BREEDING TIMBER CHESTNUTS FOR BLIGHT RESISTANCE

G.F. Gravatt, J.D. Diller, F.H. Berry,
A.H. Graves and H. Nienstaedt *

Introduction.--The Division of Forest Pathology, U.S.D.A. has been breeding chestnuts for blight resistance since 1909. The Brooklyn Botanic Garden began breeding blight-resistant chestnuts in 1930, and in 1947 transferred this project to the Connecticut Agricultural Experiment Station. The aims of both of these projects have always been fundamentally the same--to breed a chestnut tree of timber type, resistant to the chestnut blight and winter hardy. At the same time the quality and quantity of nut yield have not been totally disregarded but are of secondary importance. Other valuable by-products

* Respectively Senior Pathologist, Pathologist, Associate Pathologist, Division of Forest Pathology, U.S. Department of Agriculture; and Consulting Pathologist and Research Assistant, Connecticut Agricultural Experiment Station.

of this breeding work are the development of types suitable for preventing erosion on the drier sites and the development of prolific nut-bearing types suitable for wildlife. However, the main objective is the combination of erect, rapid growth with blight resistance.

Relative blight resistance of parent species.--Species of chestnut vary considerably in their resistance to the blight fungus. Asiatic species of chestnut, although not immune to the blight, are highly resistant. This is particularly true in the case of the Japanese chestnut, Castanea crenata, and the Chinese chestnut, C. mollissima; the latter is the most blight resistant of all the chestnut species. Two other Asiatic species, the Henry chinkapin, C. henryi, and the Seguin chestnut, C. seguinii, are less resistant to the blight in this country. This is partly due to winter injury frost cracks are ideal entrances for the chestnut blight fungus. Our native American chestnut, C. dentata" is highly susceptible, and this species has been practically eliminated by the blight.The European chestnut, C. sativa, indigenous to many European countries, is somewhat less susceptible than the American chestnut. Species of chinkapin, native to the southeastern and southcentral parts of the United States, are also susceptible to the blight, but in most cases their ability to sprout multiple stems helps them to survive.

Selection of parent trees.--In any breeding program the genetic quality of the parent material with respect to the characteristics for which one is breeding is of the greatest importance; the better the quality of the parents the better the offspring. In chestnut, the selection for one of the desired characteristics, i.e. erect growth, meets with considerable difficulties. American chestnut now occurs mainly as short-lived sprouts growing along road banks, fence rows, and other places where they have been released from selection for the desired form is almost impossible under such conditions. With regard to the Asiatic parents, the problem has been at least as serious. The introduction of these species did not begin until about the second decade of this century and we are only now beginning to get the results of the systematic tests of the introduced material growing under forest conditions. This means that for more than 20 years we have had to base cur selection of timber trees on orchard grown trees, or on trees grown as ornamentals. To this one may add that many of the introductions undoubtedly have been from orchard rather than forest trees and many have lacked hardiness when planted in this country. Probably this explains why so many of the hybrids made in the past have been of poor quality from a timber standpoint.

Performance of Asiatic chestnuts under forest conditions.--To test Asiatic chestnuts grown under forest conditions, the Division of Forest Pathology established 21 climatic plots, from 1936 to 1939, on Federal- and State-owned forests in eight eastern states. Results obtained show that the optimum range of growth and development of Asiatic chestnuts in forest plantations does not coincide with that of the American chestnut, or of our native chinkapin species. The American chestnut grew principally in the mountains and foothills of the eastern United States. Some of our native chinkapins also occur in this region, as well as along the extreme eastern. seaboard from South Carolina southward, the southern extremities of the Gulf States and in Missouri and Arkansas. The Japanese chestnut is adaptable to fertile soils in the more temperate zone, along the eastern. seaboard and the Gulf States. The Henry forest-tree chinkapin and the everblooming Seguin chestnut also do best in these southern regions. The Chinese chestnut has a much wider range of adaptability and does well in the Middle West, especially in the southern part of Indiana and Illinois, in southeastern Missouri, and on well chosen sites in the Ozarks, where only an occasional American chestnut was found or where the chestnut did not occur naturally. Certain of these Chinese chestnut progenies, however, are also adapted to the Appalachian Mountains and the Piedmont region.

Neither the Chinese nor the Japanese chestnut has quite the same forest-type growth as that of our native American chestnut. The Asiatic chestnuts are more exacting in their site requirements. They succeed best on cool, moist, fertile, north-facing situations. In their silvical requirements they are more nearly like our native yellow-poplar, northern red oak, and white ash than like the American chestnut and our native chinkapins. With respect to tolerance to shade, they are much like our northern red oak. They are not nearly as tolerant of shade, however, as our native shellbark and pignut hickory, white ash, sugar maple, or beech.

Not all Chinese or Japanese progenies have proved to be satisfactory; certain of each are far superior to others. Only certain Chinese chestnut progenies can be planted successfully in the New England, Lake and Middle Western States; Japanese and Seguin chestnuts, and the forest-type Henry chinkapin are often killed out because they are not winter hardy in these regions. Even some of the Chinese chestnuts, as well as certain hybrid chestnuts, have not proved to be winter hardy. Fortunately, a few Chinese and certain hybrid crosses show great promise of becoming forest trees with nut-producing possibilities suitable to man and wildlife. The best Chinese chestnut discovered thus far, as determined by performance in the climatic test plots and several plantations established in 1926, is P.I.58602, a seed importation made by the U. S. Department of Agriculture in 1924, from Nanking, China. As the results from the tests develop, the selection of parent material will greatly improve and the plantings will furnish material for both sexual and vegetative propagation of the desirable strains.

Breeding experiments at Beltsville.--Chestnut breeding work has been in progress in the Division of Forest Pathology since 1909, and hybrids from some of these early crosses are still growing in the Government test orchard near Glenn Dale, Maryland.

Selections of the Japanese and Chinese species have been crossed to produce hybrids fully blight resistant, but poor vigor and growth form have made most of them unsatisfactory as forest trees. Also, hybrids resulting from crosses between the Japanese chestnut and the American chestnut were unsatisfactory in most cases. Crosses between certain selections of the Chinese and American chestnut have shown the greatest promise as forest trees, and most of the breeding work carried on at present is with these two species. In 1935 a selection of the Chinese chestnut was crossed with an American chestnut sprout growing near the test orchard. The resulting hybrids, now 18 years old, average 9 inches in diameter at breast height and 37 feet in height. Most of the Chinese-American hybrids are upright in growth form, and intermediate between the parents in blight resistance. This partial resistance in the first-generation trees necessitates backcrossing to the blight-resistant parent tree. Some of these backcrosses have been observed for 15 years, and their resistance to blight appears to be unusually high. Selection work is continually carried on to obtain the best types of chestnuts to serve as parent trees.

The various species of chestnut intercross readily, indicating that all have the same number of chromosomes, 24. To date, about 40 percent of the total possible number of combinations of crosses have been made successfully.

Breeding experiments in Connecticut.--The breeding work at the Connecticut Agricultural Experiment Station has followed a somewhat different pattern. The first cross made was between the Japanese and the American chestnut. This cross looked extremely promising during the first years. It showed definite hybrid vigor, had excellent form, and showed good natural pruning; repeated inoculations failed to produce any blight symptoms; later, infections developed and the trees proved to be only slightly more resistant than the American parent. The next step was to cross this hybrid with the Chinese chestnut; this cross, the so-called CxJA, is the most promising hybrid so far developed. The plants show a considerable variation with regard to vigor, resistance to the blight organism, and form. However, a relatively large number of individuals combine a high degree of resistance to the disease with fairly good form and vigor. At present, attempts are being made to determine which individuals of the three species now growing in the Sleeping Giant plantation at Hamden, Conn., will give the best progeny and to test the progenies on a somewhat larger scale under forest conditions. Furthermore, selected CxJA hybrids are being backcrossed to the American parent, to improve their form. It is to be expected that this will lower the resistance of the hybrid and, therefore, necessitate further crossing with the Chinese chestnut.

Backcrossing of the original JA crosses to the Japanese parent has usually resulted in a loss of vigor and has been rather unsatisfactory. A few individuals, however, combine the desired characteristics and are used extensively in the breeding at present.

One more timber hybrid of some importance originated from a cross made by Van Fleet early in the breeding program at Beltsville. Although there are no records of its parentage, it is assumed to be a cross between Japanese chestnut and common American chinkapin, C. pumila. Open-pollinated seedlings of the hybrid were grown at the Sleeping Giant plantation and were backcrossed to Japanese chestnut. The resulting hybrids have a high degree of resistance and some individuals have fairly good form. Attempts are now being made to improve these trees further and test their progeny on a larger scale.

Performance of hybrid chestnuts under forest conditions.-- Since 1947 the U.S. Division of Forest Pathology and The Connecticut Agricultural Experiment Station have established 11 hybrid chestnut test plots--3 in Connecticut, and one each in Arkansas, Illinois, Michigan, Ohio, Pennsylvania, South Carolina, Tennessee and West Virginia. Two additional plots will be established in the spring of 1954 in Alabama and New York. Generally 100 hybrids (fifty furnished by each of the two agencies), and 50 Chinese chestnut P. 1. 5 8602 were planted in each plot. All plots are on favorable forest sites where Asiatic chestnuts would be expected to do well. The under-planting-and-girdling method is used in establishing the plots.

Already certain crosses are showing their superiority with reference to above-average survival, hybrid vigor and form, winter hardiness, and the all important characteristic of blight resistance. At the end of each growing season the individual hybrids are rated as to performance, and the information is made available to those engaged in the breeding work. Several crosses are showing superiority over Chinese chestnut P.I.58602.

Vegetative propagation.--Chestnuts and chinkapins graft readily when stock and scion are dormant, and a perfect fitting of stock and scion is obtained. Both interspecific and intraspecific grafts have been made successfully.

The propagation of chestnut from cuttings has been investigated. However, the percentage of cuttings taking root has always been very low in spite of the numerous treatments used. Leafbud cuttings, consisting of leaf blade, axillary bud, and a shield of stem tissue, have rooted best, but here difficulty is experienced in inducing rooted cuttings to break dormancy. If a way were found to propagate chestnut efficiently by cuttings, it would be possible to compare various planting sites by the use of a single clone and to compare clones of races or hybrids on a single site.

Inoculation tests.--The testing of hybrid seedlings for blight resistance is a difficult problem. As an example, an experiment involving 88 Chinese, 149 Japanese and 149 American seedlings can be mentioned. The plants were in their first growing season and were growing in the greenhouse where conditions for infection were optimum. Successful inoculation was obtained on 67 percent and 65 percent of the Chinese and Japanese seedlings respectively. Ninety percent of the American seedlings "took" the disease. The successfully inoculated plants showed all stages of disease development. By classifying disease development in 5 classes, it was possible to show, statistically, a highly significant difference between the Asiatic and the American chestnuts. For uniform material, results of this type may give some basis for selection, but for segregating hybrid material they would not suffice.

It would be advantageous if a better test could be designed to determine at an early age the relative resistance of hybrids. To do so a greater understanding of the factors involved in blight resistance would help. Experiments designed to determine these factors indicate that differences in the types and solubility of the tannins at least in part account for the different degree of disease resistance of the three species. The total tannin concentrations in the species are very much the same, but there is good evidence that the tannins of the Asiatic species are much more soluble than in the American chestnut and therefore more toxic to the fungus. Furthermore, the tannins of the Chinese species belong primarily to the pyrogallol group and there is some evidence that this tannin group is more toxic to the fungus than the catechol tannins found (in mixture with pyrogallol tannin) in the other two species. This seems to explain why the Chinese species is the most resistant of the three species, i.e. the Chinese, Japanese and American chestnuts.

Quick tests on the tannins have been attempted to determine the resistance of a tree. Although these have not yet been completely satisfactory, further investigations along these lines appear to be worthwhile.

Inarching to maintain promising hybrids.--Inarching, which is a kind of bridge grafting, is essential on chestnuts, which, though not blight resistant, show other valuable characters, such as straight stems and rapid growth. Since the blight is confined to the living bark, and one or two outer rings of wood, this inarching consists of cutting out the blighted area, painting it with ordinary paint, and inserting a sharpened scion (one of the basal shoots of the blighted tree) into the healthy bark above the lesion. It has been found that by such inarching the communication between leaves and roots can be maintained, that the tree in question continues in healthy growth and bloom, and that the scion continues its growth in thickness each year until it appears like a second trunk. It is best to do this work in early spring, just as the leaves begin to appear. If the lesion should appear higher up on the trunk, beyond the reach of the basal scions, a genuine bridge graft can be made, with vigorously growing shoots of the same tree as sscions.

Inarching has been practiced at the Sleeping Giant Plantation of The Connecticut Agricultural Experiment Station since 1937, and has proved entirely satisfactory. By this method, no chestnut tree that is elite material, either from a foresters or a nutgrower's viewpoint, but lacks resistance, need be lost.

Future outlook.--As in other tree-breeding work, chestnut breeding is a long-term project. Since the work was begun, however, valuable information has been accumulated on the genus Castanea; this should be very helpful in future research on this genus. The results attained thus far indicate that blight-resistant, timber-type chestnut hybrids can be produced and that their quality will be continually improved.

JUVENILE SELECTION CRITERIA

Albert G. Johnson

Research Fellow, Cabot Foundation
Arnold Arboretum, Jamaica Plain, Mass.

Due to the factor of time inescapably related to the production of trees from seedlings to their ultimate utilization at the point of economic maturity, methods for assessing or predicting the potential value of individual trees from their juvenile characteristics are essential to any practical tree breeding program. Such juvenile characteristics, to be of value to the for -ester or tree breeder, must be of such a nature that they will assist him in appraising the individual tree with respect to growth, hardiness, ultimate form, quality, disease and insect resistance, as well as general adaptability to the whole environmental complex. In addition, in the case of inter- or intra-specific hybrids, there is a need for a knowledge of criteria of hybridity for determining the validity of such hybrids. In most cases, all such criteria must be based upon some observable morphological characters of the existing phenotype.

Potential growth is grossly measurable, and in some cases probably predictable, on the basis of annual height growth in the early years, but it is more reliably indicated by phenological data covering the period of time elapsing between the initiation of growth in the spring and the cessation of such growth in the summer or fall months. In other words, potential growth can be measured by the degree of utilization of the available growing season, This does not mean, however, that very early initiation of growth in the spring is necessarily a desirable trait. On the contrary, in many species such early flushing may be decidedly disadvantageous, exposing the tree as it does to the danger of late spring frosts. European experience in this respect has shown that such early flushing trees are the slowest growing and least vigorous individuals in a given progeny. Translating this clue to practical forest management, it is immediately apparent that selective cutting as cur rently practiced, and which often discriminates against the high vigor, quickly maturing trees, can lead to genetic deterioration of naturally reproduced