PINE BREEDING IN THE UNITED STATES

J. W. DUFFIELD, PALMER STOCKWELL

Trees fit into the general rule that the plants and animals which nature gave us have not been considered quite good enough. For millions of years, it is true, nature has developed a breathtaking variety of forms, each wonderfully adapted to its surroundings. Changes in climate or the conformation of the earth's surface have caused the extinction of some forms and the development and migration of others. But during the long development of civilization man has learned to alter some of the myriad forms of life about him, making them better suited to his needs.

Centuries of breeding have developed livestock and plants that have special value, but only recently has man applied his knowledge of breeding to the development of better forest trees. Much of this work has been done with pines because of their wide distribution and their value for many wood products. Today pine-breeding research has progressed to the point that promising pine hybrids exist for each of the major timber-producing regions in the United States.

How has this point been reached? And what are the results now ready for trial?

As long as man used only an occasional tree he was not concerned with replacing it. But when he began to fell sizable sections of the forest, he observed that the succeeding cover was often different from the one he had removed. To insure another tree crop of the type harvested, he often found it necessary to sow seeds or plant young trees. This practice foreshadowed the beginning of forest-tree improvement, perhaps 500 years ago. In his early planting operations, the forester soon learned that certain local races of trees surpassed the average.

American foresters, influenced in their early work by European forestry, were quick to import one of Europe's leading timber trees, the Scotch pine, a species that, despite its name, extends from the British Isles into Siberia and from the Arctic Circle as far as southern Austria and the Iberian Peninsula. Foresters in New York State found that Scotch pine from the shores of the Baltic Sea made a respectable tree in their plantations, while the same species grown from south German seed produced gigantic corkscrews and other bizarre and useless forms. Foresters in almost every European country have studied Scotch pine from various sources and have come to recognize an almost limitless number of local races, each fitted by natural selection into the mold of the local climatic and soil conditions.

In the past few years, several workers in the Forest Service, notably R. H. Weidman, T. T. Munger, and W. G. Morris, have completed studies of local races of ponderosa pine and Douglas-fir, two of our most widespread and important western conifers. An interesting study of altitudinal races of ponderosa pine in the Sierra Nevada of California was initiated by L. Austin, also of the Forest Service. Work of this kind has led foresters to the realization that careful comparative studies of climate and soils and of the growth of local races should enable them to proceed with more certainty in their work of reforestation.

In recent years most spectacular results have been achieved by this analytical approach in parts of Italy, South Africa, Australia, and New Zealand—regions that have rather meager native conifer forests and only moderate rainfall, most of which falls in the winter. Such a climate resembles that of coastal California, where a few small patches of natural Monterey pine survive. The fossil record shows that this pine once occupied a much larger area, but because of increasing dryness along the coast it was squeezed into a smaller and smaller area. There it was making its last stand when the botanists found it. Given a fresh start in Australia, New Zealand, Italy, and South Africa, this almost extinct pine delighted foresters by its rapid growth and good form. In places where it was a complete stranger, it found just the conditions of soil and climate it needed.

These examples show the effectiveness of natural selection in shaping the heredity of trees so as to fit them for growth in specific types of environment. It would be surprising, however, if men were content with a process so slow that it can only be seen in the unfolding of the fossil record. Foresters have turned to artificial selection or sought some other man-made device to speed up the remodeling of forest trees.

Biologists generally agree that certain features of species are especially important to survival of the race. The features have to do with the survival of the individual and perpetuation of the species. Furthermore, infancy is the period in the individual's life during which the balance between survival and death is most precarious. Thus the features most strongly molded by natural selection, the so-called adaptive features, have to do largely with the start of life of the individual. The forester, however, is largely concerned with the characteristics of mature or young-mature trees. His selection has been aimed at the development of trees especially suited to producing usable products such as clear lumber, smooth veneer, or strong paper in the greatest possible quantities per acre per year. His selection therefore must take quite a different direction from the one practiced by nature.

Before our knowledge of the science of genetics was developed, selection was practiced in the woods. Seed trees of good form were left and misshapen wolf trees were cut, or, if plantings were needed, seed was collected only from the best-formed trees. With the recognition of Gregor Mendel's work at the turn of the century, some foresters realized that well-formed seed trees might carry in a recessive or concealed condition certain hereditary factors that could cause some of their offspring to be of an inferior quality. Other early work by geneticists showed that many characteristics of plants and animals—such as size, quality, and resistance to unfavorable environmental influences—were determined by many hereditary factors. So, for a tree to have the maximum growth rate or a certain form, it had to have just the right combination of a large number of hereditary factors. That fact revealed the relative ineffectiveness of selection practiced in the woods as a method of improving the heredity of a forest and eventually led to deliberate efforts to develop superior types of forest trees by genetic methods.

It is always difficult to point with certainty to the originator of an idea, and we hope to be forgiven if we unwittingly slight the "father of tree breeding." Klotzsch, in Germany, attempted to cross Scotch pine with Austrian pine in 1845. His statement that he planted the hybrid seed the spring following pollination is at variance with the facts, because 2 years are required for the formation of seed of those species. Nils Sylven in 1909 undertook to investigate the heritability of certain well-recognized crown types in Norway spruce and Scotch pine growing in Sweden. This he did by making self-pollinations to determine whether the various crown types would breed true. From 1912 to 1924, Augustine Henry, in England, and several Americans, including Helge Ness, A. B. Stout, E. J. Schreiner, and others, began controlled pollination work, the foundation stone of tree breeding.

In 1925, James G. Eddy, after seeking the advice of Luther Burbank, established the Eddy Tree Breeding Station at Placerville, in northern California. The station was later deeded to the United States, to be managed by the Forest Service as the Institute of Forest Genetics. The Institute soon narrowed the scope of its work to the genetic improvement of the timber pines. John Barnes, W. C. Cumming, and W. G. Wahlenberg pioneered in the development of pollination techniques. F. I. Righter joined the station staff in 1931 and, with W. C. Cumming, perfected the techniques and used them to demonstrate the great possibilities for genetic improvement that could be realized through species hybridization in the pines. At about this time, Philip C. Wakeley, also of the Forest Service, made a number of crosses between the timber-pine species of the Southeastern States.

Much of the pioneer work in pine breeding thus is behind us.

THREE GENERAL METHODS are available to the tree breeder today. Two of them—selection and hybridization—consist of using and recombining hereditary variations already existing among trees. The third method can be used to create hereditary variations through physical or chemical treatments.

Selection becomes much more effective when it is combined with other techniques, such as progeny testing, vegetative propagation, or hybridization. Progeny tests of self-pollinated plants help determine which parents to select for the best offspring. But since the pines are predominantly cross-pollinated, a progeny test in which only the seed parent is known tells only half of the story. Vegetative propagation, which is used by fruit growers to multiply selected trees, has not yet reached a stage of development for pines which would permit economical propagation of forest planting stock except in New Zealand, where it is practiced with Monterey pine. Great progress has been made, however, by workers in South Africa and Australia; by K. W. Dorman and his associates, who have been working with turpentine pines in the southeastern part of the United States; and by N. T. Mirov, of the Institute of Forest Genetics in California.

This work has resulted in techniques by which the clones from selected pines may be vegetatively propagated for research purposes or for establishment of seed-producing plantations. Members of a clone are merely parts of a single tree, made to produce roots and become self-supporting or supplied with roots by grafting. Numerous experiments have shown that pines and many other forest trees can produce few seed as a result of self-pollination; usually the few seedlings so produced are weak. Pollination between members of the same clone is equivalent to self-pollination. For that reason, mixing several clones in a seed-producing plantation is necessary to insure cross-pollination and satisfactory seed production. Such plantations in Sweden contain from 6 to 12 selected clones, all from a single local race to insure adaptability. When two selected trees or clones are cross-pollinated, there is no certainty that the offspring will be better than the average for the species, but when half a dozen or more selected clones are allowed to interpollinate the chance for average superiority of the offspring is increased. Only by controlled pollination can it be determined which pairs of clones will consistently produce superior offspring. Perhaps the most promising field for selection work with pines is the search for trees resistant to disease and insect attack.

The methods and benefits of pine hybridization were discussed in an article on hybrid forest trees in the 1943-1947 Yearbook of Agriculture.

Briefly, the benefits to be expected are hybrid vigor, the combination of desirable characters in a single plant, and the uncovering by hybrid segregation of hitherto unsuspected characters in the offspring derived from breeding within a hybrid population. Naturally, hybridization can be expected to be most effective if the parents are selected rather carefully.

As to the third method available to tree breeders, most of the techniques for initiating new hereditary variations are barely out of the laboratory and as yet cannot be consciously directed—they might more appropriately be called shotgun methods in their present state of development. They include the induction of gene mutations and chromosome rearrangements by X-ray and other types of radiation, heat treatments, and cold shocks. The doubling of chromosome numbers by treatment of seeds or growing points with colchicine, acenaphthene, or other chemicals was once regarded as promising for making pine hybrids true-breeders. This hope has faded somewhat in the face of a number of failures of this type of experimentation, and at present such work is placed in the category of pure research, which, given sufficient time and effort, may yet produce valuable tools for the practical tree breeder.

What has been accomplished by these methods and how and where can the accomplishments be put to use?

Perhaps the best way to answer is to make a tour of the forest regions of this country, stopping long enough in each to see what the breeders have to offer.

In the Northeastern States, the eastern white pine is most interesting to the tree breeder because of its great commercial value and because of the challenge offered by its susceptibility to the attacks of two major pests, the white-pine weevil and the white pine blister rust. This pine belongs to a group of closely related species, which includes the western white pine of the northern Rockies as well as the Pacific Northwest, Himalayan white pine, and the Balkan pine of Yugoslavia and Greece. The last two pines are of particular interest because they exhibit some resistance to blister rust.

Several pine breeders have made hybrids within this group. Workers at the Arnold Arboretum of Harvard University and at the Institute of Forest Genetics have found that hybrids between eastern white pine and western white pine, between western white pine and Himalayan white pine, and between Himalayan white pine and eastern white pine are all more vigorous than the parent species. During the first 7 years of growth, the hybrid just about doubles the height growth of the parents.

L. P. V. Johnson and C. Heimburger of Canada have crossed eastern white pine with the Balkan pine. C. Syrach-Larsen in Denmark also has made this cross and has grown hybrid seedlings that are already producing pollen.

Some of this pollen has been used in crosses with the western white pine at the Institute of Forest Genetics. By this means we hope to introduce the blister rust resistance of the Balkan and Himalayan pines into a cross that exhibits hybrid vigor. The work of A. J. Riker and associates at the University of Wisconsin has shown that in areas heavily infected with blister rust a rare tree may be found to have a high degree of resistance. These trees are now being used to produce stock that can be tested for resistance to blister rust. Dr. C. Heimburger is emphasizing both blister rust resistance and resistance to white-pine weevil attack in his breeding work with the white pines.

The practical value of all hybrids depends on their adaptation to the climate in which they are planted.

Some of the hybrids mentioned are of unknown hardiness in the Northeast, but we can be confident that others will thrive because both parent species are known to be hardy. This applies especially to the eastern-western white pine hybrid and to a less certain degree to the hybrids involving the Balkan white pine. The Himalayan pine is known to be hardy in Philadelphia, and therefore hybrids involving this species should thrive at least that far north.

Pitch pine, which is currently of minor importance in the Northeast because of its poor form and slow growth, has been successfully crossed with loblolly and shortleaf pines to yield hybrids that surpass pitch pine in form and rate of growth. The hardiness of these hybrids has not yet been tested in the more northerly region inhabited by pitch pine, but it is reasonable to expect that the hybrids will be at least intermediate in cold resistance.

The Southeastern and Southern States have four principal timber pines—all used in hybridization work. None of the crosses so far made have resulted in conspicuous hybrid vigor comparable to that found in the white pine crosses, but some of them combine desirable properties of the parent species in such a way as to be of great interest to timber growers. The cross between shortleaf and loblolly pines is generally superior to shortleaf pine in form and growth rate and gives some promise of growing in areas outside the natural range of loblolly pine, notably in eastern Texas and Arkansas.

Loblolly and shortleaf pines have both been crossed with slash pine, perhaps the most productive pine in the region for both timber and naval stores. Slash pine would contribute much more to the economy of the South if it were not comparatively restricted in its distribution; it is to be expected that crosses with loblolly and shortleaf pines can be made that will considerably extend the range of slash pine without sacrificing productivity. The natural hybrid between longleaf and loblolly pines has been known for some time, and a number of second-generation hybrids have been tested at the Institute of Forest Genetics. Some of these show strikingly good form and rapid growth under conditions wholly unfavorable to longleaf pine.

For the Lake States two important timber pines have been used in crosses, which have shown remarkable vigor. The first of these, eastern white pine, has already been discussed under the northeastern region. The second, jack pine, has been crossed with lodgepole pine of western United States to give a hybrid as vigorous as jack pine and as much as 79 percent taller than lodgepole pine of the same age. So far, this cross has been made only with the lodgepole pine of the high Sierra Nevada, which is a relatively slow-growing tree at medium to low altitudes.

It is quite possible that lodgepole pine from lower elevations in the Pacific Northwest or in the Rocky Mountains may be used with a selected local race of jack pine to produce even better hybrids. This cross should have great appeal to the pulpwood growers and is comparatively easy to produce.

Preliminary experiments at the Institute of Forest Genetics have shown that jack pine cuttings can be rooted rather easily, thus opening up the possibility of establishing clonal seed-parent blocks of this species that can be mass-pollinated with lodgepole pine pollen to produce hybrids at relatively low cost. The scheme is especially practicable for jack pine, which normally produces sound seeds at an earlier age than most other pine species.

Westward, in the northern Rocky Mountain and Pacific Northwest regions, the same hybrids that show promise in the Lake States are likely to succeed. Recent work by T. T. Munger shows that at the Wind River Arboretum in southern Washington, eastern white pine equals the western white pine in growth and form. Thus it is reasonable to expect that hybrids that have shown superior growth in tests in California and Massachusetts will thrive in the Northwest. Although neither of the parent species is generally resistant to blister rust, it is believed that resistance can eventually be introduced from resistant species such as Balkan and Himalayan pines or from resistant individuals of eastern white pine. No doubt some resistant trees of western white pine will eventually be found and brought into the breeding program.

For the central and southern Rocky Mountains, the Southwestern States, and California, a number of the hybrids have been produced. Monterey pine of the mild California coast has been crossed with knobcone pine, which is generally found in locations with much lower winter temperatures and more extreme summer drought than occur in locations where Monterey pine has survived. It is a typical combination hybrid that brings together the greater drought and frost resistance of the knobcone pine and the rapid growth and good form of Monterey pine. Studies under way at the Institute of Forest Genetics suggest that practical methods of vegetative propagation may be found to establish plantations made up of superior clones of this hybrid.

California's infant paper industry may in time derive much of its raw material from plantations of this and similar hybrids in the foothills surrounding the great Central Valley, at the lower border of the pine belt. Although the area is known to favor excellent growth of ponderosa pine, it has produced little pine timber in recent years because of frequent fires and rainfall conditions that are not often favorable to the natural establishment of ponderosa pine seedlings.

Both Monterey and knobcone pines carry their own fire insurance in the form of cones that open after fires and shower the burned-off areas with millions of seeds. The hybrid between these species is highly fertile and has "fire cones," which are produced abundantly when the trees are little more than 5 years old.

Several hybrids between the so-called yellow pines show great promise for the semiarid West, although no certain cases of hybrid vigor have been found. Ponderosa pine of the Pacific slope is known to grow more rapidly than the Rocky Mountain ponderosa pine, but the ability of the coastal variety to thrive in the Rocky Mountain region or in the Southwest is open to serious question. In tests in California, however, the hybrids of these two have caught up to ponderosa pine in height growth at 5 years. A distinct possibility is thereby offered to the forest planters in the Rocky Mountain region and the Southwest. An even more promising hybrid has been made by crossing ponderosa pine with Apache pine, a close relative from Arizona. The hybrid is remarkable for its rapid root penetration and diameter growth, both of which greatly exceed those of ponderosa pine, and for the fact that it equals ponderosa pine in height growth.

Jeffrey pine, a native of California, Oregon, Nevada, and Mexico, and long thought to be closely related to ponderosa pine, is generally of excellent form but of slower growth than ponderosa. A few years ago Jeffrey pine was found to have crossed, in several parts of its range, with Coulter pine, a species found only in California and Mexico.

Coulter pine, under California conditions, is one of the fastest growing pines although it is limby and relatively short-lived. Pollen from the natural hybrid between these pines, applied to flowers of Jeffrey pine, produced an abundant crop of backcross hybrids. In repeated tests these hybrids have grown almost as fast as Coulter pine, and have exhibited as good crown and stem form as Jeffrey or ponderosa pine. Elsewhere in this Yearbook, an account is given of insect resistance of this interesting hybrid, which may yet offer stiff competition to pondersa pine, heretofore the undisputed king of the western pines.

THESE RESULTS of research are encouraging. The principles and techniques of pine breeding are reasonably well worked out. Hybrids and strains of superior growth rate, hardiness, insect resistance, gum yield, and other qualities have been produced with trees from widely separated localities. The superior forms so far produced should be very useful, but they cannot be expected to grow equally well under all climatic and soil conditions. As with other crops, it will be necessary to breed pines to fit the major climatic regions and in some cases particular sites within a region.

The present status of pine breeding might be likened to that of corn breeding in the early 1930's. The principles and techniques had been pretty well worked out by various research workers, and a number of high-yielding corn strains had been produced. The next step was to make hybrid seed available to the farmers. When this was done, the planting of new strains spread amazingly; during the next 6 years hybrid corn came to occupy more than 80 percent of the land planted to corn in the Corn Belt, with an increased yield averaging about 20 percent. Although existing hybrid pines may be expected to increase the yield on plantation sites to which they are adapted, no seed of these superior tree strains is now available for general distribution. Devising means for production and distribution of those hybrids that seem worthy of trial in the various regions is the next step needed to capitalize on the results of pine-breeding research.

J. W. DUFFIELD, *a geneticist, joined the staff of the Institute of Forest Genetics in 1946. A graduate of Cornell and Harvard Universities, he worked as a forester for the Forest Service in Michigan and as a tree breeder for the Northeastern Forest Experiment Station.*

PALMER STOCKWELL *is geneticist in charge, Institute of Forest Genetics, a branch of the California Forest and Range Experiment Station, maintained by the Forest Service in cooperation with the University of California, in Berkeley. He has served with the Boyce Thompson Southwestern Arboretum in Arizona, the Carnegie Institution in California, the Soil Conservation Service in New Mexico, and, since 1937, the Forest Service. He is a graduate of the University of Arizona and holds the doctor's degree from the Stanford University.*

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