Possible Applications of Genetics to Forestry

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CLEAR, straight-grained, merchantable pine lumber produced in fifteen years; burl walnut, bird's-eye maple, curly birch grown without difficulty wherever and whenever desired; pinon pine seeds of a size to be readily marketable in competition with other nuts developed; pines with doubled and trebled yields of heptanes, terpenes, oleoresins, and pitch isolated; high grade pulpwoods grown in an eight year rotation. This isn't Paul Bunyan's Utopia; these are merely some of the practical possibilities which may be anticipated if genetics, the science of plant breeding, is applied to forestry.

In reviewing a number of recent papers on forest genetics, the outstanding feature noted was the seeming sparsity of the genetics background of the workers in forestry. Only a few, such as Hartley and Coville, seem to have an appreciation of the possibilities and the limitations accruing from the application of scientific breeding principles to forestry.

Undoubtedly the most important and most practical improvement to be made is a more rapid growth of timber. Any such increase means a more rapid turnover in the rotation as well as increased profit. In fact, in work on the breeding of forest trees for pulpwood reported by Stout *et al,* rapid growth and freedom from disease are considered to be characters of first importance.

Other improvements to be expected might be: the climatic adaptation of tropical trees to the southern United States or the adaptation of a normal mesophytic tree to a more xerophytic habitat; the selection of trees bearing more bird's-eye, burled, or curly wood and trees bearing wood adapted to special uses such as the willow hybrid in England (2), which is used exclusively for cricket bats and thereby commands an almost fabulous price when compared to the average willow; the breeding of quality and quantity producing strains of the various nut bearing species; and the development of strains which yield larger amounts of oleoresins, heptanes, terpenes, pitch, balsam and cedar oils, tannin, and so on. From the genetics standpoint these improvements are normal expectations when controlled breeding principles are applied.

For the benefit of those readers not acquainted with genetic terminology, a few terms to be used in this paper are defined. A *cross* or *hybrid* is the term referring to the progeny from seed developed by the fertilization of the ovule of one individual with pollen from another individual. Usually this is a cross of two individuals having marked differences.

In chemistry every substance has a formula which gives the initiate the clue to the make-up of that substance. Likewise in genetics the constitution of any individual is denoted by a formula. However, for every character that is expressed in a plant's formula, a pair of symbols is used. This is to show the part of the plant contributed by the female parent as well as the portion contributed by the male parent at the time of fertilization. These parts are the *genes* that are borne on the different chromosomes, and these genes are the so far unknown somethings which cause the expression of various characters in the plant such as: type of growth, thickness of bark, presence of chlorophyl or other color pigments, etc. Often the two members of a pair of genes do not carry the same potentiality. They both condition the expression of a particular character in the plant, but they may tend to cause different forms of expression.

If both of a pair of genes in an individual are of the same kind, the tree is said to be *homozygous* for the pair. However, if the genes are different, then the tree is said to be *heterozygous*. It is in this heterozygous condition that the term *hybrid* is usually applied in a genetic sense.

Increased growth of trees through breeding will very probably come as a result of *hybrid vigor*. Theoretically, this is the enhanced growth rate following the crossing of two individuals which are not carrying all the same homozygous pairs of genes. Ordinarly, a more uniform degree of hybrid vigor comes from the crossing of homozygous individuals than from the crossing of heterozygous individuals. Homozygous individuals come from self fertilization rather than from cross fertilization. This fact will make it difficult to get homozygous individuals among the forest trees. Usually, at least four generations of self fertilizing a normally cross fertilized species is necessary to produce any appreciable degree of homozygosity. While this is apparently futile in forest breeding owing to the length of generation, it will have to be done eventually to make maximum improvement. For this reason some of this type of work should be started very soon.

In the meantime, however, taking shots in the dark will do no harm and may accomplish enough improvement to keep producers of forest products in the game of competition with synthetic products. One of the easiest and quickest tests would be the controlled crossing of large numbers of individuals. By controlling the crosses, records can be kept of the parents of each individual cross so that whenever a desirable cross is found, more seed can be produced from the same source.

From three to five year nursery tests of the seeds procured in this way would be sufficient to locate the more vigorous growing progenies, after which more seed could be produced from the same parents. This experiment might be expected to give particularly good results if the pollen parent could be chosen from small stands which are isolated one-half a mile from other stands of the same species and which are fairly uniform for rate of growth. This isolation and uniformity in a second growth stand would tend to indicate that those trees were more homozygous, provided the stand is not too thickly planted and the conditions of growth have been uniform throughout the stand.

A gradual selection of better individuals from the progeny tests of these crosses will give some degree of improvement until more useful homozygous strains can be developed for future breeding. Methods similar to the selection of cattle breeders can be used with the additional advantage that a vegetative reproduction technique can be worked out for many trees whenever particularly desirable individuals appear. Selection methods will need to be used cautiously; for, in many instances, an apparently desirable individual will be heterozygous in genetic makeup and therefore not a prepotent parent. The reasons for this are too technical to be presented here. Because of this a technique of vegetative reproduction to propagate a desirable individual needs to be developed. Then, too, good progeny of a desirable cross may be propagated vegetatively more economically and satisfactorily if this particular cross is difficult to make.

Vegetative propagation methods which have been used successfully with forest trees include propagation by: cuttings, layerage and various types of grafting. Henry states (10) that the elm grown universally in Holland and Belgium is propagated by layerage and has been reproduced this way for two or three centuries. He also mentions the propagation of the famous Lucombe oak by grafting as having been used successfully since its discovery in 1765. The cricket bat willow has been propagated by sets or cuttings, and a vigorous hybrid poplar at Metz has also been multiplied by cuttings from this original tree. Henry has propagated walnuts successfully by grafting. The renowned Huntingdon elm has been reproduced by cuttings, according to the same author (12).

Austin (1) is working on methods of propagating pines and walnuts, and Hartley (9) reports that the Boyce Thompson Institute for Plant Research and Johns Hopkins University are carrying on research on vegetative propagation of forest trees. Stout *et al* reports (18) successful propogation of numerous *Populus* species crosses by cuttings at the New York Botanical Garden.

With this work already done it seems very probable that other trees can be propagated vegetatively if the proper method is found. From our present knowledge there is nothing impossible standing in the way of developing this technique.

The random crosses previously discussed should produce desirable results because, in the first place, occasional natural crosses have been noted in trees which were outstanding in rapidity of growth, healthiness and general vigor, and, in the second place, crosses of various species and strains made recently have shown remarkable hybrid vigor. The oldest recorded natural cross of trees (10) is that of the elm grown in Holland and Belgium. It has been continued by vegetative propagation since its discovery almost three centuries ago. It is prized for its type of growth and foliage color, which make it a popular shade tree in those countries. It has been named *Ulmus latifolia* Poederlé. Seedling tests have shown it to be a hybrid tree.

Another old hybrid is the Lucombe oak (10) discovered in an English nursery in 1765. Seedling tests of the acorns from this tree were planted in 1792, and this oak was found to be a cross of the Turkey oak, *Quercus cerris,* and the cork oak, *Q. suber.*

Henry (10) also lists the London plane tree, *Platanus acerifolia* W., as a hybrid of the European and American species of sycamore. This tree is a favorite for city planting because of vigor, drouth resistance, and resistance to a fungus commonly found on the American sycamore, *P. occidentalis.*

The cricket bat willow is considered by Barker (2) to be one of the most valuable crops which can be grown in England on otherwise unproductive ground. Henry (10) records the instance of one cricket bat willow that at 55 years was 101 feet tall and 18 feet in girth. He further states that these usually grow to be 50 to 60 feet tall and 3½ to 4 feet in girth at 14 or 15 years from the planting of sets.

Henry (10) cites a hybrid poplar near Metz which at 81 years measured 150 feet in height and 25 feet in girth 5 feet from the ground. A cutting from this tree measured at 43 years was 140 feet tall and 16 feet in girth and contained about 700 cubic feet of timber.

In an earlier paper Henry (12) mentions the Huntingdon elm growing in Victoria Park, Bath, England. It was twice as large as 40 other kinds of elms growing in the park. A cutting from this tree grew to a height of 35 feet in 10 years. From progeny tests the parents of this hybrid tree have been determined as *Ulmus glabra* and *U. montana.*

A hybrid catalpa, supposedly a natural cross of *Catalpa kaempferi* and *C. bignonioides,* was found by J. C. Teas while he was living in Indiana in 1864. In Jones' report of this (13) it is described as an erect, vigorous and rapid-growing tree having the thin scaly bark of the American species and leaves and inflorescence much larger than either of its parents. The fruits are described as intermediate in size between the fruits of the parents.

Chapman (5) reports the finding of a natural hybrid between the longleaf pine, *Pinus palustris,* and loblolly pine, *P. taeda,* in Louisiana. After nine years' growth the hybrid was compared with a typical longleaf pine. The hybrid was 13 feet 4 inches tall and 2.3 inches in diameter inside the bark one foot above the ground, while the longleaf was 2 feet 11 inches tall and only 0.6 inches in diameter.

A walnut tree, called the James River walnut, is cited by Bisset (4). It appears to be a hybrid of *Juglans cinerea* and *J. regia.* In 1914 it measured 100 feet tall with a diameter of 10 feet B. H., and a spread of 134 feet.

Leopold and Luxford (15) found an interesting variation in redwoods in California which may not, however, be due to hybrid vigor of the one tree. They found two trees growing three feet apart which were about 60 years old and 120 feet high. One was 21 inches D. B. H., crooked, thick barked, and clear of dead limbs only in the first log; while the other was 15½ inches D. B. H., straight, thin barked, and clear of dead limbs for three logs. The latter is putting on clear lumber now, but the first is not expected to do this for another decade. Leopold and Luxford estimate that a 60-year-old stand of the second type is worth about twice that of the first type.

The earliest known attempts to artificially cross fertilize forest trees were made by Klotzsch (14). In 1845 he crossed four pairs of species: *Pinus austriaca* and *P. sylvestris, Quercus pedunculata* and *Q. sessiliflora, Alnus incana* and *A. glutinosa,* and *Ulnus nitens* and *U. pedunculata.* Seeds of these crosses were grown with seeds of both parents. Eight years later the hybrids averaged ⅓ taller than the parents. From these results Klotzsch claims that rapidity of growth and durability of timber can be augmented by hybridization.

In 1921 Burbank (20) crossed the English walnut with the California black walnut and planted six of these crosses in front of his house. Three had to be cut down later because of crowding due to rapid growth. De Vries visited Burbank in 1906 and reports that the three remaining trees were 80 feet tall and 2 feet in diameter. Sections of the cut trees were shown to De Vries and he notes that the wood was of a fine grain, very compact, and of silky appearance. The annual layers measured 2 inches in thickness. Further recrossing of these trees improved the quality, and selection produced a wide variety of hard and soft, coarse and fine, plain and beautifully marked, and straight and wavy grains.

In 1911, Dr. E. M. East (13) of the Connecticut Agricultural Experiment Station crossed two species of catalpa, *Catalpa kaempferi* and *C. bignonioides.* Seven-year-old progenies of this cross were 13.1 feet tall, while the parent, *C. bignonioides,* was 11.4 feet and the other parent, *C. kaempferi,* was only 9.1 feet tall. The variation in spread was in the same proportions. Ness (16) in reporting hybrids of the live oak and overcup oak, comments upon the ease of crossing various species of oak and the remarkable success of the crosses. Seven progeny of the above cross growing at the Texas Agricultural Experiment Station are reported in 1918 as being very vigorous and uniform, although no definite comparisons are made to the parent trees. Three of these were planted in 1912 and 4 were planted in 1913.

Some interesting facts about hybrid chestnuts have been noted by Detlefson and Ruth (7). In 1899, G. W. Endicott of Illinois crossed *Castanea japonica* by *C. americana.* Three trees were raised from the seed of this cross. One bore fruit in 17 months from date of planting, a second bore fruit in 4 years, and the third bore in 5 years. The Japanese chestnut normally bears at about 6 years and the American species at about 12 years. This early maturity is another common occurrence among hybrids.

Henry concludes (11) from a number of crossing experiments that hybridization increases growth rate, size, early and free flowering, ease of multiplication, and probably disease resistance or immunity. Henry's work is of especial interest because he used such a wide range of materials. His first work was on elms (12). He found that alternate and opposite leaf arrangement was inherited and was fairly sure that variations in leaf size were inherited. He used crosses of *Ulmus montana* and *U. glabra* because the seedlings of these two parents were uniform in many respects and were therefore assumed to be fairly homozygous. From self fertilized progeny of these crosses, he reports finding about 64 distinct types of individuals.

From 1909 to 1914 he made a great many crosses of various species and attempted some generic crosses. His successful crosses included species crosses of ash, alder, poplar, larch, walnut, and elm. He found walnut and elm crosses difficult to make, but in all successful crosses hybrid vigor was found. A seedling of one of these crosses, *Populus angulata* ♀ x *P. trichocarpa* ♂, grew to a height of 7½ feet in 27 months from seeding. One of the most interesting crosses reported (10) in this series of experiments was a cross of *Fraxinus excelsior* var. *pendula* ♀ x *F. angustifolia* ♂. The pollen of the male parent was shed in England in January and the female parent did not bloom until April. The pollen was stored in glass vials stoppered with either corks or cotton, and the cross was made successfully in April. Henry also reports successful crosses from pollen shipped to him in England from Spain, France, Portugal, and the United States.

Another interesting observation which he made was that rapid growth of some hybrids improved the quality of wood. He says, "It is a popular belief that fast-grown timber is necessarily soft and comparatively worthless. This is a fact in most conifers; but in one class of broad leaf trees, the wood of which is characterized by large pores in the inner part of the annual ring, the contrary is true, as the faster the timber of these trees is grown the stronger and denser it becomes. This class includes oak, ash, chestnut, hickory, and walnut, the species in fact that *par excellence* produce the most valuable timber."

Van Fleet reported (19) finding a hybrid chestnut which produced flowers and burs 23 months from seeding. This was a hybrid of the native American chinquapin and the Japanese chestnut. The nuts from this hybrid are from four to six times as large as the native chinquapin, ripen earlier in the season, and have the flavor of the native varieties; while the tree itself has a resistance to blight equal to the Japanese parent.

This group of reviews gives some idea of what has been attempted and accomplished in past work on hybrid vigor. Only two projects have been reported recently on work that is being done at present on this subject. Stout *et al* are carrying on a cooperative project under the auspices of Columbia University, the Oxford Paper Co., and the New York Botanical Garden. Inbreeding and hybridization of a number of poplar species are being performed in the effort to locate a rapid growing poplar tree suitable for the pulpwood industry. They report (18) a hybrid of *Populus alba* and *P. tremula davidiana* which grew 7 feet by the second summer from seed. A hybrid of *P. balsamifera virginiana* and *P. trichocarpa* grew 6½ feet by the second summer from seed.

A very interesting project is being carried on by the Eddy Tree Breeding Station in California. All of the known species, races, and geographical strains of pine are being collected and studied. Selection and breeding methods have been outlined for the improvement of various pine characters. As a sideline to this work another project on walnut (*Juglans sp.*) species has been started. The preliminary write-up and outline of methods used has been reported by Austin (1).

The other important character in tree breeding, disease and insect resistance, has been the goal of recent workers. Bates (3) cites the occurrence of the Cembran pine as being resistant to blister rust. Roeser (17) cites the Dunkeld larch, a natural hybrid of the Japanese larch, *Larix leptolepis*, and the European larch, *L. europeae*, which is a vigorous grower and resistant to larch canker. He also mentions the cross of Virginia chinquapin *Castanea pumila*, and Japanese chestnut, *C. crenata*, which produces a strain resistant to chestnut blight.

Hartley (9) gives a summary of the variations which have been found in forest trees and also a detailed outline of one project to determine disease resistance. He believes that surveys should be made immediately in an effort to locate individual trees which are resistant to chestnut blight, sycamore anthracnose, poplar cankers, and white pine blister rust.

The only work reported recently on resistance to insect injury is that of Graham and Baumhofer (8). They tested the five species of pine—Western yellow, Norway, Jack, Scotch and Austrian—for susceptibility to tip moth injury in the Nebraska National Forest. Austrian pine was found to be the least susceptible, followed by Scotch, Jack, Norway and Western yellow in increasing order of susceptibility. For that region, however, Western yellow pine is the most desirable species, and selection and breeding are recommended to locate a resistant strain of Western yellow pine.

A few surveys have been made recently on some other characters which might be worth studying from a genetic standpoint. Luxford (15), in making a survey of redwoods, found striking differences in durability, paintability, strength, tendency to spiral, thickness of bark, and ease of pruning. The indications were that at least the last four were due to hereditary causes. Pillow (15) noted interesting variations in amount of curl in walnut. These variations in both radial and tangential curl could be detected by cutting a small blaze in the inner bark. Surveys are under way determining differences in heptane yields in Jeffrey pine, terpene yields in Western yellow pine, and oleoresin yields of the pine species found in the South. Pillow and Bates (15) have started work on the breeding of bird's-eye maple, but no definite report is available as yet.

These ideas should give the reader some concept of the practicability of making use of genetics in forestry. The ideas expressed have been selected at random from recent work, and it should not be forgotten that these are the surface scrapings. This is a virgin field for foresters and can hardly fail to produce satifying results when tackled in earnest.

Quotations from two of the present workers in this field give a clear idea of the attitude being taken and form a good conclusion for this paper, which can do no more than introduce the subject. Coville (6) states, "Intelligent breeding *plus* selection would probably accomplish or exceed the results of pure selection and do it in a shorter period of time."

Leopold (15) says that research should be instituted at once, but the practical side need not be neglected because "in the first place, the final untangling of environmental from genetic influences in trees is very far ahead," and "secondly, while certainty is very far ahead, probability is, at least with some characters, merely a matter of observation as seems to be indicated in the case of redwood."

There is a real challenge in these quotations to all foresters. How long will it be before they, as a group, realize the significance?

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