VARIATION IN ELM LEAF MINER INJURY ON ELMS IN WISCONSIN[1]

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ABSTRACT -- Elm leaf miner *(Fenusa ulmi)* injury was assessed on thirty elm accessions in Wisconsin during 1992. Foliar injury was most severe for several Eurasian elms *(Ulmus glabra, U. procera, U. laciniata)* and *U. rubra* from the north central U.S. A second group of elms, including *U. japonica* and *U. carpinifolia.* appeared to be somewhat resistant to injury. A third group of elms *(U. americana, U. thomasii, U. parvifolia* and *U. pumila)* were essentially completely resistant to elm leaf miner injury. Various interspecific elm hybrids sustained some leaf damage, with those having one *U. parvifolia* parent being comparable to the best species. Those hybrids with at least 50% *U. glabra /U. wallichiana* parentage sustained considerable injury. However, variation among provenances of susceptible species provides opportunities for selection of resistant parents for hybrid breeding programs.

Elm leaf miner, *Fenusa ulmi* Sundevall (Hymenoptera: Tenthridinidae), a pest of elms during late spring and early summer, was apparently introduced to North America from Europe during the latter part of the 19th century. First reported on Camperdown elms near Albany, New York, Felt (1898) described elm leaf miner on "...English, Scotch and American species . . . nearly destroyed by this insect, and many others presented a sorry appearance on account of the numerous mines." Elm leaf miner subsequently expanded its range to the northeastern U. S., southeastern Canada, and the Lake States (Slingerland 1905, Smith 1971, and others). Closely related to the birch leaf miner *(Fenusa pusilla)* and other sawflies, the larvae overwinter in cocoons in the soil and emerge as adults in early spring. Females deposit eggs in expanding foliage, with larvae appearing in seven to ten days to consume tissue between the upper and lower leaf surfaces. As elm leaf miner has only one generation per year, foliage produced after early June typically is undamaged.

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Beginning about 10 years ago, we observed elm leaf miner injury on various wild and cultivated elms in south central Wisconsin. Never more than a minor nuisance in the past, foliage injury has increased recently and damage is conspicuous in many parts of Wisconsin today. One accession of European mountain elm *(Ulmus glabra* Huds.) from Norway is almost completely defoliated each spring. Other provenances of U. *glabra* are slightly less susceptible, while smooth-leaved elm (U. *carpinifolia* Gled.) appears more resistant. The native slippery elm (Ulmus *rubra* Muhl.) also experiences significant injury each year, while American elm (U. *americana* L.) and rock elm (U. *thomasii* Sarg.) show little or no injury. Early reports from New York by Felt (1898) and Slingerland (1905) indicated that European elms were the initial hosts, where "... it blisters and kills the leaves and thus far works almost entirely on English elms . . . and Scotch elms, including Camperdown elm" (Slingerland 1905). Thus, resistance to elm leaf miner injury appears to be species and/or provenance specific with introduced cultivars of U. *glabra* and U. *procera* Salisb. as the primary hosts.

Many interspecific elm hybrids in our Wisconsin trials appear to be intermediate in terms of leaf miner damage, while others with varying degrees of *U. glabra* parentage have greater or lesser degrees of injury. However, evidence regarding susceptibility or resistance of elms and their hybrids to elm leaf miner is largely anecdotal and no quantitative comparisons of injury have been published. Host suitability of elms for elm leaf beetles *(Xanthogaleruca luteola),* an exotic pest introduced into the U. S. during the 1830's recently was assessed in Ohio (Hall et al. 1987). Elms native to Eurasia were generally preferred over North American species by elm leaf beetles, while hybrids between Eurasian and North American species appear somewhat intermediate in suitability (Hall et al. 1987).

We have compared levels of elm leaf miner injury among selected elm species, and a set of hybrids which vary in terms of parentage of putatively resistant species, as one consideration in choosing elm breeding stock, and as an aid to recommending cultivars in areas subject to elm leaf miner injury.

ELM ACCESSIONS AND MEASUREMENT METHODS

Foliage was sampled from l-3 trees per accession for 30 elm species and interspecific hybrids (Table 1) growing in our breeding arboretum at the Arlington Research Station (Columbia Co., WI), or at one trial location in Dane Co., WI. Thirteen accessions were *U. glabra*, or hybrids with some *U. glabra* parentage. Long shoots were collected from the mid-crown position on the same date during the second week of June, 1992. By this date some leaves on susceptible trees were completely consumed except for the leaf surfaces. Newly expanded foliage showed no evidence of infestation suggesting that damage was at or near a maximum for the season.

The third and fourth fully expanded leaves distal from the apex were removed from the shoot and total leaf surface area (mined and unmined) was estimated (nearest 0.1 cm^2) using an LI-3100 leaf area meter (Licor Co., Lincoln, NE). The mined portion of each leaf was then carefully removed from injured leaves using razor knives, followed by remeasurement of leaf surface area. The difference between the two measurements represents the approximate area of each leaf consumed by leaf miners. To account for variation in leaf size among trees, data were expressed as the percentage of foliage not mined. Leaves from four shoots (total of eight leaves) were measured for each species or clone.

Percentages were transformed using the arcsine-square root transformation to normalize data prior to analysis of variance (General Linear Model Procedure of the Statistical Analysis System [SAS]), followed by a comparison of means using the Least Significant Differences (LSD) procedure. Values reported (Table 1) are mean percentages of unmined leaf area expressed on a per accession basis.

Accession	Origin	Non-mined foliage (%)	
#2224	U. parvifolia x pumila	0	a
U. pumila	China	0	a
U. parvifolia	Korea	0	a
U. americana	North central U.S.	0.4	a
U. americana	Central U.S.	0.9	ab
#2245	U. parvifolia x americana	2.8	abc
#2227	U. parvifolia x glabra	3.3	abcd
U. thomasii	North central U.S.	3.8	abcd
'Cathedral'	U. pumila x japonica	5.0	abcd
U. glabra	Spain	6.9	abcde
U. carpinifolia	Europe	7.4	abcde
'Sapporo AG'	U. pumila x japonica	8.2	abcd
'Commelin'	'Vegeta' x carpinifolia	8.4	abcde
'Belgica'	U. x hollandica	11.0	bcdef
U. japonica	Japan	12.6	cdefg
'Pioneer'	U. glabra x carpinifolia	16.5	defg
U. carpinifolia	Spain	18.1	defg
#701	U. laciniata x pumila	20.1	efg
'N260'	'Vegeta' x pumila	25.0	fgh
U. rubra	North central U.S.	27.3	fgh
'Plantyn'	[glabra x wallich.] x carp.	28.6	fgh
U. laciniata	China	32.6	ghi
'Lobel'	[glabra x wallich.] x Bea Sch	34.5	ghi
'Regal'	Commelin x [carp x glab]	35.3	ghi
U. glabra	Europe	43.0	hij
U. procera	Great Britain	43.9	ijk
'Dodoens'	[glabra x wallich.] x OP	53.3	ijk
'Vegeta'	U. x hollandica	61.1	jk
U. glabra	Norway	62.5	k

Table 1. Elm accessions and origins, percentage of leaf samples not mined, and LSD t groupings for elm leaf miner in Wisconsin, 1992. Mean values of non-injured foliage followed by the same letter are not significantly different at P = 0.05 level.

SPECIES DIFFERENCES IN ELM LEAF MINER INJURY

Differences in leaf miner damage among the 30 elm accessions assessed during 1992 were highly significant as revealed by analysis of variance (Pr>F = 0.0001; 29 df), but variance estimates were large (Table 1) given leaf-to-leaf variation. Thus, several groups of accessions have overlapping LSD "t groupings"; within any one group, differences are not statistically significant even though differences in percentages of undamaged foliage appear large. Larger sample sizes might not reduce variances because phenological differences among accessions makes choice of an arbitrary leaf position (e.g. third or fourth leaf) a source of variation in damage estimation. Alternatively, choice of the most severely damaged leaf per shoot would adjust for developmental differences, but also lead to "worst case" estimates.

Chinese elm (U. *parvifolia* Jacq.), Siberian elm (U. *pumila* L.), American elm and rock elm were essentially completely resistant to elm leaf miner injury (Table 1; Figure 1). Any injury detected in these species was typically superficial, with only small translucent spots or "blisters as evidence that a miner began feeding. One accession each of U. g1abra and U. *carpinifolia* were included with this most resistant group, but these two accessions are not significantly different from U. *japonica* [(Rehd.) Sarg.] and several hybrids considered to be moderately resistant (Table 1).

Japanese elm and smooth-leaved elm appear to be somewhat resistant to elm leaf miner injury (Table 1; Figure l), but evidence of some leaf miner injury can frequently be detected on most accessions. However, injury is often inconspicuous. Casual observation of some Japanese elm accessions suggests that many may be as resistant as rock elm or American elm. A more systematic evaluation of *U. japonica* accessions would be required to document this.

Figure 1. Variation among elm species in resistance to elm leaf miner injury in Wisconsin, 1992.

Four species, including European mountain elm *(U. glabra)*, red elm *(U. rubra Muhlenb.)*, English elm *(U. procera*)and *U. laciniata* [(Trautv.) Mayr] appear relatively susceptible to elm leaf miner injury (Table 1; Figure 1). For *U. glabra,* the Norwegian provenance was the most heavily damaged accession examined (63% injury), but a second provenance from northwest Spain was at least as resistant to elm leaf miner as Japanese elm, smooth-leaved elm or several hybrids with Siberian elm parentage. We did not conduct an exhaustive survey of our *U. glabra* accessions, but it is clear that even for species with moderate to high levels of susceptibility, at least some accessions are moderately resistant (Figure 2).

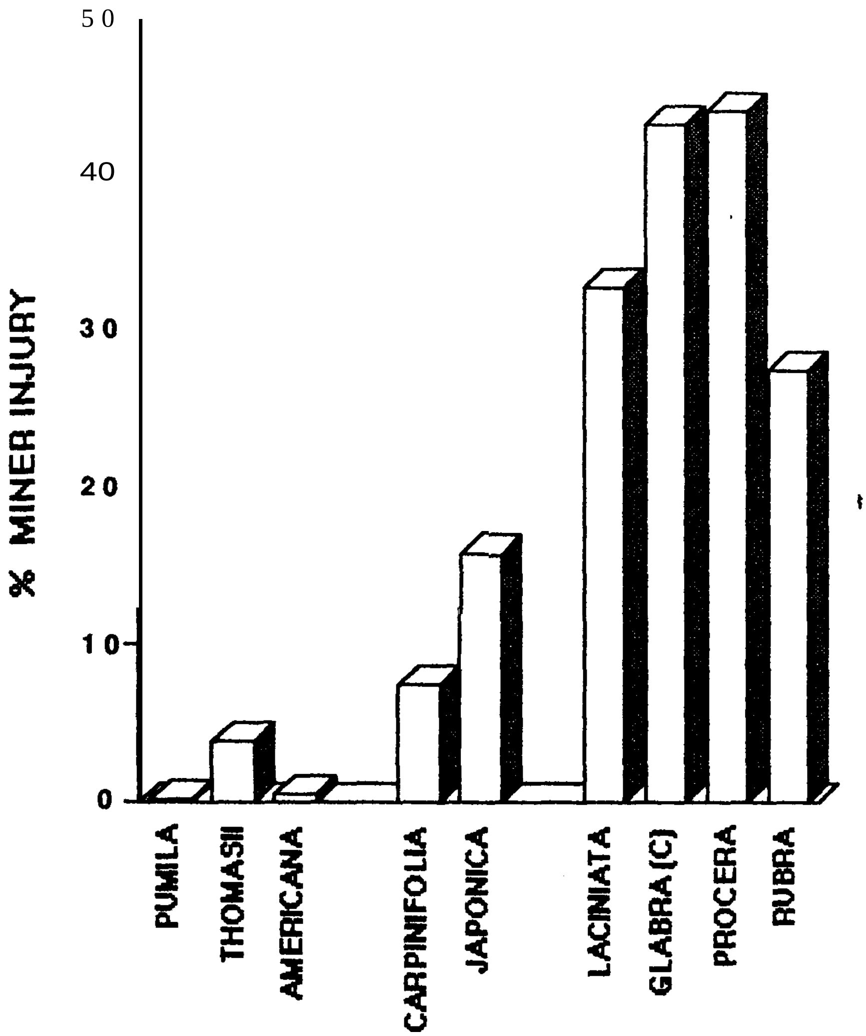
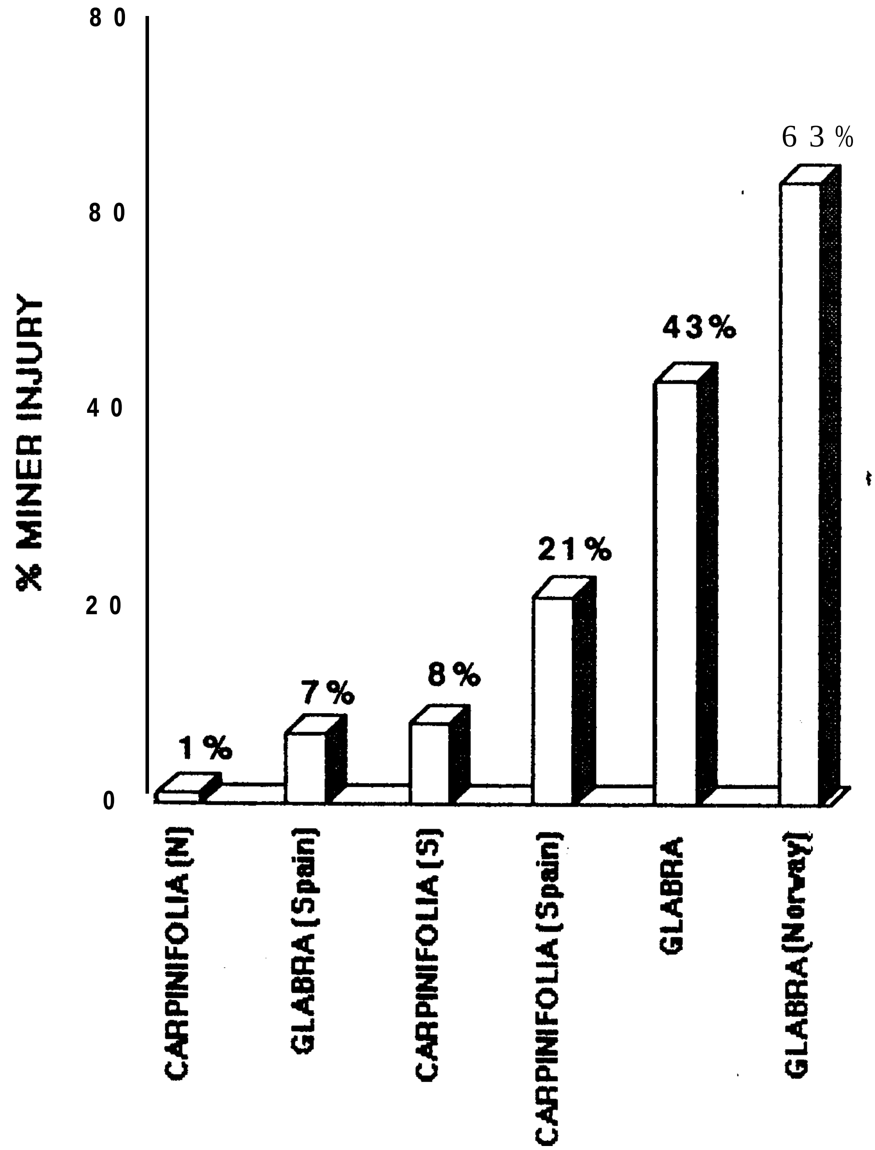

% MINER INJURY
50
40
30
20
10
0
PUMILA
THOMASII
AMERICANA
CARPINIFOLIA
JAPONICA
LACINIATA
GLABRA (C)
PROCERA
RUBRA

Figure 2. Variation among different accessions of *U. glabra* and *U. carpinifolia* in resistance to elm leaf miner injury during 1992.

Many provenances of *U. glabra* are not hardy in Wisconsin, so an extensive evaluation of elm leaf miner injury in *U. glabra* was not possible.

English elm (*U. procera)* was almost as susceptible as *U. glabra,* while *Ulmus carpinifolia* was generally more resistant. Three different accessions of *U. carpinifolia* ranged from l-21% injury, with the Spanish accession being the most susceptible (Table 1; Figure 2). *Ulmus rubra* was also susceptible to elm leaf miner injury, confirming a casual observation we have made many times in rural areas of south central Wisconsin. Although not as severely



80
80
40
20
0
% MINER INJURY
1%
7%
8%
21%
43%
63%
CARPINIFOLIA (N)
GLABRA (Spain)
CARPINIFOLIA (S)
CARPINIFOLIA (Spain)
GLABRA
GLABRA (Norway)

defoliated as some U. *glabra* accessions, leaf miner injury is so widespread on red elm in southern Wisconsin that distinguishing between U. *americana* and U. *rubra* is remarkably easy for about 2 months of the year. Wild elms with leaf miner injury in Wisconsin invariably prove to be red elms upon close inspection.

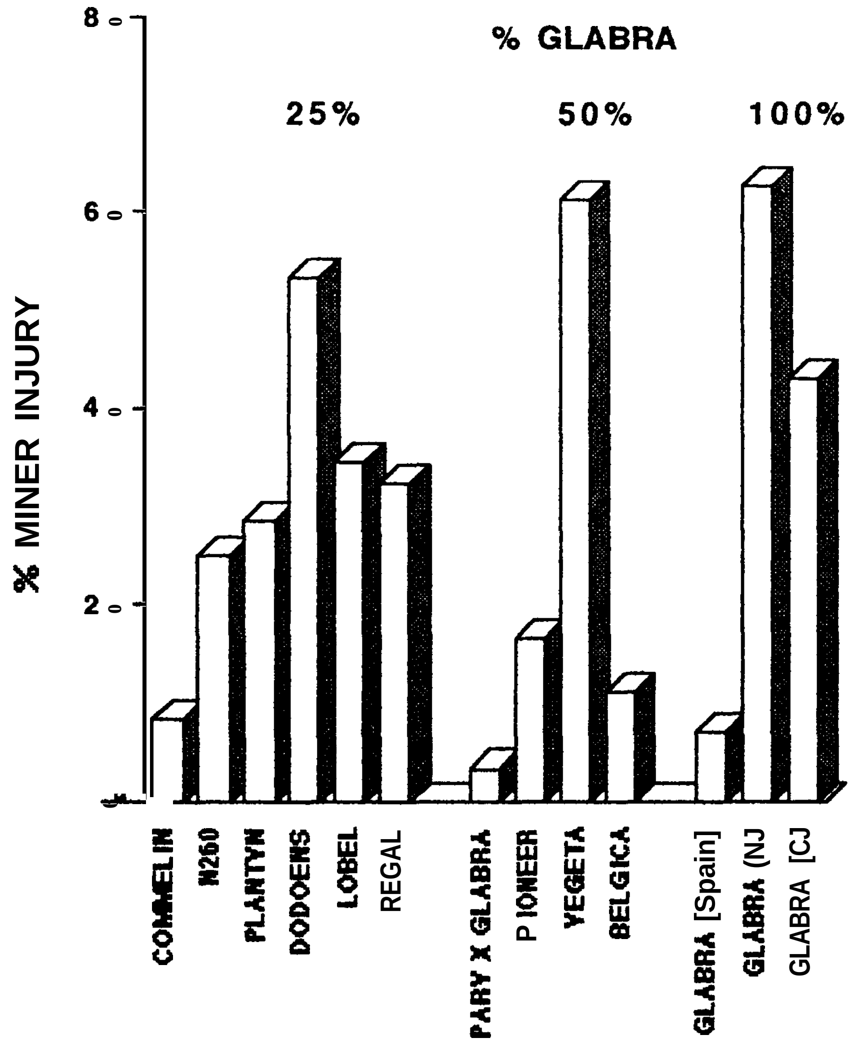
HYBRID DIFFERENCES IN ELM LEAF MINER INJURY

We expected that hybrids with U. *glabra* would be more susceptible to elm leaf miner than other Eurasian hybrids and to some extent this is true, but variation among hybrids with comparable proportions of U. *glabra* parentage is quite large (Figure 3). For example, the old cultivar 'Vegeta' (*U. x hollandica)*, a putative U. *glabra x U. carpinifolia* hybrid, was almost as susceptible to leaf miner damage as the Norwegian accession of *U. glabra,* while 'Belgica' also a "hollandica" selection, appears considerably more resistant. Undoubtedly, the multiple origins of *U. x hollandica* involved an array of *U. glabra x U. carpinifolia* hybrids which gave rise to numerous "hollandica" cultivars with varying degrees of elm leaf miner susceptibility.

Several Dutch cultivars of recent origin including 'Dodoens', 'Plantyn', and 'Lobel' were also very susceptible to elm leaf miner injury (Figure 3), and all three share a common ancestry which includes one *U. glabra* grandparent and one *U. wallichiana* grandparent (Heybroek 1983). We suspect that Himalayan elm may be somewhat susceptible to elm leaf miner, but we cannot confirm this as *U. wallichiana* (native to India) is marginally hardy in the north central U.S. 'Regal' elm, a complex hybrid with 25% *U. glabra* germplasm appears about equally susceptible to elm leaf miner as these Dutch cultivars.

Figure 3. Variation in resistance to elm leaf miner injury among selected elm hybrids/cultivars with varying proportions of *U. glabra* parentage, and several *U. glabra* accessions.

A second set of hybrids with some *U. glabra* parentage appears more resistant than those named above, and includes 'Pioneer', a recent USDA hybrid between *U. glabra x U. carpinifolia,* 'Belgica' an old U. x hollandica selection (presumably closely related to 'Vegeta'?) , 'Commelin', a complex Dutch hybrid containing 25% *U. glabra,* and a recent *U. parvifolia x U. glabra* hybrid created at Wisconsin (Figure 3). This last hybrid presumably owes its elm leaf miner resistance to its Chinese elm parent, a species observed to be highly resistant. Likewise, the 'Commelin' elm has one Siberian elm parent, a level sufficient to confer resistance. The higher resistance of 'Pioneer' and 'Belgica' relative to 'Vegeta' could be due to variation between accessions and/or individuals of either or both of the parental species, *U. glabra* and *U. carpinifolia.* However, it is clear that no consistent relationship exists between the



% GLABRA
25%
50%
100%
% MINER INJURY
8
6
4
2
COMMELIN
N260
PLANTYN
DODOENS
LOBEL
REGAL
PARY X GLABRA
PIONEER
VEGETA
BELGICA
GLABRA [Spain]
GLABRA (NJ
GLABRA [CJ

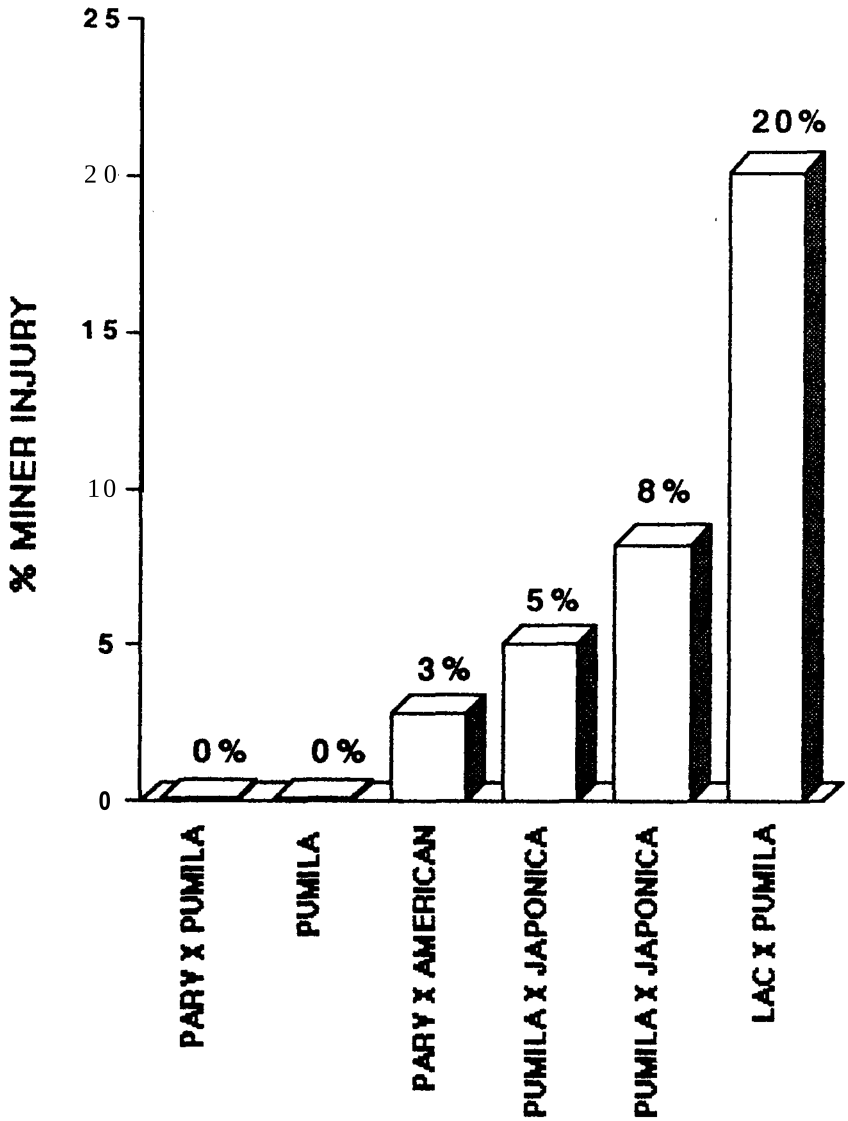
proportion of *U. glabra* parentage and elm leaf miner injury. The particular accession of *U. glabra* which served as a parent, together with the level of resistance confered by the other parent, must both be considered in evaluating leaf injury.

A final group of hybrids was essentially as resistant as the most resistant species and included 'Sapporo Autumn Gold' and 'Cathedral' elms (both *U. pumila x U. japonica* hybrids), and three recent hybrids created at Wisconsin which share a common Chinese elm mother but with *U. americana, U. pumila* and *U. glabra* pollen parents (Figure 4). The high resistance to elm leaf miner is not surprising for the hybrids with American and Siberian elm parents as both are quite resistant as species. However, we were surprised to note that *U. glabra* in combination with *U. parvifolia* was about as resistant as other Chinese elm hybrids. This suggests that one highly resistant parent, even in combination with a susceptible parent, can confer high levels of elm leaf miner resistance on progeny. This also appears true for Siberian elm as the hybrids with *U. japonica,* a species moderately resistant to elm leaf miner injury, appear to be highly resistant.

Figure 4. Variation among selected *U. parvifolia* and *U. pumila* hybrids in resistance to elm leaf miner injury during 1992.

ELM LEAF MINER INJURY AND TAXONOMIC GROUPINGS

The most resistant species to elm leaf miner injury are included in the Sections Blepharocarpus *(U. americana),* Chaetoptelea *(U. thomasii),* and Microptelea *(U. parvifolia).* All the remaining species considered here are included in the Section Madocarpus (= Ulmus), but divided into two subsections. The most susceptible elms are included in Schneider's (1916) subsection Glabrae, including *U. glabra, U. procera, U. laciniata* and ***U. rubra.*** A second group of Section Madocarpus elms (subsection Foliaceae) include species with moderate ***(U. japonica, U.carpinifolia)*** or high *(U. pumila)* resistance to elm leaf miner injury. Other measures of taxonomic affinity such as that based on cpDNA analysis (Wiegrefe 1992)


% MINER INJURY
25
20
15
10
5
0
0%
0%
3%
5%
8%
20%
PARY X PUMILA
PUMILA
PARY X AMERICAN
PUMILA X JAPONICA
PUMILA X JAPONICA
LAC X PUMILA

provide classifications which do not correspond with Schneider's (1916) groups, and which change slightly the above groupings. We do not endorse any particular classification scheme for the Section Madocarpus, and we recognize that the placement of some elms into different sections, sub-sections and series remains controversial (Heybroek 1976, Richens 1980, 1983, Wiegrefe 1992). We merely point out that at least some taxonomic treatments of elms provide groupings of species which correspond rather well to differences in resistance or susceptibility to elm leaf miner observed here. Alternative classification schemes would modify slightly the pattern shown in Table 2, but all of the most susceptible species would remain in a single section of the genus.

Species	Origin	Section (Subsection)	Susceptibility
U. parvifolia	Korea	Microptelea	Low
U. americana	U.S.	Blephocarpus	Low
U. thomasii	U.S.	Chaetoptelea	Low
U. rubra	U.S.	Madocarpus(Glabrae)	High
U. glabra	Europe	" "	High
U. laciniata	China	" "	High
U. carpinifolia	Europe	" (Foliaceae)	Medium
U. japonica	Japan	" "	Medium
U. pumila	China	" "	Low
U. procera	Europe	" "	High

Table 2. Sectional classification of elms and general susceptibility to elm leaf miner injury in Wisconsin.

While some taxonomic groupings appear to coincide with apparent resistance or susceptibility to elm leaf miner injury, these associations do not suggest a mechanism for resistance to elm leaf miner. Even the far better studied birch leaf miner (*Fenusa pusilla*) offers no clues in this regard, and no evidence as to the possible chemical, anatomical or phenological basis for species differences was noted in any published literature. We also note that ecological adaptation rather than phylogenetic origin may better account for any differences in observed susceptibility to elm leaf miner. *Ulmus glabra* and *U. laciniata,* both susceptible species, occupy similar "mountain niches" in Europe and Asia respectively, while *U. carpinifolia* and *U. japonica,* both moderately resistant, occupy similar "field niches". These ecological positions are associated with a suite of morphological traits as noted by Heybroek (1976) and Richens (1980), and suggest that any differences among species in terms of elm leaf miner preference may be related to adaptations involving ecological phenomena.

Finally, we note that one earlier comparison of elm host suitability to elm leaf beetle bears some resemblance to our study. Hall et al. (1987) found that elms which were less suitable for elm leaf beetle included those of Sections Blephocarpus, Microptelea and Chaetoptelea, while the most suitable species were members of Section Madocarpus, particularly *U. pumila, U glabra , u. laciniata* and *U. procera,* all members of Section Madocarpus.

In terms of recommendations for elm cultivars which are unlikely to experience significant levels of elm leaf miner injury, virtually any hybrid with *U. parvifolia* parentage should be highly resistant. *Ulmus japonica x pumila* (or reciprocal) hybrids such as 'Sapporo Autumn Gold' or 'New Horizon' also appear uninjured. Most Dutch cultivars, especially those with *U. wallichiana* or *U. glabra* parentage such as 'Dodoens', 'Plantyn' or 'Lobel' may not be good choices. Other hybrids with *U. carpinifolia/U. glabra* combinations such as 'Pioneer' are less predictable and likely should be tried to verify resistance or injury levels.

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