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Evaluation of Eleven Newly Acquired Asian Elms for Their Suitability to Adult Elm Leaf Beetle (Coleoptera: Chrysomelidae)[1]

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Abstract

Eleven newly introduced Asian elm species and one reference species were evaluated in no-choice laboratory bioassays for their suitability to the adult elm leaf beetle, *Xanthogaleruca* (= *Pyrrhalta*) *luteola* Müller. Adult female beetles laid significantly more eggs on *U. bergmanniana*, *U. bergmanniana* var. *lasiophylla*, *U. castaneifolia*, *U. gaussenii*, *U. lamellosa*, and *U. pumila*, indicating these species were the most suitable for ELB. The least suitable species for adult beetle feeding and reproduction were *U. chenmoui*, *U. elongata*, *U. glaucescens*, *U. propinqua*, *U. propinqua* var. *suberosa*, and *U. szechuanica*. Adult female beetles laid eggs within 7–10 days, or 4 days earlier, on the most suitable elms compared with beetles feeding on the least suitable elms. Adult male and female longevity was significantly affected by host suitability with adult males and females living nearly twice as long on the most suitable elms compared to the less suitable elms. Least suitable species *U. chenmoui*, *U. elongata*, *U. glaucescens*, *U. propinqua*, and *U. szechuanica* offer resistance to elm leaf beetle and show promise for future elm breeding programs.

Index words: Dutch elm disease, suitability, resistance, preovipositional period, longevity, urban trees, *Ulmus* spp, leaf beetles.

Species used in this study: *U. bergmanniana* Schneider; *U. bergmanniana* var. *lasiophylla* Schneider; *U. castaneifolia* Hemsley; *U. chenmoui* Cheng; *U. elongata* L.K. Fu et C.S. Ding; *U. gaussenii* Cheng; *U. glaucescens* Franchon; *U. lamellosa* C.Wang et S.L. Chang et L.K. Fu; *U. propinqua* Koidiez; *U. propinqua* var. *suberosa* Koidiez; *U. szechuanica* Fang; and *U. pumila* L.

Significance to the Nursery Industry

The research project reported here evaluated the suitability of 11 different newly acquired Asian elm species and one reference species for adult elm leaf beetle development. The elm leaf beetle, *Xanthogaleruca* (= *Pyrrhalta*) *luteola* Müller can be a serious pest of elm species in urban landscapes nationwide. *Ulmus chenmoui*, *U. elongata*, *U. glaucescens*, *U. propinqua*, *U. propinqua* var. *suberosa*, and *U. szechuanica* appear to have low suitability for the elm leaf beetle. In other studies, a majority of these same elm species have shown poor suitability for the adult Japanese beetle and elm leafminer, both potentially damaging insect pests of elms. In addition as a group, Asiatic elms appear to be resistant to Dutch elm disease (DED). Identification of elm biotypes resistant to DED as well as the elm leaf beetle (ELB), will be a critical component in a plant health care (PHC) strategy for this and other leaf-feeding insect pests of elm. This wealth of elm genotypes provides a rich source of genetic material for future elm breeding programs, which could result in elms resistant to both DED and defoliating insect pests, thus significantly reducing or perhaps eliminating the need for insecticidal and fungicidal treatments.

Introduction

The elm leaf beetle, *Xanthogaleruca* (= *Pyrrhalta*) *luteola* Müller, introduced into the eastern United States from Europe in the 1830s, is found wherever elms grow. This beetle is considered a major pest, particularly in areas where a large proportion of the urban forest and landscape contains the preferred host *U. pumila* (Siberian elm).

United States Department of Agriculture genetic improvement programs on elms have concentrated on disease resistance in the past (23). More recently, extensive breeding and selection programs have focused on insect-resistant trees for forest and landscape use (1, 2, 3, 4, 12, 13, 19, 20, 21, 22, 23). Previous efforts have focused on the resistance of various elms species and their hybrids for feeding by the elm leaf beetle (6, 7, 8, 9, 14, 15, 16, 17, 26). In all of these studies, suitability is defined as the mean number of eggs laid per female and mean percent of females ovipositing in no-choice feeding studies. In particular, Asian elms appear to have high levels of resistance to Dutch elm disease, elm leafminer, *Fenusa ulmi* Sundevall, and elm yellows (10). Additional information is needed on resistance to these or other insects and diseases as well as to the elm leaf beetle.

Recent acquistions of seeds of little-known elm species from China have made possible significant enlargement and enhancement of the Elm Collection at The Morton Arboretum, Lisle, IL, and are providing opportunities for evaluating and testing these elm species as urban trees (5). More recent additions include *U. bergmanniana*, *U. bergmanniana* var. *lasiophylla*, *U. castaneifolia*, *U. chenmoui*, *U. elongata*, *U. gaussenii*, *U. glaucescens*, *U. lamellosa*, *U. propinqua*, *U. propinqua* var. *suberosa* and *U. szechuanica* (24, 25) (Table 1).

A recent study (18) revealed that several of the above biotypes were less suitable for and less preferred by Japanese beetles. However, very little is known about the resistance of these species to elm leaf beetle, and other elm defoliating insects such as the elm leafminer, spring cankerworm, *Paleacrita vernata* (Peck), and fall cankerworm, *Alsophila pometaria* (Harris).

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Our objective was to conduct an initial screening of eleven newly acquired Asian elm species and one reference species to evaluate their suitability for adult elm leaf beetle development. This research will support the development of elm hybrids as part of a comprehensive breeding program for resistance to Dutch elm disease and to feeding by the elm leaf beetle and elm leafminer.

Materials and Methods

No-choice laboratory bioassays. No-choice laboratory feeding assays were conducted on second generation (late July-early August) adult elm leaf beetles during the 1995 growing season. Eleven Asian elm tree species and one reference species evaluated in this study were *U. bergmanniana*, *U. bergmanniana* var. *lasiophylla*, *U. castaneifolia*, *U. chenmoui*, *U. elongata*, *U. gaussenii*, *U. glaucescens*, *U. lamellosa*, *U. propinqua*, *U. propinqua* var. *suberosa*, *U. szechuanica*, and *U. pumila*, Siberian elm (control), a favored host of the elm leaf beetle. Candidate elm species are growing at The Morton Arboretum, Lisle, IL, and range from a height of 3–5 m (9–15 ft) and diameters at breast height of 5–10 cm (2–4 in).

Leaves for the bioassay tests were randomly collected from test trees at ground level from all 4 cardinal directions and held in cold storage in plastic bags at 5C (40F) for a maximum of 3 days. The leaf samples included the terminal 31 cm (12 in) of elm branches. Only fully expanded leaves were used. Leaf samples were taken in this way to control for variation in leaf quality within trees. Leaves from individual trees were kept separate and beetles were randomly assigned to dishes for the no-choice laboratory study. Five individual trees of each species were evaluated.

Adult beetles used in the no-choice study emerged from field-collected third instars and pupae shipped overnight from sites in and around Holbrook, AZ, and Albany, CA. Upon arrival in Illinois, the pupae were sexed and held under a photoperiod of 16:8 (L:D) h at ~25C (76F). Beetles from both sources were randomly assigned to the petri dishes, for all biotypes tested.

For each study tree, a pair of newly emerged, unfed adult beetles (one male, one female) was placed in each of 10 plastic petri dishes (0.6 × 10.0 cm) with foliage. Petri dishes were examined daily for evidence of feeding, onset of oviposition, fecundity, and beetle mortality. Foliage was replaced every 2 days. Females and males that died within the first 3 days were replaced with newly emerged, unfed adult female and male beetles to ensure that healthy beetles had an opportunity to feed on test elms. Petri dishes were placed in clear plastic bags to prevent drying of the foliage and were held under a photoperiod of 16:8 (L:D) h at ~25C (76F). Condensation of water on the lid of the petri dish indicated a high relative humidity. Each of the 5 trees of each species was assayed with 10 pairs of beetles.

Mean number of eggs laid per female was calculated by totaling all eggs laid by each adult female in each individual petri dish within a given biotype during the 21 day study and dividing by the number of females in the study. We also determined the overall percentage of females that oviposited on each species, and the mean preovipositional period. Male and female longevity from the date that the beetles were introduced to the candidate foliage was also determined. The measure of suitability for each species was defined by the mean number of eggs laid per female and the mean percentage of females ovipositing.

Statistical analysis. Measures of suitability, mean eggs laid per female, mean percentage of females ovipositing, mean preovipositional period, male longevity and female longevity were subjected to Analysis of Variance (ANOVA) using species as the main effect. We tested for homogeneity of variances. Non-homogenous variances were transformed prior to analysis. Proportion of females ovipositing on each tree were arcsin transformed before analysis to correct for non-normality. Means of significant effect were compared with Student-Newman-Keuls (SNK) multiple comparison test. A coefficient of correlation was calculated for the ranking for the mean percentage of females ovipositing with the ranking for the mean number of eggs laid per female. All data are presented as means ± SEM. Data were analyzed using the SigmaStat for Windows (11).

Results and Discussion

There were significant differences among the twelve elm biotypes for the mean number of eggs laid per female and the mean percentage of females ovipositing (Table 2). Adult female beetles laid significantly more eggs on *U. bergmanniana*, *U. bergmanniana* var. *lasiophylla*, *U. castaneifolia*, *U. gaussenii*, *U. lamellosa*, and *U. pumila* (reference) compared to the remaining six elm biotypes. Female beetles laid less than 6 eggs/female on *U. chenmoui*, *U. elongata*, *U. glaucescens*, *U. propinqua*, and *U. szechuanica*. *Ulmus propinqua* var. *suberosa* was intermediate in suitability with 13 eggs laid per female (Table 2).

The ranking for the mean percentage of females ovipositing was significantly correlated ($R^2 = 0.54$; $P = 0.007$) with the ranking for the mean number of eggs laid per female.

Table 1. Origin, mature height, and native growing sites and soils of eleven newly acquired Asian elm species.

Species	Origin	Mature height (m)	Native growing sites and soils
U. bergmanniana	W. Hupei	25	mountain slopes, well–drained soils (500–900 m)
U. bergmanniana var. *lasiophylla*	N/W Szechuan & Yunnan Provinces SE Tibet	25	forests, well–drained soils (2100–3000 m)
U. castaneifolia	W. Hupei & E. Szechuan Provinces	20	broad–leaf forests (500–1600 m)
U. chenmoui	Langya/Paohua Mts.	20	broad–leaf forests on mountains
U. elongata	S. Chekiang & N. Fukien Provinces	30	broad–leaf forests on mountains (250–900 m)
U. gaussenii	Langya Mts., Chuhsien, & Anhui Provinces	25	creeks at base of limestone mts.
U. glaucescens	Northern China	18	tolerant of dry soils
U. lamellosa	N. Hopei Province	10–12	dry soils
U. propinqua	Inner Mongolia N. China	25	grasslands, savanna tolerant of poor soils
U. propinqua var. *suberosa*	W. Heilongjiang Inner Mongolia	25	grasslands/savanna tolerant of poor soils
U. szechuanica	Upper Yangtze River	18	forests

Table 2. Mean (+/–) number of eggs laid per adult female, percent females ovipositing, preovipositional period, male longevity, and female longevity on *Ulmus* species.

	No–choice assays[z]					
Species	N[y]	Mean eggs laid per female	% females ovipositing	Preovipositional period	Male longevity	Female longevity
				days		
U. bergmanniana	5	56 ± 15.5c	60 ± 11.0bc	9 ± 0.5ab	9 ± 0.9b	10 ± 0.9bc
U. bergmanniana var. *lasiophylla*	5	48 ± 13.3c	60 ± 11.0bc	10 ± 1.1ab	8 ± 0.9ab	10 ± 1.0bc
U. castaneifolia	5	67 ± 18.7c	50 ± 10.0bc	8 ± 0.6a	10 ± 0.9b	13 ± 0.9c
U. chenmoui	5	5 ± 2.1a	31 ± 9.0ab	11 ± 0.9b	8 ± 0.8ab	6 ± 0.6ab
U. elongata	5	0 ± 0.0a	0 ± 0.0a	—	5 ± 0.6a	5 ± 0.7a
U. gaussenii	5	51 ± 10.1c	59 ± 9.0bc	9 ± 0.6ab	9 ± 0.7b	9 ± 0.7b
U. glaucescens	5	3 ± 1.3a	31 ± 9.0ab	12 ± 1.4ab	8 ± 0.8ab	8 ± 1.0b
U. lamellosa	5	30 ± 7.7b	79 ± 12.0bc	7 ± 0.3a	7 ± 0.9ab	8 ± 0.8b
U. propinqua	5	0 ± 0.0a	0 ± 0.0a	—	8 ± 1.0ab	5 ± 0.9a
U. propinqua var. *suberosa*	5	13 ± 4.9ab	31 ± 12.0ab	9 ± 0.9ab	8 ± 1.0ab	7 ± 0.7ab
U. szechuanica	5	0 ± 0.0a	0 ± 0.0a	—	4 ± 0.3a	5 ± 0.7a
U. pumila (standard)	5	38 ± 9.8c	94 ± 14.0c	8 ± 0.7a	9 ± 0.9b	9 ± 1.0ab
Significance		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

[z]Values within columns followed by the same letter are not significantly different ($P = 0.05$ Student–Newman–Keuls (SNK) multiple comparsion test). Percentages were arcsine transformed before ANOVA. Data are presented as means ± SEM. Means eggs laid per female, percent females ovipositing, preovipositional period, male longevity, and female longevity are based on 10 male/female pairs of adult beetles for each of five individual trees per species.

[y]Five trees of each species were evaluated.

Ulmus bergmanniana, *U. bergmanniana* var. *lasiophylla*, *U. castaneifolia*, *U. gaussenii*, and *U. pumila* had 50—94% females ovipositing—whereas < 32% of the females laid eggs on *U. chenmoui*, *U. glaucescens*, and *U. propinqua* var. *suberosa*. Females failed to oviposit on *U. elongata*, *U. propinqua* and *U. szechuanica* (Table 2). Hall and Townsend (7), Hall et al. (8), and Miller and Ware (15, 16) report similar mean percentage of females ovipositing on *U. pumila* and *U. szechuanica*.

Highly significant differences were observed for the mean preovipositional period. Females feeding on less suitable elm biotypes laid eggs approximately 4 days later as compared to females feeding on more preferred elm hosts (Table 2).

The effect of elm biotypes on male and female longevity was highly significant. Within a given biotype, males and females lived the same duration (mean = 8 days ± 1–3 days). Both sexes lived the fewest days (mean = 5 days) on *U. elongata*, *U. propinqua*, and *U. szechuanica* indicating these are less suitable hosts for ELB development. Where as they lived twice as long (mean = 10 days) on *U. bergmanniana*, *U. bergmanniana* var. *lasiophylla*, *U. castaneifolia*, *U. gaussenii*, and *U. pumila* (Table 2). Similarly, Miller and Ware (15) found that male and female beetles feeding on *U. szechuanica* lived approximately 5 days and females did not lay any eggs.

In summary, of the eleven elm species and one reference species tested in this study, *U. chenmoui*, *U. elongata*, *U. glaucescens*, *U. propinqua*, *U. propinqua* var. *suberosa*, *and U. szechuanica* are the least suitable elms for ELB development. These species look promising for future elm breeding programs as these species supported the lowest fecundity, percent females ovipositing, and male/female longevity. In addition, *U. elongata*, *U. propinqua*, and *U. szechuanica* did not support egg laying. These species should be considered in programs for developing elm varieties with resistance to the elm leaf beetle.

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