

## SELECTING AND TESTING ELMS: THE WISCONSIN ELM BREEDING PROGRAM

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**ABSTRACT** - - Selecting and testing elms for urban areas has required a substantial commitment of land, greenhouse space, equipment and labor over thirty years time. The development and continued survival of this program has depended primarily upon satisfying and education/basic research function; the production of improved cultivars has been an important but secondary product. Although resistance to Dutch elm disease (DED) has been a major focus of the selection and testing program, crown architecture, leaf characters, and resistance to other pests have also been emphasized. Many elements of the testing program have been developed to accelerate the early screening of plant material. We believe that long-term tree breeding and testing programs are both possible and desirable and can lead to the development of superior trees for urban areas.

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A program of selecting and breeding elms for use in urban landscapes was initiated in Wisconsin in 1957. In its formative years, emphasis was placed upon assembling elm germplasm from throughout the north temperate region, establishing field trials to evaluate adaptability to the north central United States climate, and screening of well-adapted materials for resistance to Dutch elm disease (DED). The initial motivation for creating an elm research program in Wisconsin was widespread public alarm at the decimation of American elm (*Ulmus americana*) population in urban areas. However, politics alone could not sustain a viable program and

justification for continuing elm research involved a transition from short-term fungicide and chemotherapy work to long-term breeding and host-pathogen studies. Our most important product continues to be the training of graduate students and the discovery of basic facts about elm biology and the nature of host-pathogen interactions. Unlike other scientists whose research results in ideas to be disseminated in journals, we also produce a tangible product, the disease-resistant, ornamentally attractive elm. However, it is important to note that this latter product alone could not justify the continued involvement of the university in selecting and testing elms.

## A BIOLOGICAL BASE FOR TESTING

Every plant breeding program depends upon a source of raw materials from either wild populations or from germplasm accessions in public or private collections. In 1957, the only sources of “improved” elm germplasm were the Dutch breeding program at Wageningen, and the U.S.D.A. program, then at Columbus, Ohio, but subsequently moved to Delaware, Ohio. Materials received from the Dutch program have been evaluated here in Wisconsin for many years, but most such introductions have not been sufficiently hardy in our north central United States climate. Cultivars from the Wageningen program have been marketed in the United States (e.g. ‘Groeneveld’), but their use is limited to hardiness zones 5-7. The Dutch germplasm base has emphasized Ulmus glabra, U. carpinifolia, and other species better adapted to maritime climates. Thus, a germplasm base adapted to harsh continental climate was sought for use in the Wisconsin program.

Many accessions of Eurasian species, especially U. pumila and U. japonica had the requisite adaptability to the north central region, and also possessed moderate to high levels of resistance to Dutch elm disease. A great deal of work completed during the 1960’s involved the creation and evaluation of various hybrid combinations using Siberian elm (U. pumila) as a source of DED resistance. Some hybrids developed during this

period were, and continue to be, useful as cultivars and as breeding materials. Despite its many other flaws, Siberian elm continues to be the major source of DED resistance genes for virtually all hybrid elm cultivars in use today. A great deal of intuition was also acquired during this period, and continues to guide our choice of parents for breeding, as well as our choice of research problems. We have continued to add to our earlier germplasm base with additional accessions of these species, but also U. parvifolia, U. laciniata and other Eurasian species in a continuing search for new and useful germplasm. However, continued expansion of the germplasm base poses a maintenance dilemma. Although new germplasm especially from geographic regions not previously studied (e.g. People’s Republic of China) is of vital importance, the continued introduction of new accessions, together with new progeny arrays from systematic breeding, places a great strain on program resources. This dilemma leads (inevitably) to a hierarchy of activities with respect to germplasm use.

## PROVENANCE TRIALS

Most of the germplasm in our program, like a peacetime army, “sits and waits” to be used in a variety of studies. During long periods of time, provenance collections are exposed to the vagaries of climate, diseases, insects and competitive interaction with their sibling. In time, and with only general maintenance or a screening for

DED, we learn a good deal about the adaptability of provenances from exotic sources. Not every winter provides a harsh environment and not every summer witnesses intense insect activity. Response to wind, soils, ice, and other effects also serves to accumulate information on adaptability. Such collections also serve as a base for taxonomic and physiological research not otherwise possible in their absence.

### BREEDING TRIALS

A smaller portion of the germplasm base finds more active use in our immediate breeding research. At present, two particular collections are of interest. The hardy remnants of U. parvifolia accessions, together with parents from other programs such as The Morton Arboretum, are being used to generate a series of wide hybrids to combine the smaller size and putative insect and disease resistance of the Chinese elm with larger leaf size and increased vigor of selected specimens of other diploid elms; even American elm has served as a male parent and yielded hybrids currently in testing.

A second line of research involves the selection and breeding of an  $F_2$  population of American elms using survivors of past screening in Wisconsin as well as the best remnants of other now defunct American elm programs. In fact, a few of the American elms considered for release as "American Liberty Elms" are included as parents. Our objective here is to evaluate the "combining

ability" of various individuals and determine whether future efforts should emphasize elite clones or seedling arrays. Although we consider the "American Liberty Elm" as acceptably resistant, for certain uses, the potential for increasing resistance via recurrent selection is only now being tested.

### HOST-PATHOGEN STUDIES

Finally, a very limited number of well-studied trees find use in intensive studies of host-pathogen interactions in efforts to elucidate the mechanism(s) of resistance to DED. Individual clones that have been well-characterized for their level of resistance to DED are used for a variety of biochemical studies to examine specific hypotheses regarding the site and mode of action of resistance. Although such material represents only a very small fraction of available germplasm, it is extremely important for basic research. While breeders of agronomic crops have known for years that well-characterized germplasm is only available in long-term programs, the idea that tree breeders also need to characterize their germplasm still appears to be a novelty.

### THE WHAT, WHEN AND WHERE OF TESTING

If resistance to Dutch elm disease was the only requirement for returning elms to the urban forest there would be no real need for a long-term breeding effort. Many elms have adequate resistance to Dutch elm disease, but typically fall short on

ornamental characters. There is more to selecting and breeding elms than disease resistance; in fact, the identification of DED resistance can be completed quite quickly. The evaluation of mature form is the lengthy process in this program. However, resistance to DED is a major priority, and a good deal of effort has been devoted to improving DED screening techniques.

### THE NATURE OF RESISTANCE

Few elms possess “absolute” resistance to DED, and numerous trials over many years have demonstrated that screening on several occasions is necessary to describe the interaction between host and parasite in elms. Accessions which appear to be resistant under one combination of temperature and precipitation may actually suffer considerable damage under another combination. A number of interacting factors play roles in the elms expression of resistance to DED. Different races of the pathogen differ in their temperature optima and range for pathogenicity . Individual elms vary in the duration and degree of susceptibility to these different races of the fungus. Except for a period of a few weeks in the spring, all elms have mechanisms for resisting infection by the pathogen. Seasonal susceptibility trials were developed to provide a profile of relative susceptibility throughout the growing season. In general, the late spring season (15 May to 10 June in southern Wisconsin)

marks the peak susceptibility to DED but annual fluctuations may be large. In short, field screening for resistance to DED is not a “one-time shot”; repeated evaluations over several years are required to establish the true interaction between the host and pathogen.

### THE INITIAL SCREENING

Given the large land requirements for replicated tests, and the impossibility of thoroughly screening more than a handful of selections, we have devised a multi -stage screening process that allows the evaluation of large numbers of seedlings followed by a more intense screening of a few individuals. When new accessions are received or new progeny arrays created, we try to provide optimal cultural conditions during their pi-e-screening growth. Typically this involves greenhouse growing of seedling in ‘book planters’ (Spencer – LeMaire Roottrainers) during the first year with over-wintering in our coldroom the first winter. Field planting into well-tilled fields followed by mechanical (only!) cultivation during the next two years is crucial to the production of vigorous, uniform saplings free from competition. Branch/shoot inoculation with a spore suspension of a mix of several virulent strains of DED in early June usually results in optimal damage to susceptible trees. Crown damage is evaluated 75 days after inoculation and again the following year.

## GREENHOUSE AND CLONAL TRIALS

By 5 years from seed we are able to evaluate hardiness, preliminary resistance DED, leaf size, juvenile vigor and form. This may still leave a moderate number of candidates for further study, too many perhaps for replicated field trials. At this point clonal propagation for a greenhouse intensive screening helps narrow the field of candidates for further testing. Those candidates that propagate easily from "greenwood cuttings" are evaluated for resistance under more rigorous controlled conditions in the greenhouse. After low temperature storage to break dormancy, one-year-old rooted cuttings in 12.6 cm (5-inch) clay pots are cut back to 10 cm and subsequently bud pruned to restrict plant development to a single dominant bud. After approximately 60 days' growth, plants are wound inoculated at a single point in the lower stem with conidia (10<sup>6</sup> spores/ml) from highly virulent strains of the pathogen. Usually several strains of the pathogen which represent the different races are contrasted using 10 tree replications. Thirty to 40 days following inoculation, plants are harvested, foliar wilt symptoms assessed, and the volume of the internal lesion calculated by measuring the length of the lesion discoloration developing from the wound and the extent of cross-section invasion at various points along the stem. This procedure gives us a highly accurate measurement of relative DED susceptibility for a particular clone as

contrasted to highly susceptible American elm controls. This is a very severe procedure conducted under very uniform conditions with vigorous plants. Frequently we measure substantial disease under these conditions in elms which remain apparently symptomless after inoculation in the field. In fact, we consider that the greenhouse susceptibility method actually provides an absolute and highly reliable assessment of an individual elm clone's resistance to DED. The most resistant clones identified in this way are later subject of a final field evaluation using replicated plots.

## OTHER TRAITS OF INTEREST

Like resistance to DED, leaf size and juvenile vigor cannot be evaluated at an early age. Leaf size in particular is of interest because of a preference for large leaves typical of American elms in the United States or U. glabra cultivars in Europe. Japanese elm (U. japonica) is one of the best sources of large leaf types and has the added advantage of also conferring resistance to DED. Unfortunately, many U. japonica clones have *small* juvenile leaves and are difficult to propagate. Hybrids between U. japonica and other species (especially U. pumila) are easier to propagate and therefore of interest. And although it is widely assumed that hybrid progenies from  $F_1$  crosses should be intermediate between the two parental types, such progenies usually are highly variable, requiring careful evaluation. Choice of parents in such crosses is extremely important and

represents the difference between useful progeny arrays and “hopeful monsters”. It is apparent that even within “resistant species” great variation exists, and choice of the most resistant parents is critical. Even for supposedly resistant Siberian elms, experience has shown that many accessions and individuals have some level of susceptibility to DED.

Crown architecture, perhaps the most important metric trait, is also one of the most difficult to evaluate. The complex geometry of most adult trees, and the complex hybrid nature of new interspecific combinations, makes the prediction of adult form from juvenile characters a most difficult process. Early selections such as ‘Sapporo Autumn Gold’, which appeared to have an “American elm-like form”, did not ultimately realize this form as adults. In fact, it is not at all obvious upon casual inspection how the “frond-like” juvenile form of American elm gives rise to the vase-shaped form so characteristic of the species. The more erect, single -stemmed saplings of most European elm types certainly don’t lead to an American elm form, and only a few Eurasian species seem to bear any resemblance to this unique architecture. We are currently examining the question of Ulmus crown architecture using various hybrid progenies and growth models developed for ecological purposes. The roles of apical dominance and apical control may be important in determining overall crown architecture in elms.

## THE FUTURE OF BREEDING FOR URBAN TREES

There is relatively little that has happened during the past decade that would make anyone optimistic about the long-term prospects for bigger and/or better selection and breeding programs to develop new cultivars for urban tree use. In fact a variety of obstacles to initiating or continuing such programs for any taxa have become even more formidable in recent years. Chief among them are:

- severe shortage of available research funding
- institutional disinterest in supporting long -term “applied” research
- lack of a reward system to encourage young scientists to enter the field
- perception that biotechnology will provide rapid solutions to long -term problems

Despite the obvious difficulties associated with such long-term programs, we believe that there are valuable benefits to be obtained from urban tree breeding and testing programs, including:

- a source of well-characterized germplasm
- opportunities for long-term systematic breeding efforts
- interdisciplinary interaction
- regular release of superior cultivars

It is still something of mystery why tree -breeding programs which

emphasize urban plant materials are such “orphans”. Agricultural commodities enjoy considerable (and growing) support bases for cultivar development, and forest tree breeding programs are alive and well throughout the world. All of these practitioners see the value of long-term breeding programs, so what is wrong with the urban arena? Is something missing from the political or social dimension that makes support difficult to garner, or is the technical support or commercial interest lacking?

We have no magic formula for overcoming these difficulties. Perseverance and commitment to a long-term program are still required. A vision of beautiful trees gracing urban boulevards also helps to inspire further testing. But perhaps the most important motivation of all is the fascination of nurturing a new array of progenies through the screening process in the expectation of discovering a truly superior tree.

#### AVAILABILITY

The elm cultivars listed in Table 1 are currently (or will be soon) available from breeding programs and/or selected commercial nurseries. Inquiries about ‘Sapporo Autumn Gold’, ‘Regal’ and ‘New Horizon’ elms should be direct to McKay Nursery Company, Waterloo, WI **53594**; about ‘American Liberty’ to the Elm Research Institute, Harrisville, NH 03450; about ‘Homestead’ and ‘Pioneer’ Elm to J. Frank Schmidt and Son, 9500 SE 327th Avenue, Box 189,

Boring, OR 97009; about ‘Urban’ elm to Lake Co. Nursery Exchange, 5052 S. Ridge Road, Perry, OH 44081; about ‘Dynasty’ elm to Dr. Frank Santamour, U.S. National Arboretum, 3501 New York Avenue, N.E., Washington, DC 20002; about ‘Accolade’ and ‘Danada’ elms to Dr. George Ware, Morton Arboretum, Lisle, IL 60532; and about various Dutch clones to the Princeton Nurseries, Princeton, NJ 08540.

#### REFERENCES FOR TABLE 1

- Heybroek, H. 1983. Resistant elms for Europe. In: Research on Dutch elm disease in Europe (D.A. Burdekin, Ed.), For. Comm. Bull. #60, pp. 108-113.
- Smalley, E.B. and D.T. Lester. 1973. ‘Sapporo Autumn Gold’ elm. HortScience 8:514-515.
- Smalley, E.B. and D.T. Lester. 1983. ‘Regal’ elm. HortScience 18:960–961.
- Smalley, E.B. Unpubl.
- Smalley, E.B. and D.T. Lester. 1990. ‘American Liberty’ elms. Manuscript prepared.
- Schreiber, L.R. and H.V. Main. 1976. ‘Urban’ elm. HortScience 11:517-518.
- Townsend, A.M. and W.O. Masters. 1984. ‘Pioneer’ elm. HortScience 19:900.

Townsend, A.M. and W.O. Masters.  
1984. 'Homestead' elm.  
HortScience 19:897-898.

Ware, George. 1986. Personal  
communication.

Santamour, F.S. 1984. 'Dynasty' elm.  
HortScience 19:898-899.

Table 1. Summary of named elm cultivars suitable for use in hardiness zones 3-5 and currently (or soon) available from selected nurseries.

Name	Program	Year Released	Parentage	Resistance to DED	Hardiness Zone	Reference
Sapporo Autumn Gold	WI	1973	pumila x japonica	excellent	3	1
Regal	wI	1984	'Commelin' x (pumila x carpinifolia)	very good	4-5	2
New Horizon	WI	1990	japonica x pumila	excellent	3	3
American Liberty	WI	1986	american x american	good <sup>1</sup>	3	4
Urban	USDA	1976	('Vegeta' x carpinifolia) x pumila	very good	4-5	5
Pioneer	USDA	1984	glabra x carpinifolia	very good	5	6
Homestead	USDA	1984	pumila x ['Commelin' x (pumila x carpinifolia)]	excellent	4-5	7
Dynasty	USDA	1984	parvifolia	good	5	8
Accolade	Morton	1987	japonica x wilsoniana	very good	4-5	9
Denada	Morton	1987	(japonica x wilsoniana) x open-pollinated	very good	4-5	9
Lobel	Dutch	1973	('Exoniensis' x wallichiana) x 'Bea Schwarz' selfed	good	5	10
Dodoens	Dutch	1973	('Exoniensis' x wallichiana) x open pollinated	good	5	10
Groenveld	Dutch	1963	glabra x carpinifolia	fair	5	10

<sup>1</sup>Mature Plant Resistance

