A FIRST STEP IN BREEDING RESISTANT ELMS

by

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American elm *(Ulmus americana* L.) has been a desirable shade tree. It withstood city and small-town conditions, attained large sizes,' and had a vase-shaped form which distinguished it from other shade trees. European foresters consider their native elms as valuable timber producers. In America the wood is valued by some manufacturers of veneer and fine furniture.

Dutch elm disease caused by *Ceratocystis Willi* left a serious gap in the American landscape. Spray programs to control the insect vector are effective but at a high cost in money and risk to wildlife. Entomologists wish for a better solution. Systemic fungicides to kill the fungus and not the tree offer promise but their effectiveness is not yet known. The breeding of genetically resistant varieties offers much promise in the long run. Once produced, a new variety does not require additional expense for control and has no undesirable side effects.

GOALS

The primary goal in an elm-breeding program must be resistance to the Dutch elm disease. A new variety should also be adaptable to a range of site conditions and should have the traditional vase-shaped form that means "elm" to most Americans. We now have Siberian *(U. pumila)* and Chinese *(U.* parvifolia) elms with resistance but they do not have the growth characters most people want. I will be happy if we can attain the three primary goals—anything else will be extra.

EUROPEAN EXPERIENCE

The Dutch elm disease, which is probably native to Asia, has been present in Europe as long as in the United States. Only the Dutch have attempted serious control measures. The disease has made serious inroads in Great Britain but has by no means exterminated the elms there. One British elm authority, R. H. Richens, wrote in a letter that he thought one English town might contain more different kinds of elm germplasm than present in all of the Netherlands. The British do not know whether their elms escaped because they are resistant or because of some climatic control on spread of the disease.

One correspondent from Innsbruck, Austria wrote that there were no native elms remaining in the vicinity of the city, so he travelled into southern Bavaria to collect seed. Two other correspondents from Innsbruck did manage to collect seed from a few living elm trees.

I asked one German tree breeder, Klaus Stern, to give me a concise summary of elm breeding activities in that country. I love his brief answer—there has been none and will be none. There the disease is present and there are many dead elms. But there are also many living elms of all species. That also seems to be -true of Czechoslovakia, Hungary, Italy, the U.S.S.R. and several other European countries.

The disease is prevalent in Romania, especially in the western parts. A 1963 survey indicated real differences in amount of damage among the four species which are most commonly grown there. The Siberian elm appeared resistant there, as it does here. *U. glabra* and *U. laevis* also had a certain amount of resistance.

Elm has been considered a desirable timber tree in the Netherlands. Almost all planting was done with clones selected for desirable timber qualities. The trees were planted along roads, canal banks, etc. According to the Netherlands elm breeder, Hans Heybroek, there were about a million old elms when the Dutch elm disease was introduced and a third of these belonged to the susceptible clone `belgica'. That is why the Dutch started breeding work in 1929 at the Willie Commelin Scholten at Wageningen, near Amsterdam. The early work involved selection and crossing of trees growing in the Dutch countryside. Later the genetic base of the work was enlarged to include introduced species. The most thoroughly tested selections were produced prior to 1940 and are based mostly on species native to northern Europe.

Most of the Dutch selections have been introduced into the United States and are under test here. For several reasons, they may not supply all our needs. Their selections have been made for timber form rather than shade-tree form. Resistance testing has been concentrated on a 20-acre site near Amsterdam, with an average January temperature of 37°F.; hardier types may be needed for Lansing, Michigan, where the average January temperature is 22°F. Disease conditions are very severe in the United States and it is possible that resistance testing under Dutch conditions is not rigorous enough for our needs. Even now there are 80-foot unsprayed specimens of susceptible clone telgica' in Amsterdam and the British think that a lot of their escapes may be due to climate.

AGE AND RESISTANCE

There is an age effect that complicates any elm breeding program. Trees become more susceptible to Dutch elm disease as they grow older. One gets visual evidence of this effect along nearly any road in southern Michigan—there are many healthy young trees 15 to 20 feet tall in aim where all old elms are dead. The Dutch have found that this is not due merely to escape from insect attack. In earlier years they inoculated at ages one or two; now they inoculate at age four. This is only partially effective. Trees can survive several early inoculations only to die when they are 10 to 15 years old.

The implications to a tree breeder are clear. No matter how promising the first results, definitive conclusions as to the resistance of a new variety can come only after several years.

Some thought has been given to early identification of the substances or morphological traits responsible for resistance so that seedlings can be screened at ages 2 or 3. We cannot expect immediate help from this direction because valid comparisons require trees of proven resistance and proven susceptibility; such types are not yet available in the U.S. I discount the advisability of using comparisons between resistant *U. pumila* and susceptible *U. americana* because two such different species could differ in many ways not associated with resistance.

SHOULD WE WORK WITH NATIVE OR INTRODUCED SPECIES?

A quarter of a century ago Dr. Welch of Cornell collected seed from surviving American elms in New York and progeny tested them. Nearly all have died. This is not a critical test of the possibility of developing resistance in American elm because at that time the disease had not run its course. There were still many genetically susceptible trees that were to die in the ensuing years and it is not surprising that the offspring have suffered heavily.

Smalley and Kais in Wisconsin obtained seed from survivors in heavily infested eastern areas and in Wisconsin. They inoculated the seedlings at age 4. All were susceptible, although the disease-development pattern differed somewhat among sources.

Other species may offer a clue as to the possibility of breeding a resistant variety of American elm. The chestnut blight killed all the native American chestnuts, so that a new chestnut variety must be produced by hybridization with foreign species. On the other hand, there is enough inherent resistance within loblolly and western white pines to permit the development of rust-resistant varieties by selection and crossing within those species. Thus it seems that the American elm story might go either way.

From some standpoints it would be desirable to pursue the work that Welch started. We would not have to worry about site adaptability or tree form in American elm. Development of a new variety by selective breeding within the species would be a simple matter of selecting and testing for disease resistance. In some instances it would not even be necessary to resort to controlled pollination to produce full-sib families for a progeny test, because if there were only two survivors in a stand, one would pollinate the other.

The logistics of such a program are formidable, however. It would not suffice to locate one or two resistant clones because they might prove susceptible to other pests. One-clone varieties have been used in banana, sugarcane and poplar, always with serious disease problems. Also, one or two clones do not contain enough genetic variability to form the basis for further breeding work. It is more reasonable to think in terms of locating many resistant clones. That would involve a great deal of field work—perhaps two man-years—to search woodlots for the lone trees left standing long after all surrounding elms had died.

Aerial photographs taken in early spring might be useful. Also, press releases asking help from local people could be used. However, every report would have to be checked by a ground search to eliminate young trees, sprayed trees, or trees that had not been exposed long enough to the disease. So, even with help, the job of searching for rare survivors would be large.

Five other American species might be considered. None are as common as American elm, so the problem of locating rare survivors would be even greater.

There are about twelve European and Asiatic species. They vary in size and shape, and some contain types similar to the ideal American elm. *A priori* reasoning indicates that those native to Asia—the supposed home of the Dutch elm disease—are resistant. This is known to be true in the case of Siberian elm. Dutch experience indicates that there may be a usable amount of resistance in some European species. That is borne out by the Romanian survey and by the large number of survivors in England.

We chose to concentrate on the European and Asiatic species. Adequate resistance is almost assured and the main problem is to locate resistant types with adequate growth characters. Also, it is probably more economical to test the exotics than to conduct a laborious search of the forests of eastern America.

THE MICHIGAN STATE UNIVERSITY PROJECT

In the spring of 1968 Dr. George Parmelee, Curator of Woody Plants at Michigan State University and I wrote friends in all elm-growing countries of Europe and Asia. We asked for seed from native trees, from planted trees in arboretums where hybridization might occur, and from the most promising Dutch selections. We also requested grafting material from the Dutch selections although several of those clones are already in the U.S. This was a fair-sized letter writing project—all the letters were personal and individually typed. Forty went to the U.S.S.R. and corresponding numbers to other places. We requested a minimal amount of information but most correspondents added much more on their own initiative.

We were happy with the responses. Most people answered because they wanted to help in a scientific project. Some answered because they wanted contacts in this country or liked to collect stamps. During the spring and summer months a total of 524 seedlots arrived, distributed as follows among species.

U. laevis	100
U. glabra	135
U. procera	47
U. carpinifolia	63
U. pumila	41
U. elliptica	6
U. parvifolia	2
U. davidiana	40
U. wallichiana	1
U. sukaczewii	1
U. plotii	7

Each seedlot was collected from one tree, usually native. Most collectors sent seed from each of two or three trees per species. Also, most collectors sent a considerable amount of supplementary information on the possibilities of hybridization, progress of the disease, etc.

The U.S.S.R. sent the most seed-124 seedlots in all. Italy, Japan and Czechoslovakia sent 47 seedlots each. Although almost all the British correspondents replied, few were able to send seed—their most common species grow and flower well but do not produce viable seed in normal years. A severe hail storm destroyed the crop of *U. wallichiana* seed in part of Pakistan. Thus, although the 524 seedlots represent the most complete collection of elm material available, there are still gaps. These will be filled in 2 or 3 years, after the present material is digested and distributed.

Seeds germinate immediately in some elms and can be stored up to 4 years in others. To be on the safe side, nearly all seeds were shipped by air and sown as soon as possible after receipt. The need for this precaution was evident when a shipment from Italy germinated en route—we had living trees in Lansing 7 days after the seeds were collected.

Each seedlot was split into two parts as a matter of insurance. Dr. Parmelee sowed a few dozen seed from each parent in greenhouse flats filled with sphagnum moss. These usually germinated completely within a few days. They were potted individually when 2 to 3 weeks old and after another 2 to 3 weeks were transferred to outdoor nursery beds. The remainder were sown in outdoor nursery beds. Even when the weather was warm and the seedbeds were kept constantly moist, these did not germinate as rapidly or as completely. However, they grew better and form the bulk of the material now growing.

An inventory during September 1968 indicated that germination occurred in 85 percent of the seedlots received and that the elm collection includes about 50,000 living seedlings from 2 to 4 months old.

The seedlings are now 6 to 18 inches tall. They will be transplanted to wider spacings in the nursery in 1969 and moved to permanent test plantations in 1970. It would be possible to keep them in the nursery until they could be inoculated at age 4, planting only the survivors in permanent test plantations. That could be disastrous, however, because inoculation at age 4 is not a guaranteed way to kill elm trees. We could be left with 25,000 large survivors to be field planted when 5 to 6 years old.

The design of the permanent test plantations presents problems not encountered in most other species. There are several conditions to be met. The elms require good soil and must be exposed to the Dutch elm disease for at least 15 years. In Michigan it may be necessary to buy high quality, high-priced land specifically for the testing because there is little publicly owned land in the southern fifth of the state where the disease is prevalent. We will probably not be able to use either public or private cooperators, who might be unwilling to encourage death of the trees just when they were starting to look nice.

Data should be forthcoming on crown form and adaptability to a wide range of site conditions. This means planting in several localities—possibly in several states—and the use of a wide enough spacing to assess crown form after 30 or 40 years.

Unless we assume that the perfect tree will be forthcoming in one generation and is 'to be clonally propagated, it is necessary to look ahead to the second and third generations. A future breeder will benefit most if he is endowed with the maximum amount of information concerning the distribution of resistance among species, among races within species, and among individuals within races. Except for *U. pumila*, such information is at present fragmentary, based on crosses among a few clones per species or on natural mortality in Europe. Also, a future breeder will want to save the maximum number of genetically resistant trees in order to practice selection for other traits.

These last two objectives can be accomplished best if the tests follow a randomized complete block design with 1-tree plots and adequate spacing for good crown development. Then, no matter what the genetic variation pattern, survivors will be scattered uniformly over a test area.

But it is also desirable to consider mass production of a resistant variety should the 15-year results warrant. It is possible—even probable—that some families, races, or species will possess adequate resistance and such growth form that they could be recommended for immediate planting. The 1-tree plots will not permit immediate mass production except by controlled pollination (expensive in elm) or by clonal propagation. However, mass production would be a simple matter if all trees of one family or one species were to be planted together so that they could cross pollinate naturally.

Thus, we want no replication for one purpose and maximum replication for other purposes. Where numbers permit and there is *a priori* evidence of resistance, seedlots will be treated both ways—some trees will be planted in well-replicated tests and others will be placed in seed orchards.

We will probably follow the Dutch practice of slashing each tree with a knife dipped in a spore suspension. The age at which this artificial inoculation is performed is not so critical as if the trees were to be left in the nursery. Reliable results will be forthcoming only at age 15 whether mortality starts at age 4 or at age 8. Early inoculation will, however, permit closer initial spacing—perhaps 3 x 3 or 4 x 4 feet.

THE RUSS FOREST PLANTATION

A quarter century ago several hundred European elms were planted at the Fred Russ Forest in southwestern Michigan. The records are scanty but the trees are tentatively identified now as *U. procera.* The spacing was 6 x 6 feet. American elm mortality in the vicinity is nearly complete but there are many survivors in this plantation. Most are over 60 feet tall and of good timber form but it is difficult to judge their shade tree form.

This plantation may be unique in the U.S. because it contains so many non-American, non-Siberian elms that have been exposed to the disease. It might be used now as a seed orchard for the production of a partially resistant type for forest planting where the expected 50 to 75 percent mortality could be considered as a thinning and therefore not serious. However, a shade tree grower needs a much better guarantee of success.

I regard this plantation as a challenge. It shows what we do and do not know after 25 years of testing. More definite answers must be forthcoming from the new work after 15 years. Artificial inoculation will help some. So will the provisions for testing a great variety of material under similar conditions. But even those improvements in technique will leave many important genetic questions unanswered. I think it necessary to do some hard thinking and plan additional work beyond that outlined here in order to get maximum results in the next decade and a half.

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