

RECENT ADVANCES IN THE FIELD OF FOREST GENETICS

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Forest genetics is beginning to come of age, having but recently passed through an awkward and confused stage of early growth. It has been slow to follow the lead of plant breeding in agriculture and horticulture. The reasons lie not so much in scientific backwardness as in the economic and biological conditions that surround the growing of timber products.

Much of our timber in the past has been "mined" rather than consciously grown. It seemed to be present in almost unlimited amounts. The price of stumpage was relatively low and there was little economic incentive to practice the scientific culture of forests. In addition, the great length of a tree generation and the inadequate knowledge of vegetative propagation of forest trees were further barriers to rapid advances in forest genetics. Because of these economic and biological factors, forestry training in the past has been lacking or weak in the science of heredity, and this science has not always been adequately applied in the practice of forestry.

But all this has now been changed. First of all, we are faced with the necessity of growing our own timber as a crop. The virgin forests are nearly gone in the United States and the supply of timber from foreign sources is limited. If we must grow our own trees, why not grow good

ones? Second, the impact of highly successful breeding work with other plants and the almost spectacular results from some early experiments with trees has shown the need for research in forest genetics and for the application of the results to silviculture.

This paper summarizes the background for recent advances in forest genetics, states the general goals of a forest genetics program, shows some of the progress toward those goals, and outlines future prospects.

BACKGROUND

Most of the early observation and research in forest genetics was made in the field of provenance, i.e., geographic or climatic races (ecotypes) within a species. The occurrence of climatic races was impressed upon foresters by the usually definite and sometimes spectacular results of planting young trees or seed far from the native seed source. High altitude strains of a species when planted in the lowlands retained their alpine characteristics. Progeny of seed from a lowland source suffered severe freeze damage when planted at higher altitudes. Wide distances in latitude, and even in longitude, between seed source and planting site often caused bad results. The evidence for the existence of geographic or climatic strains

within species is now rather conclusive (3, 9). Provenance studies have not only had real practical value in themselves but have stimulated advancements in other, more intensive phases of genetics.

Past exploitation of forests through retrogressive selection and bad choice of seed have reduced the proportion of good genotypes in the world's forest population. This fact has been recognized only recently. In Sweden heavy and prolonged selective fellings, which took only the best trees, has resulted in some deterioration of the forests, and collection of seed from inferior parent trees has resulted in plantations of poor quality (9). The same thing has happened in this country (6, 13, 15), but only recently have we realized the true genetic significance of these events. It has been strongly emphasized that valuable genetic combinations, once lost in a population, cannot be recovered by breeding in that population (9).

Research foresters, aided by plant geneticists, are now well on the way toward providing facts and procedures through which superior trees and forests can be developed and grown. In this country one of the leaders in the field is the Institute of Forest Genetics of the U. S. Forest Service (26).

GOALS OF A FOREST GENETICS PROGRAM

Probably all the aims of a forest genetics program can be grouped under three general objectives (2, 4, 17, 23, 28):

(1) Delineate geographic races and determine the limits of range around the planting site within which the

seed of a given species should be collected. Many provenance studies of this nature have been concluded or are nearing completion. The results of these studies will aid greatly in the realization of the other two main objectives.

(2) The discovery, perpetuation, and dissemination of the best remaining genotypes still present in natural stands or plantations.

(3) The further improvement of the better genotypes by controlled breeding and hybridization.

The attributes of forest trees may be good or bad depending upon: (1) the suitability of geographic seed source, (2) inheritance of specific characteristics in individual trees, or (3) the effect of environment (important as environment is to tree growth we cannot consider it here). Inherited tree characteristics are manifest through tree vigor, tree quality, and resistance to damaging factors. Either disharmonious geographic seed source or certain inferior genes may be responsible for low vigor, poor quality, or low resistance. For example, a given tree genotype, when grown within its own climatic and edaphic range, might produce trees of high vigor, good quality, and high resistance. If grown in a disharmonious climate or soil, this same genotype usually would produce trees with undesirable characteristics of either vigor, quality, resistance, or perhaps all three. Conversely, trees located within a harmonious climatic range inherit specific characteristics which may result in low or high vigor, quality, or resistance. Fortunately, disharmonious geographic range can be easily avoided. Foresters are now

generally agreed that trees should not be planted far from their native seed source until it is demonstrated that a particular strain will be successful.

The goals of a forest genetics program are concerned with determining how and to what degree the various tree characteristics are inherited, how this inheritance is influenced by environment, and how trees with superior traits can be produced. The following characteristics are believed to be inherited to a greater or lesser extent and worthy of intensive research (6, 9):

Vigor

(1) Growth rate and ultimate size. This includes both height and volume in a given environment on both an individual tree and a forest stand basis.

(2) Reproductive vigor. Trees of high growth potential may not be highly fruitful.

(3) Yield of special products such as oleoresin and maple sugar.

Quality

(1) Stem characteristics: (a) straightness; (b) taper and shape; (c) natural pruning; (d) apical dominance (strong central stem with an absence of forking); (e) epicormic sprouting (sprouting along the stem greatly lowers the lumber quality).

(2) Crown characteristics: (a) shape—relatively long, slim crowns are usually preferable because they allow more trees per acre without crowding; (b) branch size—relatively small branches are usually preferable because they produce smaller knots and a larger proportion of the total volume of the tree is composed of stem wood.

(3) Physical properties of wood: (a) straightness of grain; (b) special properties such as "bird's-eye" and curly grain; (c) wood density.

(4) Chemical properties of wood such as proportion of cellulose and tannin.

Resistance

(1) Hardiness to climatic extremes.

(2) Resistance to disease.

(3) Resistance to insect attacks.

PROGRESS TOWARD THE GOALS

The greatest progress in forest genetics has been made in the field of provenance or geographic strains. The evidence is now conclusive that local seed sources are usually best for planting in a given place. The literature on this subject is voluminous and only a few examples are given here. The geographic source of loblolly pine (*Pinus taeda* L.) seed directly affected the growth, yield, and disease resistance of plantations (27). The differences among sources were even greater than those caused by large changes in site quality. Altitudinal races in ponderosa pine (*Pinus ponderosa* Laws.) have been demonstrated (18). Progeny of red pine (*Pinus resinosa* Ait.) differed in survival and early growth depending upon the geographic source of the parent trees (8, 21), and similar results were obtained with jack pine (*Pinus banksiana* Lamb.) (22).

Progeny tests in Europe with 20 sources of spruce and pine planted in several localities showed that the local sources were best in all cases (7). Other extensive tests in Europe showed that plant breeding material should be collected from the same

region where it is to be grown (20). Most American workers in forest genetics now generally agree that local native seed sources should usually be used for reforestation purposes. Exceptions to this rule do exist. Sometimes even exotic species thrive in a new environment. If the new climate is not too different from the parent climate, some imported strains may be superior to trees from local seed sources. The discovery and propagation of these really superior genotypes is one problem of genetics research.

A slightly different provenance problem is encountered in southern Illinois. This region has no native pine and, so far, introduced loblolly and shortleaf pine (*Pinus echinata* Mill.) have proved to be the best

species for reforesting the worn-out and eroded old fields of the region. Until a few years ago, little attention was paid to the source of the seed to be used in southern Illinois.

Starting in 1949, the Carbondale Research Center established a series of replicated field trials including seven sources each of loblolly and shortleaf pine. During the second winter, loblolly progeny from Mississippi, South Carolina, and southeastern North Carolina suffered severe freeze damage (16). Trees grown from seed collected in Arkansas suffered only moderate damage, while trees from Maryland, Virginia, and Tennessee seeds were free of injury (fig. 1). At the end of the third year, survival, height growth, and form of the northern-source



FIG. 1.—Loblolly pines grown in southern Illinois from seed from different sources show marked differences in appearance three years after planting. The source of the trees to the left of the white $2\frac{1}{2}$ -foot plot stake is Worcester County, Maryland. The source of those to the right is Pender County, North Carolina. The Maryland trees are taller, have denser and darker foliage, and show better form and survival.

progeny were significantly better than for the southern-source trees. Progeny of hybrid crosses between loblolly and shortleaf pine planted in other southern Illinois experimental plots were undamaged. At the State Tree Nursery near Jonesboro, Illinois, whole beds of loblolly pine seedlings from eastern South Carolina seed were killed by the cold, while adjacent beds from Maryland seed remained virtually undamaged.

Other differences among the various sources on the experimental plots will undoubtedly develop as the trees become older. In this particular case our objective is to find or develop a strain of southern pine well suited to the climate and soils in southern Illinois.

Evidence that individual trees inherit traits of vigor and quality independent of environment has gradually accumulated. The methods of study used have been chiefly progeny tests, controlled breeding, and hybridization. In Australia (19) open-pollinated seed from exceptionally good (plus) loblolly and slash pine (*Pinus caribaea* Morelet) trees produced twice as many superior progeny as the average seed. By inbreeding the best trees, 3.5 times more superior progeny were produced than from average trees. The 5-year results of a one-parent progeny test (14) with loblolly pine in South Carolina showed highly significant differences in height growth and survival between the progenies. Similar results have been obtained with Scots pine (*Pinus sylvestris* L.) (10) and black locust (*Robinia pseudoacacia* L.) (5). Progeny tests with Monterey pine (*Pinus radiata*) in South Africa (24) showed that vigor, branch size, length of internode, stem

straightness, and crown shape were inherited independently of environment. Latex production from rubber trees has been trebled by seed selection (11). The capacity of longleaf pine (*Pinus palustris* Mill.) for the production of oleoresin is an inherited variant (12). Forestry practice in Sweden and some other European countries is based directly upon the use of "plus" trees and "elite" stands for seed production and breeding purposes.

It will not surprise plant scientists to hear that trees inherit resistance to diseases and insects. The location and breeding of such resistant strains, however, has been a slow process and lags far behind work on food crops. Disease resistance of trees has been shown in a few cases. About half of the progeny of open-pollinated mimosa (*Albizzia* sp.) trees resistant to the mimosa wilt were themselves resistant, whereas almost none of the progeny from average seed were resistant (25). Rooted cuttings from resistant trees showed high resistance. Slash pine trees resistant to the pine rust canker have been observed in the South (6). The Division of Forest Pathology, U. S. Department of Agriculture, together with some private nurseries, has for years been breeding and testing blight-resistant strains and hybrids of chestnut (*Castanea* sp.). This work has been based partly on Asiatic breeding stock. Several resistant strains, which promise to have desirable nut and timber producing traits, are now available. Some of these are now being tested on our Kaskaskia Experimental Forest. Intensive work in the interior region of the United States is now being conducted on the

location and breeding of western white pine (*Pinus monticola* Dougl.) trees resistant to the white pine blister rust (1). The work has already uncovered several apparently resistant strains, and several phenotypes of exceptionally high quality have been found.

A LOOK AHEAD

Someday in the future, American forestry will have an adequate scientific program which will include the intensive application of forest genetics to silviculture. It will include a seed procurement policy based on seed orchards of trees or elite stands with proved superiority. Trees will be grown only in climatic

or edaphic environments to which they are adapted and these geographic zones will be known and delineated. Superior strains and hybrids will be used for all reforestation purposes. Through careful selection, natural stands will consist largely of high quality, vigorous, and pest-resistant trees, and the best or elite trees will be reserved for seed. It is also not inconceivable that trees will be bred for particular purposes, for example, high-cellulose trees for making paper or rayon, high wood density and strength properties for certain structural uses, and high yielders of oleoresin for production of naval stores. Forest genetics research and its application to forestry practice has just begun.

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