INTERSPECIFIC HYBRIDIZATION FOR COMMERCIAL PRODUCTION OF DISEASE-RESISTANT ELMS

D. T. Lester and E. B. Smalley'

Attempts to locate host resistance in Dutch elm disease *(Ceratocystis ulmi* [Buisman] C. Moreau) and to combine resistance with ornamental qualities are being made in several research programs. Enough results have been achieved to identify some research directions as more promising than others. This paper reports the direction chosen by the authors and illustrates the reasons for our choice.

At least three groups of elm materials should be considered as potential sources of host resistance.. The first, American elm (*Ulmus americana* L.), is the ornamental standard against which products of elm breeding most likely will be compared. Although several resistant individuals have been found, transmission of parental resistance to either seedling or clonal progenies has been poor (Lester and Smalley, 1972c). Until problems of resistance transmission are better understood and accommodated, we see little promise in developing commercial quantities of resistant American elms. The second group of materials includes European species, principally *U. carpinifolia* Gled. and *U. glabra* Huds. and hybrids. European species have been the basic materials from which Dutch breeders have developed elm clones now widely planted in Holland. Perhaps the materials developed in Holland will be directly useful in comparable American climates; but, in Wisconsin, only one of fourteen Dutch clones has survived. Moreover, crown form in the Dutch clones is markedly different than in American elm. The third group of species is Asian, principally *U. pumila* L. and *U. japonica* (Rehd.) Sarg. We are emphasizing Asian species, possibly with some genes from the native slippery elm *(U. rubra* Mal.). Our objective is seedling propagation, in commercial quantities, of elms with high resistance to Dutch elm disease, with spreading crowns, and with moderate-sized leaves.

The research results leading to our emphasis are as follows: (1) Screening of world-wide elm seed collections has substantiated the identification of Siberian elm as the most resistant elm species. (2) A progeny outstanding for both disease resistance and ornamental features has been obtained from wind-pollination of one Siberian elm in the Botanic Garden of Hokkaido University in northern Japan. Proximity to surrounding trees of Japanese elm and subsequent breeding studies indicate that this progeny is a natural hybrid. (3) Seedlings from bulked wind-pollination of the Siberian X Japanese hybrid progeny were tested for disease resistance, and 70 percent of the individuals were symptomless after artificial inoculation (Lester and Smalley, 1968). A similar test of seven maternal wind-pollinated progenies from the same hybrid gave a frequency of symptomless individuals ranging from 78 to 93 percent, with an average of 87 percent (Lester and Smalley, 1972c). (4) A clonal test of one individual (only one has been studied) from the Siberian X Japanese hybrid has shown a high level of resistance.

From these preliminary results we conclude that resistance in the Asian materials can be transmitted to seedling and clonal progeny. Some indication of how resistance may be transmitted to seedlings comes from results of controlled pollinations. We recognize that our conclusions are based on small samples and may need adjustment when more trees are available for testing.

Table 1. Sample size, mean response to artificial inoculation with *Ceratocystis ulmi*, and mean leaf length for six types of elm progenies

Species Combination	Sample Size (no.) Progenies	Sample Size (no.) Individuals	Frequency of Symptomless Seedlings (%)	Leaf Length (cm.)
j x j[1]	1	80	64	—
j x pj	3	89	74	—
pj x pj	3	142	85	4.8
p x pj	8	337	90	4.0
p x p	8	350	93	3.6
a x wind	4	156	1	10.8

[1] j = *U. japonica*, p = *U. pumila*, a = *U. americana*

[1] Associate Professor of Forestry and Professor of Plant Pathology and Forestry, respectively, University of Wisconsin, Madison. Research support by the College of Agricultural and Life Sciences and Cooperative State Research Service is gratefully acknowledged.

[2] *E. B. Smalley*, unpublished data

Table 1 summarizes results of two experiments, one unpublished, involving crosses between Siberian elm, Japanese elm, and hybrids. A more detailed discussion of host response to the fungus is available in Lester and Smalley, 1972b. The principal points are the moderate to low susceptibility shown when the Asian materials were compared with American elm and the decrease in susceptibility as the proportion of genes from Siberian elm increased. By contrast, the ornamental character of leaf length was far from the American elm standard. The apparent negative correlation between leaf length and susceptibility has been discussed elsewhere (Lester and Smalley, 1968), and it seems to be an obstacle, though not an insurmountable one, to combining low susceptibility with high ornamental value.

Table 3. Sequence of crosses possibly leading to disease-resistant, ornamentally desirable seedling progenies of elm

Generation	Cross	Distribution of Germplasm (%)		
		p	j	r
1	p x r [1]	50	0	50
2	pr x p	75	0	25
3	prp x j	37.5	50	12.5

[1] p = *U. pumila*, j = *U. japonica*, r = *U. rubra*

Table 2. Sample size, mean response to artificial inoculation with *Ceratocystis ulmi*, and mean leaf length for six types of elm progenies

Species Combination	Sample Size (no.)		Frequency of Symptomless Seedlings (%)	Leaf Length (cm.)
	Progenies	Individuals		
r x pr [1]	7	249	22	9.4
pr x pr	2	81	53	6.0
r x p	6	463	27	6.8
pr x p	11	415	69	4.6
p x p	8	350	93	3.6
a x wind	2	91	2	10.8

[1] r = *U. rubra*, p = *U. pumila*, a = *U. americana*

Susceptibility was much higher over all in crosses between Siberian elm and slippery elm (Table 2), and disease response was again a function of the proportion of genes from Siberian elm. The apparently anomalous response of pr x pr crosses is probably the result of backcrossing to Siberian elm in the pedigree of one natural hybrid. Host response was discussed more fully in Lester and Smalley, 1972a. The value of slippery elm in transmitting genes for larger leaf size is also apparent in Table 2. In three-species combinations, the addition of genes from Japanese elm increased symptom frequency between 0 and 8 percent over comparable Siberian-slippery elm hybrids. Quantitative relationships among these crosses suggest the possibility that species may be combined to produce ornamentally desirable trees from seedling populations in which at least 90 percent of the individuals are highly resistant to Dutch elm disease. Figure 1 graphically illustrates species combinations so far tested and presents a range of combinations within which we plan to concentrate crossing in the next few years. Combination A, for example, can be achieved in three generations of crossing, leading to progenies with an average of 37.5 percent germplasm from Siberian elm, 50 percent from Japanese elm, and 12.5 percent from slippery elm. Table 3 outlines the crossing sequence. Combination B, which also can be achieved in three generations, will contain 62.5 percent germplasm from Siberian elm, 25 percent from Japanese elm, and 12.5 percent from slippery elm. We presently have flowering material from two of the three required generations.

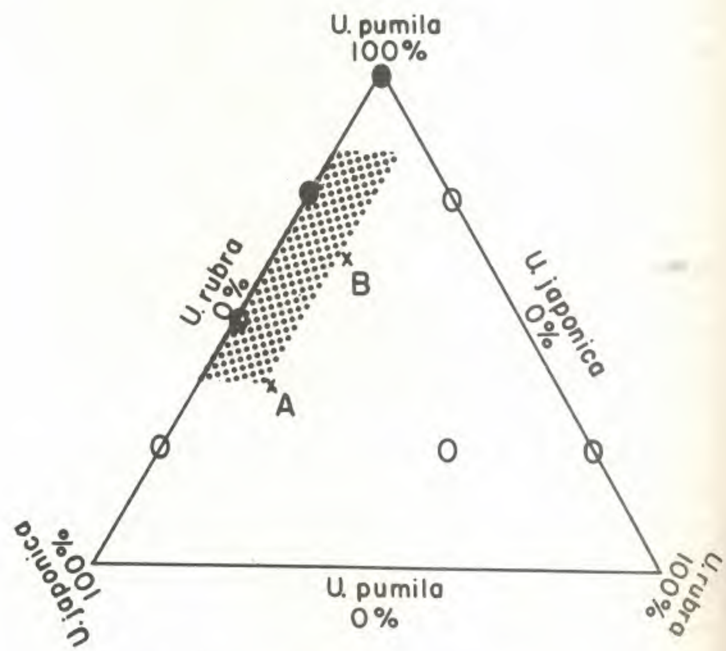

Figure 1. Summary of results from various combinations among three species (0 = symptom frequency in progeny exceeded 10 percent; ● = symptom frequency was less than 10 percent) and area in which future crossing will be concentrated (hatched). Points A and B are discussed in the text.

A wide range of other breeding approaches would be possible. Selection of ornamental individuals with greater-than-average resistance within each species might allow production of suitable hybrids between two species only, or even elimination of interspecific hybridization altogether. Backcrossing to break the apparent linkage between leaf size and resistance is another possibility. The quickest means to achieve genetic improvement would be vegetative propagation of those large-leaved individuals which demonstrate high resistance in nearly every progeny regardless of progeny-mean resistance. Clonal propagation of outstanding individuals will be a part of our short-term objectives, but our emphasis will remain on seedling propagation and interspecific hybridization. We hope to find species combinations which will be suitable for crossing of many genotypes and, hence, for maintenance of genetic variability for traits other than resistance to Dutch elm disease.

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