THE SELECTION AND BREEDING OF PEST-RESISTANT LANDSCAPE TREES

by Frank S. Santamour, Jr.

Abstract

The development of pest-resistant landscape trees is considered to be the most efficient and long-lasting control method for the insects and diseases that plague trees growing in urban and metropolitan areas. Drawing largely on his own work at the U.S. National Arboretum, the author describes some of the approaches and results of research to select and breed trees resistant to Dutch elm disease, sycamore anthracnose, mimosa wilt, *Metasequoia* canker, white-pine weevil, bronze birch borer, mimosa webworm on honeylocust, and chestnut blight and chestnut gall wasp.

I doubt seriously whether many persons would take exception to the concept that the most ecologically and economically sound method of pest control is the development of pest-resistant plants. I also doubt whether many persons consider this approach altogether feasible when dealing with trees; trees that must survive for decades against the ravages of pests whose life cycles may be measured in hours or months.

To further complicate the host-pest relationships of street and landscape trees, the wide range of biotic and abiotic stresses to which the tree is subjected may lower any potential resistance below "threshold" levels.

Still, any tree genetics or improvement project worthy of the name must consider pest resistance as a major goal and strive to produce cultivars or populations that are superior in pest resistance to the trees commonly used in the nursery trade. Selection of trees for vigor, cold hardiness, salt and air pollution tolerance, rapid wound healing, and other "adaptability" factors is, in effect, a type of selection for pest resistance.

Further trials of resistance, employing artificial inoculation with plant pathogens, caging of insects on plants or the enhancement of natural infection or infestation must be undertaken to establish, at least, varying levels of pest susceptibility. "Resistance" is a relative term, and may encompass anything from "immunity" to "less susceptible." The geneticist must be constantly on the lookout for potential pest resistance and must use every means at his disposal to assure that the products of his research will be truly superior in resistance.

Other factors in pest resistance testing are *time* and *location*. The long-term testing period and nation-wide evaluation scheme that is used by the U.S. National Arboretum tends to insure that if any problems are likely to develop, they will do so during this phase.

It is axiomatic that the more trees of a particular cultivar or species that are planted, the more intensively and extensively the trees will be observed. With closer and longer-term observation, more pests will be found. However, the fact that trees have persisted in spite of injurious pests has produced, in some of us, a certain optimism regarding the development of better pest-resistant trees.

In the following paragraphs, I have attempted to outline our current involvement in the selection and breeding of pest-resistant trees at the National Arboretum.

Dutch elm disease

The approach to the selection and breeding of elms resistant to Dutch elm disease (DED), caused by the fungus *Ceratocystis ulmi* (Buism.) C. Moreau, has varied according to time and place. In the Netherlands, great reliance was placed for many years on intercrossing among resistant selections of the native European elm complex (Heybroek, 1957). Interestingly, the new Dutch cultivars, which are far more resistant to the "aggressive" strains of the fungus than the earlier selections, do contain some germplasm from Asiatic elm species (Heybroek, 1976). Early projects of the U.S. Department of Agriculture and Cornell University attempted to select disease-resistant individuals of American elm (*Ulmus americana* L.), our most popular and useful landscape tree. This type of research is continuing at the University of Massachusetts, using seedlings that have developed from irradiated seed. Breeding projects at the University of Wisconsin and the Nursery Crops Research Laboratory (USDA, Agricultural Research Service) in Delaware, Ohio have been based on the disease resistance of Siberian elm (*U. pumila* L.), Japanese elm (*U. japonica* (Rehd.) Sarg.), and some other spring-flowering Asiatic elm species.

Perhaps it was natural, when our research project was initiated in 1967, that we decided to explore other possibilities. The cornerstone of our breeding program has been the fall-flowering Chinese elm (*U. parvifolia* Jacq.) which, we considered, was superior in disease and insect resistance, and in certain cultural characteristics to the other species used as sources of resistance to DED.

Our accomplishments to date are listed below:

1. Determined the chromosome number of Chinese elm, and several other native and exotic species to be diploid with 2n=28 chromosomes (Santamour, 1969).
2. Discovered the first natural triploid hybrid between the tetraploid 2n=56 American elm and the diploid Siberian elm (Santamour, 1970). This hybrid, was fertile in crosses, giving rise to aneuploids and genetic combinations not hope of transmitting the DED-resistance of Siberian elm to a hybrid that resembled an American elm in growth form and habit. Unfortunately, this natural hybrid did not exhibit the vase-shaped form of American elm, although it did retain the DED-susceptibility of the American species (Santamour, 1974).
3. Created, for the first time, a large number of interspecific crosses between fall-flowering and spring-flowering elm species (Santamour, 1972b).
4. Determined that the triploid American x Siberian hybrid, as well as another natural triploid hybrid, was fertile in crosses, giving rose to aneuploids and genetic combinations not possible at the euploid level (Santamour, 1971, 1972c).
5. Demonstrated the high heritability of DED-resistance from Chinese elm in many interspecific combinations (Santamour, 1973, 1974).

After several years of growth, propagation, and inoculation studies we presently have seven selections under nation-wide evaluation and observation. One of these is a pure Chinese elm that showed a marked tendency to develop a vase-shaped form and, in addition, a good, reddish autumn leaf coloration. The other selections are hybrids with Chinese elm as the female parent and *U. wallichiana* Planch. (Himalayan elm), *U. thomasii* Sarg. (native rock elm) and *U. laciniata* (Trautv.) Mayr. (another species from China) as male parents. These trees also show a propensity to develop into vase-shaped trees.

Obviously, the testing period has just begun. We need data on cold hardiness in other regions and information on growth rate under nursery conditions. It may be that other pests could cause problems in certain areas. Other scientists will also be inoculating with the DED fungus to determine disease resistance.

But we have created some new genetic combinations, from which may emerge a tree that is worthy to take its place in the American landscape. When the first-generation hybrids reach sexual maturity, a new cycle of breeding, inoculation, and selection can begin.

Sycamore anthracnose

The major problem confronting the growers of sycamores or planetrees (*Platanus* sp.) is the fungus *Gnomonia platani* Kleb., the causal agent of sycamore anthracnose disease. Himelick (1961) described four stages of the disease, of which shoot blight, the dying back of new growth in the spring, is the most obvious and destructive phase.

All American sycamores are susceptible to this disease, including the eastern species (*P. occidentalis* L.), *P. racemosa* Nutt. from California, and *P. wrightii* Wats. from Arizona and New Mexico. The Turkish plane (*P. orientalis* L.) is highly resistant to the disease, but it is not widely grown in the United States (Santamour and Meyer, 1970).

Some 300 years ago, the accidental mating between *P. occidentalis* and *P. orientalis* took place in England (Henry and Flood, 1919), giving rise to the so-called "London Plane" (*P.* x *acerifolia* (Ait.) Willd.). Unfortunately, the vast majority of "London" planes in the United States have resulted from seed propagation from hybrid trees derived fro m hybrid trees derived from seed from hybrid trees. Thus, they may represent advanced generation segregates or backcrosses to *P. occidentalis*, and most of them are susceptible, in varying degrees, to sycamore anthracnose disease. Only the clonal 'Bloodgood strain' of the London plane, which has been propagated by cuttings in the United States since at least 1900, can be considered as "resistant." It should be remembered, however, that seedlings from this cultivar will show a great range of variation in disease susceptibility.

The National Arboretum contained several mature specimens of true *P. orientalis*, of Turkish origin, at the time our urban tree improvement project was begun. We first re-created the "London" plane hybrid in 1968, and, in 1970, repeated this cross and added new hybrid combinations with the western American species (Santamour, 1972a).

Heritability of disease resistance from *P. orientalis* was high in the first generation hybrids with *P. occidentalis* (Santamour, 1976a). At present we have several disease resistant hybrids, of varying crown shapes, under nationwide evaluation. It is likely that one or more of these hybrids will prove to be highly disease resistant and show enough other desirable horticultural attributes to warrant their eventual release as new cultivars.

Mimosa wilt

The wilt disease on *Albizia* (mimosa) species, caused by the fungus *Fusarium oxysporum* f. sp. *perniciosum* (Hepting) Toole, represents a case where "resistant" clones became naturally infected some years after their release and the trees have practically disappeared from the nursery trade.

The disease was first noted on trees of *Albizia julibrissin* Duraz. in 1935 (Hepting, 1936) and testing and selection of resistant types began in 1939 (Toole and Hepting, 1949). Two disease-resistant cultivars were released in 1949, 'Tryon' (red-flowered) and 'Charlotte' (white-flowered), and several test plantings of these and other clones were established in six states (Toole, 1955). It should be mentioned that these cultivars are true "clones," in that they are reproduced by root cuttings.

According to Gill (1964), the first natural infection in 'Tryon' occurred in 1957 and in 'Charlotte' in 1963. Both 'Charlotte' and 'Tryon' have survived for more than 20 years in an abandoned nursery area at the National Arboretum.

However, beginning in 1968, we started to lose a number of "mimosas" of seedling origin to the mimosa wilt. These seedlings were about 10 years old and were spaced about 15 feet apart in an ornamental planting. By 1971, all eleven trees had been killed by mimosa wilt and had been cut down.

Fortunately, Denzell Gill (USDA, Agricultural Research Service, Tifton, Georgia) had been continuing the inoculation-selection procedure to find new disease-resistant trees. In 1970, we received plants (propagated from root cuttings) of 'Charlotte,' 'Tryon,' and six new selections. These young trees were outplanted in 1971 into the same area where all the trees has died from wilt infection, and in which the root systems of the recently-killed trees had been left. No infection of the "resistant" clones has been observed in the six growing seasons since planting.

Thus, the Arboretum is serving mainly as a cooperative tester and evaluator in the project to develop disease-resistant trees of mimosa. Our experience would indicate that planting of 'Charlotte' and 'Tryon' would be feasible in certain areas outside the south, especially in soils where nematodes do not influence the infection process. None of the newer clones produce flowers as good as 'Charlotte' or 'Tryon,' but one dwarf clone with deep pink flowers may offer some landscape potential.

As with many other landscape trees, there is more than one cultural "problem." Mimosa webworm (*Homadaula anisocentra* (Meyr.) attacks all of the select clones, but the damage is far less severe than on honeylocust. Then, too, the abundant fruit and seed production of *Albizia* may be regarded as an undesirable feature of the plant. As the popularity of mimosa waxes and wanes, we will maintain this 'bank' of superior germplasm as an investment for future research.

Metasequoia canker

The dawn redwood (*Metasequoia glyptostroboides* Hu & Cheng) is not presently a popular landscape tree, but it is widely planted because of its botanical/historical interest. As recently as 1947, this tree was known only as a fossil. Then, the discovery of living trees in China focused worldwide attention on this species. It could be expected that this "living fossil," like *Ginkgo biloba* L., would have few pest problems.

However, in 1971, Stipes, Santamour, and Lambe (1971) reported a destructive canker disease on dawn redwoods at the U.S. National Arboretum. The causal organism was the imperfect (*Dothiorella*) stage of the common apple white rot fungus *Botryosphaeria dothidea* (=ribis) (Moug. ex Fr.) Ces & de Not. Nearly half of the 95 trees of seedling origin at the Arboretum are infected with the perennial trunk canker disease. The most obvious external symptom is the production and accumulation of whitish resin on the trunk at the base of the branches that serve as initial infection points (Santamour and Stipes, 1972).

In 1972, we selected and propagated, by cuttings, 10 canker-free trees with fair to excellent growth characteristics. These rooted plants were subjected to artificial inoculation with the fungus in Blacksburg, Virginia and Washington, D.C. One tree, of outstanding form, survived this screening procedure, and we are now re-propagating this clone in moderate numbers for further testing.

It is interesting that cankered dawn redwoods have, thus far, been reported only in the Washington, D.C. metropolitan area. A similar disease syndrome does occur, however, on the related genera *Sequoia* and *Sequoiadendron* when planted outside their native ranges in California.

Whether the disease will become more widespread or our selected clone will become widely planted is problematical. Still, if *Metasequoia* is to be planted at all, it might be well to use a clone selected for resistance to a known, although presently infrequent, disease problem.

White-pine weevil

The white-pine weevil (*Pissodes strobi* Peck) is certainly the major pest of eastern white pine (*Pinus strobus* L.) throughout most of the tree's native range. There appears to be no significant variation in susceptibility between geographic origins (provenances) of eastern white pine. Garrett (1972) reported that weeviling ranged from 71 per cent to 100 per cent over a three-year period in a provenance test plantation in Maine. Selection of unweeviled "resistant" trees from the wild has not been effective, and no significant differences in weeviling have been found between sexually or asexually propagated populations or clones that were initially selected as "resistant" and "susceptible" (Heimburger, 1967; Connola and Beinkafner, 1976).

Our approach to the problem at the National Arboretum is based on earlier work that showed that the cortical oleoresins of certain white pine species and individuals exhibited a differential crystallization when a crushed head of a weevil larva was stirred into the resin droplet (Santamour, 1965). This may seem like a rather drastic procedure, but crystallized resin is found in killed leaders of white pine. A later study (van Buijtenen and Santamour, 1972) indicated that selection of trees that produced resin that did not crystallize in the larva-head test could result in a tree population in which approximately 85 percent of the trees would not be damaged by the white-pine weevil under average population levels.

Thus, we are dealing with a selection and testing program on a "correlated character" and not resistance itself. There are many such morphological, physiological, or biochemical "correlated characters" that have proved useful in the breeding of crop plants. However, the correlation or association between the character and the host response to the pest is seldom perfect, and the correlation does not imply a cause-and-effect relationship.

Still, we have carried this correlation procedure one step, or a step-and-a-half, further. Recent work has indicated that the presence of strobic acid in the resin is responsible for the insect-induced resin cyrstallization and furthermore, that strobic acid is inherited as a dominant trait (Santamour and Zinkel, 1976a,b). Furthermore, it is likely that individual trees that produce cortical resin which lacks strobic acid may be rare and the selection of suitable parents for breeding may be difficult and time-consuming. The progenies produced by artificial crossing among selected "non-strobic" trees should retain this potentially desirable character.

When will all this theory be put to the test? Hopefully, in the very near future. Studies presently underway by the Arboretum and the U.S. Forest Service could lead to some meaningful results in the next five years.

Bronze birch borer

Anyone who has wandered about in a well-stocked arboretum has probably seen an exotic white-barked birch with high resistance to the bronze birch borer (*Agrilus anxius* Gory), the major pest limiting the successful culture of the white-barked birches throughout most of the United States. Unfortunately, the chances are that the label on the tree or the records pertaining to the tree would be incorrect! Aside from the normal errors that creep into any record-keeping system, past (and current) arboretum practices of seed collection and distribution have contributed to the identification problem.

Trees of rare species, mainly of Asiatic origin, growing in arboreta, have been used as seed sources of that species without regard to the possibilities of interspecific hybridization. These seed or seedlings may then be distributed to other arboreta or to commercial nurseries, from whence the hybridization and distribution pattern may be repeated. As a result, many of the birches in arboreta are not true to the species they are supposed to represent and, in some cases, may not even contain any germplasm of the species named on the label. Thus we find tree types of normally shrubby species, white-barked representatives of dark-barked species, and complex hybrids that defy any rational interpretation of their parentage.

A recent case that illustrates the identification problem is that of monarch birch (*Betula maximowicziana* Reg.), which has recently been noted as a white-barked species resistant to the bronze birch borer (Kozel and Smith, 1976). The monarch birch may, indeed, be resistant to borers, but the claims made for the species were based on incorrectly identified trees. True monarch birch is extremely rare in the United States, and there may be fewer than five sexually mature specimens presently in cultivation (Santamour and Meyer, 1977). Furthermore, the bark of the true species, is, at best, yellowish-white.

The major drawbacks to the use of these wild and wonderful hybrids with potential borer resistance are the lack of testing and the absence of any really valid identification. The absence of a reasonable identity might not be an obstruction to widespread culture and testing if birches were normally propagated by cuttings or by grafting. However, the normal mode of propagation of our most popular white-barked birches (*B . papyrifera* Marsh. and *B. pendula* Roth.) is by seed. Until deliberate selection, propagation, and testing programs are carried out, the potential of many trees can never be determined.

The current research program at the National Arboretum involves the delineation of species' characteristics and the identification of true-to-type specimens, long-term species and provenance testing, interspecific hybridization, clonal selection, and the development of seed orchards for the continual production of seed of known parentage.

Webworm on honeylocust

The recent increase in popularity of thornless and fruitless cultivars of our native honeylocust (*Gleditsia triacanthos* L.) has been paralleled by the increase in range of a most destructive insect pest, the mimosa webworm (*Homadaula anisocentra* Meyr.). It is interesting that, in 1940, the first American-named thornless cultivar ('Stephens') was introduced and, in that same year, the mimosa webworm was discovered in Washington, D.C., infesting the leaves of *Albizia julibrissin* Duraz.

The insect soon discovered a more delectable host plant, however, and spread rapidly. At the present time, infestations of the mimosa webworm have been reported from 28 contiguous Eastern, Central, and Southern states and from several counties in Northern and Central California (U.S.D.A., 1976). With usually more than two generations per year, the webworm can render a honeylocust tree leafless by late summer.

There is some variation in webworm susceptibility among honeylocust cultivars, with 'Moraine' being the most resistant of those tested or observed (Schuder, 1973; Santamour, 1976c). However, the growth form of 'Moraine' is not desirable in the opinion of many horticulturists. Thus, there is a need for insect-resistant trees possessing a range of growth rates and forms. We did not know if interspecific hybridization offered any hope in the development of superior cultivars.

Although the genus *Gleditsia* may contain 14 to 16 species, few of these non-native species are in cultivation in the United States, even in arboreta. Trees of exotic species, or even *G. triacanthos* growing in isolation from other honeylocusts or "mimosas" may not be infected with webworm, and observations on these trees are not indicative of potential resistance.

Beginning in 1972, we attempted to obtain seed of all *Gleditsia* species, and were successful in growing 11 species, one variety, and one natural hybrid population. These seedlings were grown in containers in permanent or temporary coldframes situated where neighboring trees of *Albizia* and *G. triacanthos* provided an annual source of natural infestation. Based on data taken in 1974 and 1975, no hardy species of *Gleditsia* possessed a degree of webworm resistance high enough to be judged suitable for a breeding program. *Gleditsia fera* (Lour.) Merr. from Hong Kong and *G. amorphoides* (Griseb.) Taub. from Argentina were rated as highly resistant, but neither species could consistently survive the winters in Washington, D.C. (Santamour, 1976c). At present, the most feasible approach to developing superior webworm-resistant cultivars of honeylocust appears to be the mass-screening of thornless seedlings of *G. triacanthos* under conditions of high insect populations.

Whatever the reason for the observed resistance of 'Moraine,' that resistance was not effectively transmitted to the progeny of an interspecific cross. A single, isolated tree of *G. melanacantha* Tang & Wang was located at the U.S. Plant Introduction Station in Glenn Dale, Maryland, and it had never been attacked by the mimosa webworm. Crosses between this tree and 'Moraine,' the first recorded man-made interspecific crosses in the genus, were made in 1973 and 1974 (Santamour, 1976b). Under webworm-test conditions, the selfed seedlings of *G. melanacantha* were heavily defoliated and the hybrids with 'Moraine' did not show significantly less damage.

Chestnut Blight and **Chestnut Gall Wasp**

Finally, I would like to mention a situation in which the Arboretum has no direct research involvement but which illustrates at least one of the potential frustrations that may confront a geneticist dealing with the improvement of long-lived trees.

We are all familiar with the demise of American chestnut (*Castanea dentata* Borkh.) caused by the chestnut blight (*Endothia parasitica* (Murr.) Anderson. We should also be familiar with the reasonably successful efforts of U.S.D.A. and the Connecticut Agricultural Experiment Station to develop disease-resistant hybrids with acceptable tree form and nut quality. Propagation problems have retarded the introduction of these hybrids into the nursery trade.

Recently, a new discovery was made that seemed to "open the door" to successful culture of the American chestnut. Van Alfen *et al* (1975) reported on hypovirulent strains of the disease fungus which, when placed in contact with virulent strains in living trees, seemed to prevent or allow "healing" of the canker. Obviously, there were many questions to be answered, but the possibilities of growing new chestnut forests were exciting.

Before this excitement wore off, however, a new pest entered the chestnut arena. Payne *et al* (1975) reported on the discovery of an oriental chestnut gall wasp (*Dryocosmus kuriphilus* Yasumatsu) infesting the vegetative buds of Chinese chestnuts (*C. mollissima* Blume) in Georgia. Most gall-formers do little damage to their host plants, but repeated heavy attacks by this insect may severely retard growth and practically eliminate nut production.

Presently, this insect appears to be confined to a small area in Georgia, outside the native range of American chestnut. We do not know if

American chestnut is susceptible to this insect. If it is susceptible, and the pest continues its northward march, the abundance of American chestnut sprouts in the woods, and planted Chinese chestnuts, would insure the spread of the insect throughout the eastern United States.

Has the recently-brightened future of American chestnut been once again dimmed by the gall wasp? Only time will tell.

Can genetics research be called on again to develop pest-resistant trees? The history of the insect in Japan illustrates the potential problems along that line. In 1941, the chestnut gall wasp was discovered in Japan, and it spread rapidly through the chestnut-growing area. Breeding and selection studies were initiated and insect-resistant cultivars were developed and widely planted. By 1970, the gall wasps were causing severe damage to the "resistant" trees. Perhaps, with the limited research resources available, it would be better to work on pest resistance in species that are still economically important, rather than to try to raise another species "from the dead."

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Research Geneticist, U.S. National Arboretum
Agricultural Research Service,
U.S. Department of Agriculture,
Washington, D.C.