RECENT PROGRESS IN THE BREEDING AND SELECTION OF ELMS

Alden M. Townsend and Lawrence R. Schreiber 1/

Abstract.--Breeding and selection of disease-resistant elms have been carried out intermittently at Delaware, Ohio, for the past 20 years. An accelerated breeding program since 1970 has produced more than 60 hybrid progenies. Trees are selected for resistance to Dutch elm disease and horticulturally desirable shapes, sizes, colors, and leaf characteristics. Ramets from clones that offer promise for release are inoculated periodically during spring and summer with a mixture of *Ceratocystis ulmi* isolates which vary in aggressiveness. Ramets from those clones showing high disease resistance are outplanted over a wide geographic range of sites to test for adaptability, hardiness, and disease-resistance. One hybrid clone has just been released. Several other selections, including one American elm, show superiority in disease resistance and other traits and are in the final stages of testing for release.

INTRODUCTION

The gradual demise of the American elm as a result of Dutch elm disease has stimulated the development of several elm breeding and selection programs (Lester and Smalley, 1972; Santamour, 1972; Townsend and Schreiber, 1972; Wright, 1968). All of these programs have one common purpose: to release disease-resistant elm trees that will fill the void left by the death of thousands of American elms. Even though many other tree species have been used as replacement stock, most of these species, unfortunately, lack the vigor, hardiness, and tolerance to stresses shown by almost all elm species (Schreiber, 1970).

We agree with many nurserymen and arborists that an intensified effort is needed to develop disease-resistant elm cultivars from a variety of elm species and hybrids.

1/ Research Plant Geneticist and Research Plant Pathologist, Shade Tree and Ornamental Plants Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Delaware, Ohio.

GOAL

Our goal is practical: the periodic release of superior, disease-resistant clones that either can be propagated as cultivars or eventually can serve as parents in producing genetically improved seed. We plan to release a variety of clones with diverse parentages, to prevent genetic uniformity that could result in widespread susceptibility to pests.

New cultivars must be suitable for planting on diverse urban and suburban sites. Ability to survive once trees are planted in these locations, is the most important criterion for release. Survival ability includes disease resistance, as well as adaptability and tolerance to urban stresses. However, these criteria alone will not entice the nurserymen to grow or the public to buy a new elm selection. Unique horticultural attributes such as attractive and desirable shape, size, growth rate, and leaf size and color are also necessary. Many of these criteria are the same as those of the Dutch breeding program (Heybroek, 1966).

BREEDING

Hybridization within the genus *Ulmus* has revealed few interspecific crossability barriers among the diploid elm species. The lack of breeding obstacles has allowed us to cross genotypes with widely different attributes. We have used as resistant parents hybrid clones from the Dutch program and selections made from the following species growing at Delaware: *U. pumila* L., *U. parvifolia* Jacq., *U. wilsoniana* Schneid., *U. glabra* Huds., *U. carpinifolia* Gleditsch, and *U. rubra* Muhl. Progenies resulting from crosses between these species have varied significantly in disease resistance and in many physiological and morphological traits. We have shown that certain hybridizations yield progenies markedly superior in disease resistance, growth rate, and form. Therefore, we believe that rapid genetic progress can be made by selecting the best seedlings from the superior progenies we have already created.

A few selections of American elm have moderate resistance to Dutch elm disease (Schreiber, 1970). We hope to release one of these American elms, but only after it has passed a rigorous screening for resistance. The hypothesis of a balanced and coexisting host - pathogen system has been proposed to explain disease epidemiology and resistance in many forest trees (Bingham et al., 1971). Probably, over the next 20 years, certain American elm populations will have accumulated sufficient genes for resistance to provide a high probability of survival.

SELECTION AND TESTING

Table 1 lists our schedule for selecting, propagating, testing, and releasing new elm cultivars from F1 or F2 progenies. The entire plan is based on the concept that rapid genetic progress can be made by our selecting the best individuals from the best seed source and hybrid progenies.

Table 1.--Schedule for hybridization, selection, testing, and release of elm clones from F1 or F2 hybrid progenies

Year	Action
1	Make crosses and outplant progenies
4	Inoculate all progenies with a mixture of aggressive and nonaggressive isolates of *Ceratocystis ulmi*.
5	Select and propagate most promising clones
6	Outplant ramets for seasonal susceptibility tests
7 8	Inoculate ramets at periodic intervals from May through July (seasonal susceptibility test)
9	Ship most-promising clones to testing sites, and plant
10	Inoculate clones growing at various test sites
11	Release to the public superior clones from crosses made in year 1

Hybrids are first inoculated at 3 years of age. In the 5th and 6th years after crossing, we select and propagate those clones that show exceptional or unique disease resistance, growth rate, and desirable appearance. In the 7th and 8th year, ramets of each clone are inoculated at different times throughout 4 months of susceptibility, to ensure that each clone is disease-tolerant and will survive, regardless of the time of inoculation. Ramets from clones that pass the seasonal susceptibility test (Lester and Smalley, 1972) are planted on diverse geographic sites and reinoculated in years 9 and 10. This latter method enables us to determine not only adaptability, but also disease resistance and shape under different environmental conditions. In the 11th year, we release ramets from the new cultivar to any nurserymen interested in propagating and growing them.

One major consideration heretofore neglected in breeding for disease-resistant trees is knowledge of variation in the aggressiveness of the pathogen (Bjorkman, 1964; Heimburger, 1962; Toole, 1966; and Townsend, 1972). During the last 3 years, we have shown significant pathogenic variation among about 30 isolates of Ceratocystis ulmi (Buism.) C. Moreau from throughout the U.S. The percentage of foliar symptoms induced in American and Siberian elms differs widely among these isolates. Aggressiveness appears to be a bimodal characteristic. An isolate is either aggressive or nonaggressive and seldom intermediate. American elms inoculated with nonaggressive isolates have a good chance of survival the year after inoculation. Survival after inoculation with aggressive isolates is rare. We have yet to find any indication of host-pathogen interaction. For example, evidence to date indicates that aggressive isolates are more aggressive than nonaggressive isolates on all elm species and hybrids, regardless of parentage. Lack of interaction would facilitate testing for disease resistance among a wide variety of Ulmus genotypes. Because disease reaction of newly created genotypes cannot be predicted, however, we test resistance with a mixture of aggressive and nonaggressive isolates.

RELEASES

One of the trees that has withstood the rigors of the selection and testing phases is shown in the cover photo. This tree, the 'Urban Elm,' is a hybrid between Siberian elm and a Dutch selection, N148 (U. hollandica Mill. 'Vegeta' x U. carpinifolia). It has dense, dark leaves, an upright branching habit, and a high resistance to Dutch elm disease. These qualities have enhanced its acceptance by many nurserymen who are propagating and growing it. It was officially released in the fall of 1974.

Results from seasonal susceptibility trials on several current selections are listed in Table 2. The 'Urban Elm' shows the highest degree of disease resistance.

Delaware No. 2, an American elm, has repeatedly shown high resistance and has good potential for release, depending on its performance in other locations and its susceptibility to elm phloem necrosis. Its marked superiority over average American elm seedlings (checks) is shown in Table 2. After 2 years, 85% of the ramets from Delaware No. 2 showed no more than 25% symptoms, compared to only 3% from check seedlings. Delaware No. 2 shows the typical vase shape of American elm.

Table 2.--Results from periodic inoculation with *Ceratocystis ulmi* of ramets from promising elm selections

Clone designation	Type of propagation	Date of Inoculation[a]						Overall average
		5/25/73		6/25/73		7/26/73		
		Reading Date						
		6/25/73	7/3/74	7/23/73	7/3/74	8/28/73	7/3/74	
		Ramets with no more than 25% foliar symptoms (%)						
'Urban Elm' (N148 x *Ulmus pumila*)	softwood cuttings	100	100	100	100	100	100	100
	grafts	90	70	100	100	100	100	93
Delaware No. 2 (*U. americana*)	grafts	92	62	92	62	100	100	85
Delaware No. 2 checks[b] (*U. americana*)	seedlings	0	0	0	0	20	0	3
U. carpinifolia 6-11	softwood cuttings	60	80	60	40	100	100	73
U. carpinifolia 7-6	softwood cuttings	80	100	90	70	90	100	88

[a]From 10 to 13 ramets/clone were inoculated on each date.

[b]These were American elm seedlings grown from seed collected from several parents of unknown resistance and interspersed at random within the rows containing Delaware No. 2 grafts.

Two *U. carpinifolia* selections have shown exceptional attributes. *U. carpinifolia* 6-11 has a columnar shape, rapid growth, and moderate to high resistance to Dutch elm disease (Table 2). We believe it will substitute well for Lombardy poplar, which is too disease-susceptible to be planted. Another *U. carpinifolia*, 7-6, which has shown higher resistance than 6-11 (Table 2), shows a broad crown and dense shade, which are characteristics of a good lawn tree.

We are currently making selections from hybrids developed in 1970 and 1971. These progenies vary widely in shape, growth rate, resistance, and hardiness and, therefore, offer good opportunities for genetic advancement.

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