Bagworm Survival and Feeding Preferences as Indicators of Resistance among Maples[1]

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Abstract

The bagworm (*Thyridopteryx ephemeraeformis* (Haworth)) is a polyphagous, native pest of numerous deciduous and evergreen ornamental plants. Bagworm larvae were used to investigate host plant susceptibility among ten species and cultivars of maples that are economically important and commonly encountered in landscapes in the eastern United States. Data analyses from 48-hour choice assays, conducted in the laboratory during 2000 and 2001, indicated that differences existed among maples for bagworm feeding preferences and host plant susceptibility. Results from the 48-hour trials were not as accurate as seasonal no-choice assays, however. No-choice assays during both seasons quantified resistance among maples that limited larval bagworm survival and development. Measurements of larval feeding injury demonstrated resistance in paperbark maple (*Acer griseum* (Franch.) Pax) and trident maple (*A. buergerianum* Miq.) when compared with other maples. Laboratory results were corroborated during 2001 by a no-choice field assay, in which early instar bagworm larvae performed well on the majority of maples. In contrast, paperbark maple and trident maple were resistant to bagworm feeding, while 'Autumn Blaze' Freeman maple (*A.* x *freemanii* E. Murray), a hybrid cross obtained by breeding *A. rubrum* with *A. saccharinum*, showed moderate resistance.

Index words: integrated pest management, IPM, host plant resistance, bagworm, Lepidoptera, Psychidae.

Species used in this study: 'Autumn Blaze' Freeman maple (*Acer* x *freemanii* E. Murray 'Autumn Blaze'); 'October Glory' red maple (*A. rubrum* L. 'October Glory'); 'Autumn Flame' red maple (*A. rubrum* L. 'Autumn Flame'); 'Crimson King' Norway maple (*A. platanoides* L. 'Crimson King'); boxelder maple (*A. negundo* L.); 'Silver Queen' silver maple (*A. saccharinum* L. 'Silver Queen'); 'Legacy' sugar maple (*A. saccharum* Marshall 'Legacy'); hedge maple (*A. campestre* L.); paperbark maple (*A. griseum* (Franch.) Pax); trident maple (*A. buergerianum* Miq.).

Significance to the Nursery Industry

Feeding injury by native bagworm caterpillars has been reported on at least 128 host plants and can cause aesthetic or economic injury on many deciduous and evergreen ornamentals. Resistance among plant genera or species to bagworms is not well understood. Laboratory and field assays of economically important or common landscape maples indicate that significant levels of resistance to bagworm feeding exist. Assays showed that paperbark maple (*Acer griseum* (Franch.) Pax) and trident maple (*A. buergerianum* Miq.) were resistant to bagworm feeding. 'Autumn Blaze' Freeman maple (*A.* x *freemanii* E. Murray), an *A. rubrum* x *A. saccharinum* hybrid, showed moderate resistance. In landscapes with a history of bagworm infestation, susceptible maples can be scouted for bagworm bags in early summer, after larvae have dispersed. Early diagnosis of larval activity will help landscape managers prevent aesthetic injury to susceptible maples.

Introduction

Determinations of plant resistance that are made within a single host-plant genus are frequently limited to observations on the predominant pest species. This may be partly attributed to populations of alternative pests that are not seasonally reliable in nature or that may be difficult to rear. Thus, the number of pest individuals that are available for experimental resistance trials is restricted. The availability of empirical research that allows for the understanding of plant resistance within genera to multiple pest species is still relatively limited. The information gap in host-plant suitability to multiple pests is an important problem that limits the acceptance of integrated pest management programs (3, 11). Once pest- or disease-resistant plants are reliably identified, they can be marketed and incorporated in new landscape installations, or planted to replace dead and dying susceptible ornamental varieties. In turn, the use of pest- and disease-resistant plants is expected to reduce labor and pesticide inputs (11).

The bagworm (*Thyridopteryx ephemeraeformis* (Haworth)), is a native and abundant species of moth (Lepidoptera: Psychidae) that ranges throughout the eastern United States (6, 9). While the bagworm is a key pest of many evergreen ornamental plants in the landscape (16, 17), larvae of bagworms have been observed to feed on more than 128 species of deciduous and evergreen trees and shrubs (6). Larval survivorship and weight are typically greater, and development occurs more rapidly, on evergreen host plants including arborvitae, spruce, cedar, and eastern white pine. However, larvae will achieve reproductive maturity on deciduous hosts, which include maple, oak, black locust, dogwood, ash, buckeye, sycamore, and hawthorn (6, 13, 19). The suitability of several non-traditional host plants, like honeylocust, has also been experimentally demonstrated (1, 13).

Several aspects of the biology and behavior of bagworms can influence host-plant utilization and, consequently, landscape aesthetics and management decisions (4, 5, 9, 10, 18). Wingless, adult female bagworms never leave the bag, which is constructed of silk and organic debris. Female bagworms mate within the bag, oviposit up to 1000 eggs, and die leaving the eggs enclosed within the female exoskeleton to overwinter. Larvae, which hatch and disperse in late May in Tennessee (Klingeman, unpublished data), develop through seven stages, or instars, before pupating and emerging as adults. To emigrate, newly hatched larvae extrude silken strands from labial glands and are wind dispersed. Larvae adrift without a

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bag have been recovered as far as 75 m (245 ft) away from their point of origin (5). Such wind-dispersed larvae have no apparent directional control or choice of landing sites. Upon landing, larvae are subjected to selection and development on host plants of varying suitability. Thus, in landscapes or production systems where bagworm populations are high, injury can be expected among adjacent plants.

A study of feeding by larval gypsy moth (*Lymantria dispar* (L.)) on *Acer* and *Prunus* species revealed a wide range of host plant resistance levels and a need to screen ornamental cultivars (14). Although host preference discrimination has been demonstrated by bagworms offered 23 juniper cultivars (8), variability in larval bagworm feeding preferences among cultivars or species of related plants has not been thoroughly investigated. The objective of this research was to determine if bagworms could be used to investigate host-plant suitability among several economically important or environmentally common maples.

Materials and Methods

A comparison of host suitability for bagworms of maple species and cultivars, emphasizing those that are economically important in the nursery trade or which are commonly found in the landscape, was undertaken in 2000 and 2001 (Table 1). Laboratory assays and a field trial utilized maples from a collection of mature trees grown in landscape rows at the Tennessee State University Nursery Research Station in McMinnville, TN (35°41' N × 85°46' W). Maple trees were installed in replicated field rows in 1992, in conjunction with cultivar evaluations for USDA plant hardiness zone 7 (21). Trees were planted on 3.0 m (10 ft) centers with 3.7 m (12 ft) between rows. Pesticides and fungicides had not been applied to the trees since planting. Herbicides were used seasonally as needed within rows to control weeds.

Larval host preference among maples was investigated through choice and no-choice laboratory assays during 2000 and 2001. A no-choice, caged field assessment was undertaken in 2001. Choice and no-choice trials in the laboratory were conducted using a 11.5 mm (0.45 in) diameter cork borer to cut maple leaf disks. For the choice trials, 50 newly-hatched bagworm larvae were released into the center well of a 28.5 cm (11.25 in) diameter Caterware® Eclipse® disposable serving tray (Pactive, Lake Forest, IL) that served as an experimental arena. Unrestricted larvae were able to disperse throughout each of eight replicated arenas. Numbers of larvae observed on 416 mm^2 (0.64 in^2) leaf tissues, per maple species or cultivar, at 24 hour intervals during the 48-hour assay were recorded. At the conclusion of the assay, the percentage of the known leaf tissue area that was missing from larval feeding was estimated to the nearest ten percent. Estimates were recorded independently by two observers and were averaged to provide larval damage values.

During no-choice assays, 15 newly-hatched larvae were introduced into each of six replicated arenas per maple cultivar or species. Larvae were presented four adaxially and four abaxially oriented, 11.5 mm (0.45 in) leaf disks, for a total of 832 mm^2 (1.3 in^2) total leaf-area. Leaf disks and larvae were introduced onto a moistened 90 mm (3.5 in) diameter, Whatman No. 1 filter paper (Whatman International, Maidstone, UK). Arenas were maintained in a Percival Model I-35VL growth chamber (Percival Scientific, Boone, IA) under 16-light:8-dark photoperiod at 25C (77F) ± 3C (5F) and 85% ± 5% relative humidity. Maple leaf disks were replaced as needed. Leaf areas of leaf tissues consumed by larvae were estimated, as in the choice assays, on 5, 10, and 21 days after infestation (DAI). In 2000, the no-choice assay was concluded after 21 days, at which time the thermostat on the growth chamber failed killing the larvae. Relevant measurements were taken the following morning. In 2001, the assay ran for the full 28-day period.

In June 2001, a live-tree assay of six replicates of 15 newly-hatched larvae was conducted using the same maple treatments. Larvae were introduced into a 15 cm (6 in) by 30 cm (12 in) sleeve of Reemay spunbonded polyester row cover (Reemay, Inc., Old Hickory, TN). The Reemay sleeve, which covered the leaves and stem of a 15 cm (6 in) long maple branch tip, was sealed with a twist tie to prevent bagworm escape and predator entry. Sleeves were situated in light shade, on the north side of the trees, to limit mortality from direct sun exposure. Stem sections with sealed sleeves were removed 28 days after introduction, and surviving bagworms and bags were recovered.

As laboratory and field assays were concluded, surviving bagworms were tallied and bag length and larval head capsule sizes were measured. Larval instars were determined from head capsule measurements, using an ocular micrometer, after Kaufmann (10). Percentage data for defoliated leaf tissues were adjusted using the arcsine transformation prior to statistical analyses (22). Transformed data and larval survivorship, bag and head capsule size data were subjected to analysis of variance (ANOVA) using PROC GLM in SAS (SAS Institute, Cary, NC). Means among statistically significant variables were separated by least significant difference procedures (LSD, $P = 0.05$).

Results and Discussion

Evidence of bagworm survival and development, from both laboratory and field assays, indicate that maples differ in susceptibility to early-instar bagworm feeding damage. Native origin of maples did not reliably indicate bagworm preference or host suitability. In choice laboratory assays, larval presence (24 and 48 hour counts; $F = 2.41$ to 6.01; df = 9, 133; $P = 0.0192$ to < 0.0001) and feeding activity (range of leaf area removed during feeding: $F = 5.65$ to 9.67; df = 9, 133; $P < 0.0001$) differed among maples during both seasons (Table 1). At timed intervals, more larvae were consistently counted on 'Autumn Flame' red maple leaf disks. Comparatively few larvae were counted on trident maple (*Acer buergerianum* Miq.) and paperbark (*A.griseum* (Franch.) Pax) maple leaf disks. In both years, at the conclusion of 48-hour larval choice assays, leaf area missing from 'October Glory' and 'Autumn Flame' red maples supported heavy larval feeding. Boxelder (*A. negundo* L.) maple was also heavily consumed in 2000, as were 'Silver Queen' silver maple (*A. saccharinum* L.) and 'Legacy' sugar maple (*A. saccharum* Marshall) in 2001. By contrast, hedge maple (*A. campestre* L.), paperbark, trident, and 'Autumn Blaze' Freeman maples (*A.* x *freemanii* E. Murray) had the least feeding injury (Table 1). However, results of 48-hour choice assays were less consistent and less resolved than 21-day (2000) and 28-day (2001) no-choice assays.

In no-choice laboratory assays, run concurrently with choice trials, larval survival and leaf areas consumed were compared at regular intervals among maples. While larval survival did not differ among maples at 5 DAI in either season ($F = 0.54$ to 1.45; df = 9, 45; $P = 0.84$ to 0.21), differ-

Table 1. Mean number of bagworm larvae observed on leaf disks, and leaf area removed by larval feeding, during 2000 and 2001 choice laboratory assays.

	Number of larvae on leaf disks				Leaf area removed during feeding	
	2000		2001		2000	2001
Species/Cultivar[z]	24-hours	48-hours	24-hours	48-hours	mm^2	mm^2
Acer x *freemanii* 'Autumn Blaze'	1.4bc[y]	1.2bcd	2.6bc	1.3bc	9cd	30cd
A. rubrum 'October Glory'	1.8bc	1.9abc	2.4bc	3.1a	28ab	52b
A. rubrum 'Autumn Flame'	4.2a	2.4a	3.7ab	2.7a	33ab	91a
A. platanoides 'Crimson King'	1.8bc	1.2bcd	1.9cd	0.4c	13cd	22cd
A. negundo	2.1b	2.2ab	1.4cd	1.4bc	40a	32c
A. saccharinum 'Silver Queen'	2.3b	2.0abc	3.6ab	2.1ab	18bc	67b
A. saccharum 'Legacy'	0.9bc	0.9cd	4.6a	1.4bc	12cd	60b
A. campestre	1.6bc	1.4abcd	0.7d	0.9c	11cd	25cd
A. griseum	0.6c	0.5d	1.4cd	0.6c	2d	15d
A. buergerianum	1.3bc	0.9cd	1.6cd	0.6c	10cd	19cd

[z] 'Autumn Blaze' Freeman maple (*Acer* x *freemanii* E. Murray 'Autumn Blaze'); 'October Glory' red maple (*A. rubrum* L. 'October Glory'); 'Autumn Flame' red maple (*A. rubrum* L. 'Autumn Flame'); 'Crimson King' Norway maple (*A. platanoides* L. 'Crimson King'); boxelder maple (*A. negundo* L.); 'Silver Queen' silver maple (*A. saccharinum* L. 'Silver Queen'); 'Legacy' sugar maple (*A. saccharum* Marshall 'Legacy'); hedge maple (*A. campestre* L.); paperbark maple (*A. griseum* (Franch.) Pax); trident maple (*Acer buergerianum* Miq.).

[y] Means within columns that are followed by the same letter(s) are not significantly different at the $P = 0.05$ level by least significant difference method.

ences in leaf consumption by individual larvae were evident among maples ($F = 24.15$ to 29.48; df = 9, 45; $P < 0.0001$) (Table 2). In both seasons, less feeding was evident by larvae provided only trident, paperbark, and 'Autumn Blaze' Freeman maple leaf disks. By 10 DAI, the fewest larvae survived on trident maples. Leaf consumption by individual larvae was lowest among trident and paperbark maples. Larval survival and leaf consumption trends remained consistent at 21 DAI (Tables 2 and 3).

In no-choice laboratory (2000 and 2001) and field assays (2001), differences were significant among maples for mean bag length ($F = 20.35$ to 81.45; df = 9, 45; $P < 0.0001$) and

Table 2. Average leaf tissues consumed by bagworm larvae at 5, 10, and 21 days after infestation (DAI) during 2000 and 2001 no-choice laboratory assays.

	5 DAI		10 DAI		21 DAI	
Species/Cultivar[z]	No. live larvae	Leaf area eaten (mm^2) per larvae	No. live larvae	Leaf area eaten (mm^2) per larvae	No. live larvae	Leaf area eaten (mm^2) per larvae
			2000			
Acer x *freemanii* 'Autumn Blaze'	13.3	28d[y]	10.7bc	121c	8.7b	105b
A. rubrum 'October Glory'	14.8	86c	13.8a	185a	13.3a	234a
A. rubrum 'Autumn Flame'	14.0	106b	13.2ab	146abc	12.7a	258a
A. platanoides 'Crimson King'	15.0	138a	13.2ab	171ab	12.3a	232a
A. negundo	14.7	107b	13.0ab	189a	12.5a	259a
A. saccharinum 'Silver Queen'	15.0	82c	13.5ab	139bc	12.0a	124b
A. saccharum 'Legacy'	13.5	70c	10.8abc	135bc	7.7b	155b
A. campestre	14.8	81c	13.5ab	166ab	12.8a	250a
A. griseum	14.0	42d	11.7ab	51d	2.8c	45c
A. buergerianum	12.0	28d	8.7c	34d	1.8c	11c
			2001			
Acer x *freemanii* 'Autumn Blaze'	13.3	114d	10.3e	184d	7.3de	289bcd
A. rubrum 'October Glory'	14.2	214b	13.5abc	227bcd	11.0ab	321bcd
A. rubrum 'Autumn Flame'	13.7	218b	14.2a	220bcd	12.2a	349bc
A. platanoides 'Crimson King'	13.7	207b	12.7a–d	212cd	6.7de	637a
A. negundo	13.3	206bc	11.7b–e	260ab	7.8cde	454ab
A. saccharinum 'Silver Queen'	12.8	279a	13.7ab	295a	11.3ab	320bcd
A. saccharum 'Legacy'	13.7	186bc	12.8a–d	214cd	9.3bcd	367bc
A. campestre	14.2	165c	11.5cde	231bc	10.2abc	325bcd
A. griseum	13.8	99d	11.3de	139e	5.8e	179cd
A. buergerianum	13.5	34e	7.0f	53f	0.2f	78d

[z] 'Autumn Blaze' Freeman maple (*Acer* x *freemanii* E. Murray 'Autumn Blaze'); 'October Glory' red maple (*A. rubrum* L. 'October Glory'); 'Autumn Flame' red maple (*A. rubrum* L. 'Autumn Flame'); 'Crimson King' Norway maple (*A. platanoides* L. 'Crimson King'); boxelder maple (*A. negundo* L.); 'Silver Queen' silver maple (*A. saccharinum* L. 'Silver Queen'); 'Legacy' sugar maple (*A. saccharum* Marshall 'Legacy'); hedge maple (*A. campestre* L.); paperbark maple (*A. griseum* (Franch.) Pax); trident maple (*Acer buergerianum* Miq.).

[y] Within years, means within columns that are followed by the same letter(s) are not significantly different at the $P = 0.05$ level by least significant difference method.

Table 3. Mean bag length and larval survivorship at the conclusion of 2000 and 2001 no-choice laboratory and field assays.

	Bag length (mm)			Number of surviving larvae		
Species/Cultivar[z]	**2000: Lab**	**2001: Lab**	**2001: Live-tree**	**2000: Lab**	**2001: Lab**	**2001: Live-tree**
Acer x *freemanii* 'Autumn Blaze'	3.8d[y]	6.5c	8.6e	8.0b	7.3de	2.2bc
A. rubrum 'October Glory'	4.8c	7.7ab	8.2e	12.8a	11.0ab	4.2ab
A. rubrum 'Autumn Flame'	5.9ab	8.1a	10.1de	12.2a	12.2a	4.0ab
A. platanoides 'Crimson King'	6.2a	6.6c	16.5a	11.5a	6.7de	5.5a
A. negundo	5.9ab	7.0bc	13.8bc	11.2a	7.8cde	5.5a
A. saccharinum 'Silver Queen'	4.2d	7.0bc	11.9cd	12.3a	11.3ab	4.5ab
A. saccharum 'Legacy'	3.3e	6.5c	12.4bcd	6.7b	9.3bcd	6.3a
A. campestre	5.7b	8.1a	14.5ab	12.7a	10.2abc	4.7ab
A. griseum	2.2f	5.1d	3.7f	2.3c	5.8e	0.8c
A. buergerianum	2.2f	2.5e	8.7e	3.2c	0.2f	3.7abc

[z] 'Autumn Blaze' Freeman maple (*Acer* x *freemanii* E. Murray 'Autumn Blaze'); 'October Glory' red maple (*A. rubrum* L. 'October Glory'); 'Autumn Flame' red maple (*A. rubrum* L. 'Autumn Flame'); 'Crimson King' Norway maple (*A. platanoides* L. 'Crimson King'); boxelder maple (*A. negundo* L.); 'Silver Queen' silver maple (*A. saccharinum* L. 'Silver Queen'); 'Legacy' sugar maple (*A. saccharum* Marshall 'Legacy'); hedge maple (*A. campestre* L.); paperbark maple (*A. griseum* (Franch.) Pax); trident maple (*Acer buergerianum* Miq.).

[y] Means within columns that are followed by the same letter(s) are not significantly different at the $P = 0.05$ level by least significant difference method.

larval survivorship ($F = 2.40$ to 20.40; df = 9, 45; $P = 0.0260$ to < 0.0001) (Table 3). In 2000 and 2001 laboratory assays, bag sizes were consistently smallest among larvae confined to paperbark and trident maples. These maples also had the fewest surviving larvae at the conclusion of no-choice laboratory confinements. In the 2001 field assay, larvae restricted to paperbark maple produced the smallest bags and had the fewest survivors (Table 3).

At the conclusion of laboratory and field no-choice assays, head capsules from surviving larvae were measured to determine larval developmental stage. With the exception of first, third, and sixth instars that were recovered at the conclusion of the 2001 field assay ($F = 1.46$ to 1.88; df = 9, 45; $P = 0.19$ to 0.08), the numbers of larvae in each developmental stage differed among maples in the 2000 and 2001 no-choice assays ($F = 2.99$ to 14.60; df = 9, 45; $P = 0.004$ to < 0.0001) (Table 4). Larval developmental times therefore, differed among maples in no-choice laboratory and field assays. Larvae achieved the third instar by 21 days in 2000. In 2001, after 28 days, the most mature larvae in laboratory assays had developed to the fourth instar. In the field after 28 days, however, some larvae feeding on 'Crimson King' Norway (*A. platanoides* L.) maple, boxelder maple, and hedge maple in Reemay bags also matured to the fifth and sixth instar, which identifies these maples as suitable host plants. By contrast, paperbark, trident and 'Autumn Blaze' Freeman maples generally supported the fewest surviving larvae at the conclusion of no-choice assays (Table 3) and had larvae that were consistently the least mature (Table 4). Delayed development of bagworm larvae on these maples indicates that they are unsuitable hosts for sustained larval development. Results suggest that susceptible or specimen maples should be scouted in early summer, particularly in landscapes that have had a history of bagworm infestations. In turn, scouting efforts are expected to prevent aesthetic and potentially economic feeding injury by newly dispersed larvae.

Table 4. Determination of surviving larval developmental stages at the conclusion of 2000 and 2001 no-choice laboratory and field assays.

	Instar stage among surviving larvae[y]												
	(Number of larvae)												
	2000: Laboratory assay[x]			2001: Laboratory assay				2001: Live-Tree assay					
Species/Cultivar[z]	**1st**	**2nd**	**3rd**	**1st**	**2nd**	**3rd**	**4th**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**
Acer x *freemanii* 'Autumn Blaze'	5.5a[w]	2.5de	0.0e	0.2b	3.8a	3.3de	0.0c	0.0a	0.0b	0.2a	2.0bc	0.0b	0.0a
A. rubrum 'October Glory'	2.0bcd	7.3ab	3.5d	0.0b	1.7b	9.2a	0.2bc	0.0a	0.2b	0.7a	2.8b	0.0b	0.0a
A. rubrum 'Autumn Flame'	0.3d	4.7cd	7.2a	0.0b	2.7ab	8.7ab	0.8a	0.0a	0.0b	0.5a	3.5ab	0.0b	0.0a
A. platanoides 'Crimson King'	0.7cd	5.5bc	5.3bc	0.7b	1.5bc	4.3de	0.8a	0.0a	0.0b	0.2a	2.0bc	2.3a	1.0a
A. negundo	0.3d	4.7cd	0.2ab	0.0b	1.7b	5.5cd	0.7ab	0.0a	0.2b	0.7a	3.8ab	0.5b	0.5a
A. saccharinum 'Silver Queen'	2.7bc	9.3a	0.3e	0.0b	2.8ab	8.5ab	0.0c	0.0a	0.0b	1.5a	3.0b	0.0b	0.0a
A. saccharum 'Legacy'	5.7a	1.0ef	0.0e	0.0b	2.2b	7.0abc	0.2bc	0.0a	0.0b	0.5a	5.8a	0.0b	0.0a
A. campestre	1.5bcd	7.0abc	4.2cd	0.0b	2.3ab	6.8bc	1.0a	0.0a	0.0b	0.2a	1.7bc	2.7a	0.2a
A. griseum	2.3bcd	0.0f	0.0e	1.0a	2.2b	2.7e	0.0c	0.3a	0.0b	0.5a	0.0c	0.0b	0.0a
A. buergerianum	3.2b	0.0f	0.0e	0.0b	0.0c	0.2f	0.0c	0.2a	2.2a	1.8a	0.0c	0.0b	0.0a

[z] 'Autumn Blaze' Freeman maple (*Acer* x *freemanii* E. Murray 'Autumn Blaze'); 'October Glory' red maple (*A. rubrum* L. 'October Glory'); 'Autumn Flame' red maple (*A. rubrum* L. 'Autumn Flame'); 'Crimson King' Norway maple (*A. platanoides* L. 'Crimson King'); boxelder maple (*A. negundo* L.); 'Silver Queen' silver maple (*A. saccharinum* L. 'Silver Queen'); 'Legacy' sugar maple (*A. saccharum* Marshall 'Legacy'); hedge maple (*A. campestre* L.); paperbark maple (*A. griseum* (Franch.) Pax); trident maple (*Acer buergerianum* Miq.).

[y] Larval instars based on head capsule determinations (after Kaufmann, 1968) (10).

[x] 2000 laboratory assay concluded after 21 days. 2001 laboratory and field assays were concluded after 28 days.

[w] Means within columns that are followed by the same letter(s) are not significantly different at the $P = 0.05$ level by least significant difference method.

Although pest resistance in paperbark and trident maples has not been compared with other U.S.-native and economically important maples, insect resistance in 'Autumn Blaze' Freeman maples is corroborated by field evaluations that found limited feeding damage by potato leafhopper (*Empoasca fabae* (Harris)) (2, 15, 20). Although the amount of feeding among maples was not consistent at rated intervals during the no-choice assays, bagworms fed heavily on boxelder maple, 'October Glory' and 'Autumn Flame' red maples, 'Silver Queen' silver (*A. saccharinum* L.) maple, 'Legacy' sugar (*A. saccharum* Marshall) maple, and Norway maple throughout the study (Table 2). Greater potato leafhopper feeding injury was more often present on red maples than on Norway and sugar maples (15).

Identification of the characteristics of paperbark, trident or 'Autumn Blaze' Freeman maples that limit larval bagworm survival and development was beyond the scope of this study. Fleming (7) observed that red and silver maples were seldom damaged, while Norway maple and Japanese (*A. palmatum* Thunb.) maple were highly susceptible to Japanese beetle feeding. The susceptibility of Japanese maples to bagworm feeding has not been determined. Cultivars of Japanese maples, which are frequently used as specimen plants in landscapes, were not included among the maples being screened for cold hardiness and horticultural characteristics in McMinnville, TN, and thus were not available for this study. Loughrin and others (12) have demonstrated that both Japanese beetle-resistant and susceptible maples emit similar volatile compounds from intact leaves. In response to Japanese beetle feeding, however, susceptible maples produce more fruit-scented esters and linalool while resistant leaves emit a greater percentage of volatile terpenes. Neither the response of bagworms to volatile compounds nor any compounds produced by bagworm feeding have been described among maples.

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