Selecting and Breeding Blight Resistant Chestnut Trees

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ABSTRACT.—Background information of the species of *Castanea,* their identification, flower morphology, and cross-pollination techniques are important to understanding chestnut breeding. The future of chestnut breeding depends on several factors, but in the long run breeding will play a role in the continued existence of this species.

"Work of this kind (breeding) is extremely valuable and, although slow in yielding results, may eventually prove to be the only means of continuing the existence in our land of a greatly esteemed tree."

These words were written by Arthur H. Graves in 1914, who worked with chestnut from 1911 to 1962 and began breeding chestnut trees in 1929. Little did he realize how slow progress might be; however, it was and still is a valid approach that has proved successful with agronomic, horticultural, and forest crops.

Some background on the species of *Castanea,* their identification, flower morphology, and the techniques of cross-pollination are important to understanding the breeding that has been and can be done. Much of what I have to say is a review of information already in the literature (Dierauf, 1977; Jaynes, 1969, 1972; Keys *et al.,* 1975).

SPECIES

There are 13 species of chestnut native to the north temperate zones of Asia, Europe, and the United States. Only the American chestnut *(Castanea dentata* [Marsh.] Borkh.) was a notable forest tree. Several of the species are small trees or shrubs of minor economic importance. The European *(Gastanea sativa* Mill.), Chinese *(C. mollissima* Bl.), and Japanese *(C. crenata* Sieb. & Zucc.) chestnuts are all valued primarily as nut producers and only secondarily for wood. Although the latter three species can grow to large size they seldom develop the straight clear bole that was characteristic of forest-grown American chestnut. Two species, the Chinese and Japanese chestnut, have high levels of resistance to the chestnut blight fungus, *Endothia parasitica* (Murr.) P. J. & H. W. And. The resistant species and the parasite evolved together, whereas the American and European chestnut species evolved without the selective pressure of the chestnut blight fungus and, therefore, were genetically unprepared when exposed to the disease organism.

IDENTIFICATION

There is often confusion over identification of the various chestnut species. Any one trait is often inadequate to distinguish the species, but taken together, leaf shape, leaf margin, hairs on the leaf undersurface, twig color, and bud shape are useful key characteristics (Fig. 1). Whenever we have reports of large American chestnuts, 10-in. diameter breast height (dbh) or larger, we attempt to have a twig and leaf sample sent to us to confirm identification. Usually such reported trees are not the native chestnut. Confirmation by mail forestalls many unrewarding field inspection trips.

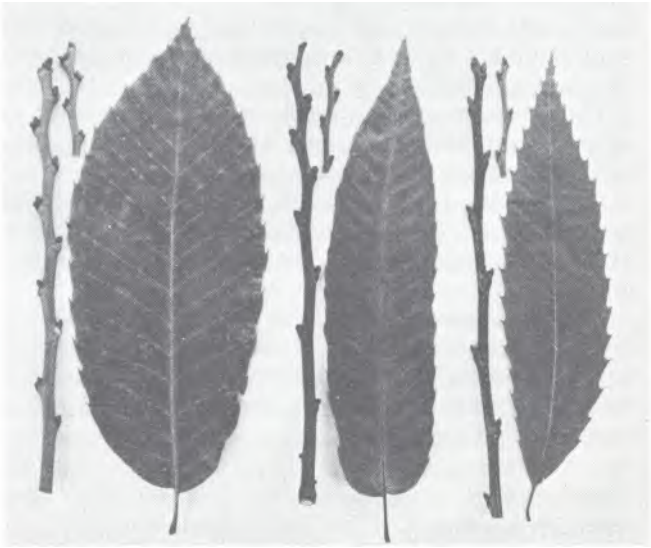

Figure 1. Twigs and leaves of three species of chestnut. *Left,* the Chinese chestnut twigs have a light, yellowish-buff winter twig color; there are simple hairs at the tip of the twig and the leaf is broad. *Center,* the Japanese chestnut has rounded buds and a leaf that is narrow and bristle tipped with a crenate margin. *Right,* the American chestnut leaf has an angular base compared to the two Oriental chestnuts and the leaf margin is more dentate. The size of leaf varies and is not critical in identification.

FLOWERS

Chestnuts are monoecious, that is, male and female flowers are separate but both occur on the same tree. They are borne on the current year's growth. Two types of inflorescence are found: the unisexual male catkins, located on the lower parts of the shoot, and the bisexual catkins toward the

terminal end of the shoots (Fig. 2). Pistillate or female inflorescences appear singly or in clusters of two or three at the base of the bisexual catkins. The bur or involucre of the true chestnuts (American, Chinese, European, and Japanese) normally contains three chestnuts, whereas the chinkapins are characterized by one nut.

Flowering is late compared to most temperate tree species and occurs after the first leaves have fully expanded. There is variation according to species, clone, and season. The male catkins shed pollen first, then in a few days the styles of the pistillate flowers spread, and last the male flowers of the bisexual catkins open. Chestnuts rarely self-pollinate. They are predominantly a wind-pollinated species with insects playing a minor role in cross-pollination.

Figure 2. Chestnut flowers. The male or staminate catkins have started to shed pollen. The developing burs are at the base of the more distal, bisexual catkins. The styles are beginning to spread. Pollen will not be shed from the male flowers on the bisexual catkins for several days.

CONTROLLED CROSSES

Female flowers are not receptive until five days after pollen shedding by the male catkins begins (anthesis); best results with controlled crosses are obtained when pollinations are made 10-13 days later. There is a temptation, because of the spread styles on the pistillate flowers, to not wait long enough before pollinating. Female flowers to be pollinated are generally isolated in water-proof paper bags just prior to their period of receptivity. Crosses are made with fresh catkins that have been bagged and are shedding pollen or with stored pollen. Pollen can be dried and stored frozen for a year. Controlled crosses are not especially difficult but are time consuming.

One alternative, which has value in some situations, is to take advantage of the self-sterility of chestnut trees. Two different isolated chestnut clones will normally intercross. Theoretically, large numbers of hybrid seed could be obtained from isolated two-clone plantings.

BREEDING CHESTNUT

A true awareness of the value of the American chestnut as a nut tree began to develop in the late 1800's. Some efforts were made at selecting outstanding native clones, and European selections, namely the 'Paragon,' were grafted on to native chestnut sprouts. Luther Burbank in California and Walter Van Fleet in Maryland had begun to hybridize the different species to produce better nut-bearing selections. A significant domestic chestnut-orchard industry was in the making when the chestnut blight fungus struck. The American and European trees were killed but Japanese chestnuts and some of their hybrids were resistant.

The breeding for a forest tree with characteristics of the American chestnut plus the trait of resistance to *E. parasitica* was begun in earnest by Flippo Gravatt and Russell B. Clapper of the USDA in 1922. Arthur Graves started his chestnut breeding in 1929 and these efforts have been continued by. Nienstedt, myself, and others at the Connecticut Agricultural Experiment Station. Numerous other individuals and institutions also have played a role in the selection and breeding of hybrid chestnuts.

Hybridization among the species is not difficult. Indeed, the numerous F_1 crosses made among ten species illustrate relative free compatibility, indicating the potential for gene exchange among the species. Breeding for a blight resistant forest tree has concentrated on the use of three species: the American, Chinese, and Japanese chestnut.

Early workers hoped that F_1 hybrids would meet their needs but as these trees matured it became apparent that, despite good form and vigor, they lacked adequate field resistance to the blight. Numerous second and third generation crosses of various combinations of the three species were tested but no one cross has yielded the desired result. In fact, there are few if any single, hybrid trees of large size that can be pointed to as growing like an American chestnut and being blight resistant. One of the most promising and highly publicized hybrids was the `Clapper' chestnut which succumbed in 1976 after carrying a latent infection for many years.

Failure to achieve the desired result does not condemn the methods used. Three major handicaps

to the breeding work are: 1) the lack of a satisfactory means to screen young seedlings for blight resistance, 2) no ready means to vegetatively propagate and thus test selections on their own roots, and 3) populations of hybrids have been too small to obtain the desired segregation. There appears to be linkage of traits for poor form with blight resistance and, conversely, good form and vigor with blight susceptibility. Breeders have failed to recognize the need for, or have been unable to grow, large populations of hybrids.

The largest hybrid chestnut planting is on the Lesesne State Forest in Virginia. Through the financial aid of Mrs. Arthur Valk and the cooperation of the Virginia Division of Forestry and the Connecticut Agricultural Experiment Station over 10,000 hybrid chestnut seedlings were planted between 1969 and 1975. Survival has been good. The oldest plantings have formed a closed canopy, with trees up to 30 feet tall and 4 in. dbh. A few of the trees in this planting are from controlled crosses, but most of them are from single parent selections such as the 'Clapper' chestnut. In many cases the seed parent was in a planting of selected hybrids and so the offspring are the products of natural crossing of selected hybrid trees. They represent third to fifth generation selections. At this early date only 4 percent of the seedlings at the Lesesne State Forest promise to be good timber types. Little blight infection has occurred among these hybrids as contrasted to a nearby planting of American chestnut seedlings. These hybrids represent the best gene source in the country for future selection and breeding of a blight resistant forest tree. With substantial effort, it should still be possible to develop clonal selections and even relatively true breeding lines of blight resistant, timber chestnuts for the eastern United States.

THE FUTURE

Whether the selection and breeding of hybrid chestnut trees should continue with vigor depends on many factors, not the least of which is the practical control of the chestnut blight fungus. Obviously, if American chestnut can again be grown, species-hybrid chestnut trees are not needed for the forest. However, even if we should be able to grow the native chestnut, we need to recognize that, as much as the tree has been idolized, it is not perfect and selective breeding within the species may well be warranted. Certainly there is considerable variation within the species for numerous characteristics. It also is possible that the hypovirulent strains could exert effective control on trees which we now consider to have inadequate field resistance, such as the 'Clapper' chestnut. Should this be true then selected hybrids at Lesesne might have immediate value.

Finally, regardless of the outcome of biological control of the blight, there is interest and demand for ornamental and nut-bearing chestnuts for the home and orchard. Chinese chestnut seedlings supply some of this need, but clonally propagated selections would be more satisfactory. Hybrids, present and future, would play an important role, such as third and fourth generation selections of the Chinese-Seguin *(C. mollissima-C. seguinii)* hybrids. These offer the advantages of the blight resistant Chinese chestnut with prolific, precocious bearing on trees of small stature.

Chestnut breeding is in a state of flux. The future will depend on many factors: the spread of the newly introduced gall wasp (Payne, 1979), improvement of vegetative propagation techniques, rapid screening of seedlings for disease resistance, and, most important, on the outcome of present biological control efforts. Breeding, in the long run, will play a role in the continued existence of this greatly esteemed tree.

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