining the geographic races of these two species best adapted to the area. Several other state forests in the northern part of New South Wales have the same problems and opportunities.

Some genetical investigations are under way in the genus Eucalyptus, in Australia, although there is little that may be termed tree improvement work in the narrow sense. The genus Eucalyptus is generally credited with approximately 600 species, restricted to Australia, New Guinea, Timor New Britain, New Ireland, and the Philippine Islands. Most of the species, however, are restricted to Australia. For many years, it was believed that the flower structure common in this genus would not permit cross pollination, and therefore, since species hybridization was thought to be impossible, hybrids were not found. Wild hybrids have become respectable and even popular in recent years, and the genus Eucalyptus has turned out to be not so exceptional after all. Hybrid swarms have been found wherever careful study has been made, and several investigators are now engaged in the experimental study of these swarms and the verification of hybridity by synthesizing artifically hybrids which have been occurring spontaneously. In the Capital Territory, L. D. Pryor of the Division of Parks and Gardens is doing experimental breeding and growing open pollinated progenies of suspected spontaneous hybrids. In Tasmania, similar work is being done by R. G. Brett of the Education Department, by J. M. Gilbert of the Forestry Department, and by N. T. Barber of the University of Tasmania. In Western Australia, J. H. Harding of the Forests Department is making controlled pollinations within the species E. ficifolia, an important ornamental, in an effort to fix resistance to Sporotrichium destructor, a fungus which causes the development of cankers which eventually girdle the trees.

New Zealand

In almost every respect, the forest situation in New Zealand differs importantly from that in Australia. Nevertheless, the planting of exotic conifers has been even. More actively prosecuted in New Zealand than in Australia, and there is every indication that these plantations will play an increasingly large role in New Zealand's economy. Whereas, Australia, with a population of 8 million, and slight indigenous softwood resources is a softwood-importing country, New Zealand, with a population of 2 million, has, on the basis of its indigenous softwoods, developed an active export trade. This has been done, however, at the expense of the growing stock, for New Zealand's indigenous softwoods have proven extremely difficult to regenerate and slow-growing. This situation was realized rather early, and afforestation with exotic softwoods dates back to 1896 (9). At present, there are 900,000 acres of exotic plantations in New Zealand, 300,000 of these being privately established and owned (13). A rather large proportion of New Zealand's land area offers climates favorable to conifer culture. Temperatures are not extreme, except in the higher mountains. Precipitation is abundant and well distributed, except for an area in Central Otago on South Island. In the Canterbury Plains, on South Island, the controlling climatic factor is frequent high winds which are often highly desiccating and sometimes cause widespread windthrow of plantations and shelterbelts. Out-of-season frosts are experienced in many areas, and depressions are likely to be revealed as frost pockets if they are planted with frost-susceptible species.

The major exotic is Monterey pine, which covers 550,000 acres, and which yields up to 10,500 cubic feet per acre at 30 years (9). This species is followed by Pinus ponderosa Laws. (90,000 acres), P. nigra Arn. (65,000 acres), and Pseudotsuga taxifolia Britt. (50,000 acres). Other species are Larix europaea DeC., Pinus contorta Doug., P. strobus L.,P. patula Schecht. and Cham., Chamaecyparis lawsoniana Parl., Cupressus macrocarpa Hart., Thuya plicata D. Don, and the three southern pines, P. taeda L., elliotti Engelm. and palustris Mill. (13). It is interesting to note that this list includes only two Old World species. Many other exotics have been planted, some rather successfully, but few of these are Old World species. A rather conspicuous, and surprising failure has been Sequoia sempervirens Endl. which has done well as specimen trees and in one famous plantation at Rotorua on North Island, but has failed to establish stands in spite of large scale attempts to establish plantations (9).

The only species of those listed which does not present a problem in geographic origin is Monterey pine, which shows little evidence of being composed of geographic races, but does show wide individual variation (9). Accordingly, I. J. Thulin, the tree breeder working at the Forest Research Institute, has selected this species for intensive improvement work, pending the results of a series of provenance tests planned for a number of other species. As in Australia, plantations of Monterey pine include a large proportion of poorly formed trees, but the well-formed trees justify the expectation that substantial improvements can be made. Very occasionally one finds a tree - perhaps one in a million - which is clearly outstanding in phenotype. An example is a tree recently found on the lands of the New Zealand Forest Products Co., which at 25 years of age is 130 feet tall and 27 inches d.b.h., with a straight stem and rather fine horizontal branches. This tree is located in a permanent sample plot in which mean d.b.h. is 16.2 inches. About ten trees of comparable excellence have been found, and from them clones are established by means of grafting, since trees in the higher age classes often produce cuttings which are difficult to root. When the grafts have ramified for several years, they will be used as sources of cutting material. Meanwhile, any pollen produced by the grafts will be used in controlled pollination progeny testing.

There are probably few places where one can see the disastrous effects of disregarding geographic origin of seed on a larger scale than in New Zealand. A large proportion of the 90,000 acres of Pinus ponderosa Laws is covered with either the scopulorum variety, which appears to offer little prospect of ever producing acceptable crops, or with geographic races which appear to have come from British Columbia or the northwestern United States. These northern races may produce useful crops, but the rotations will of necessity be from 70 to 100 years, as compared with the normal 30 to 40 year rotation of Monterey pine. In the Kaingaroa State Forest on North Island is a small provenance test of P. ponderosa Laws. which includes two lots from the central Sierra Nevada of California. These lots have far outgrown all the other geographic races represented in the test, and have produced some quite acceptable trees. There are also some very satisfactory plantations on both islands which are undoubtedly of Central California origin.

Pinus nigra Arn. presents a similar picture. Some plantations are clearly of the rapid-growing, well-formed Corsican and Calabrian races, some are equally clearly of the inferior Austrian race, and some are thorough mixtures. With Douglas the results have been more fortunate, for while seed origins are not known with sufficient precision, the majority of the plantations are performing satisfactorily. However, it is quite possible that geographic races not yet tried in New Zealand may give even better results.

Many geographic races of Pinus contorta Doug. are present in New Zealand plantations, and their performance varies from quite satisfactory to the production of worthless shrubs. Trees which suggest the rough-barked coastal type can be recognized, and these are some of the best. However, at Hanmer State Forest on South Island, a stand which strongly suggests the Sierra Nevada type is of excellent form, and has made good growth.

The planting of the southern pines is one of the newer developments in New Zealand, and has been confined mainly to the northern portion of North Island. An example is Rotoehu State Forest, where planting was commenced in 1936 and about 10,000 have been planted. The major species here are slash and loblolly pines, often planted in mixture. The results so far seem to justify the use of these species, although here too, little is known in detail as to seed origins. The southern pines seem likely to assume great importance in this part of New Zealand, because of their good growth and properties, as well as because of the need to find a substitute for Monterey pine. This species in certain localities on Northern Island has suffered mortality which appears as high as 90 percent of the stems in a stand as a result of the attacks of Sirex noctilio. Little is yet known of the epidemiology of this insect, which has been known as a minor pest for some years, but has recently started to make epidemic attacks. However, it seems only prudent to attempt to find acceptable substitutes for P. radiata D. Don.

Conclusion

I have attempted to show that in both Australia and New Zealand there are new, active programs in tree improvement getting under way, and that the workers have ample opportunities to make substantial contributions to their nations' economies. I have suggested also that their work can be greatly facilitated by workers in this country willing to furnish good seed of known origin. I would like to ask that, where possible, in U. S. A., southern workers setting up seed source tests, seriously consider placing some of their test plantations in Australia and New Zealand.

The traffic need not be one-way. Already, Australian and New Zealand workers have found outstanding Monterey pine phenotypes which can be used to advantage in California, and we can expect similar discoveries as the work with other species progresses. There is also the advantage of pollen exchange with workers whose seasons differ from ours by six months. Because of our personal acquaintance with the workers in these countries, the staff of the California Forest and Range Experiment Station will be glad to facilitate initial contacts and exchanges of material.

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